# INTERNATIONAL INSTITUTE



TROPICAL

OF

1971 REPORT

# International Institute of Tropical Agriculture

INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE

Oyo Road, P.M.B. 5320

Ibadan, Nigeria.

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## About this report

This annual report is the first produced by the International Institute of Tropical Agriculture, not because there was nothing to report but because emphasis was on construction and development rather than on reporting. Research started in 1969 as will be learned from the report and the 1969-71 work is reported herein.

Readers will note also that the Director's Introduction reports limited facilities occupied in 1971. Our facilities for printing were commissioned late in 1972. That is why most people will receive their copy of this report in 1973, almost at the same time they receive the 1972 report.

Our format tries to eliminate details in reporting research. We report major accomplishments and significant research results as briefly as possible and trust readers to seek additional details directly from the scientists in the research programs.

#### Director's introduction

The HTA building program began late in 1968 and by January 1971 only one building, Threshing and Crop Drying, the major farm operations facility, was occupied.

Administrators, scientists and technicians moved to temporary office and laboratory space on the IITA campus in April. At the same time, additional clearing enlarged the area for field research to approximately 100 hectares, including five hectares of rice paddy. Substantial additions were made during 1971 to the network of roads, irrigation facilities and landscaped areas. These activities will continue through the next several years.

During 1971 research activities were organized into four interdisciplinary programs. The three crop improvement programs (Cereal, Grain Legume and Root, Tuber and Vegetables) each include a breeder, agronomist, plant physiologist, plant pathologist and entomologist. Grain Legume and Root, Tuber and Vegetables have a biochemist. The program teams work on combinations of new varieties and cultural practices that will serve as a technological basis for increases in productivity and quality of selected crops.

The Farming Systems program combines scientists from 12 disciplines. This team studies means of overcoming the socioeconomic, biological and physical problems related to a move from shifting cultivation to farming systems that will more efficiently utilize the soil and water resources of the humid tropics and be more compatible with the technology developed by the crop improvement programs.

The IITA staff and the Board of Trustees focused during 1971 on more clearly defining the scope and objectives of the research program. It was decided that farming systems research would clearly be circumscribed by ecological definitions, with activities and responsibilities related to the humid tropics on a global basis. In the crop improvement programs, on the other hand, the selection of species would be based on the importance of the various crops in the humid tropics, but the research on the species selected would benefit agricultural production wherever the crops are grown rather than regions within narrow ecological limits.

In the case of species for which other institutes have clear international responsibilities, the IITA research program will be considered as regional. While staff were being recruited and facilities being developed in 1971, the scientific staff already at the Institute engaged in an active program to produce the results summarized in the main body of this report.

#### Highlights of these results are:

- Achievement of yields in excess of 2,000 kg/ha for cowpeas and 3,000 kg/ha for soybeans.
- Identification of sources of resistance to

the major cowpea diseases and the development of a laboratory screening technique for cowpea anthracnose disease.

- Definition of the relationships between levels of thrips infestation and yields, and the identification of possible sources of resistance to thrips in cowpeas.
- Determination of key periods when weed control is most essential in cowpeas.
- Achievement of rice yields of more than eight tons per bectare are under irrigation and more than four tons per hectare under upland conditions.
- Identification of sources of resistance to the more virulent strains of rice blast disease existing in West Africa.
- Completion of the second three-generation cycle of recurrent selection on one major maize composite and incorporation of Opaque-2 genes and Central American germplasm into maize composites.
- Development of a method of induction of aerial tubers in years.
- Determination of major changes in nematode populations and species distribution following clearing of forest and cultivation of crops.
- Development of the basis for a simulation model of the decision-making process for Yoruba small holders.
- Identification of high soil temperature as a major factor limiting yields of maize grown on ridges.

#### STAFF CHANGES

 Dr. Royse P. Murphy, plant breeder who launched the IITA grain legume program

- while a visiting scientist on subbatic leave, returned to Cornell University in January after one year of service.
- Dr. A.H. Lamey, plant pathologist, resigned in June to accept an FAO position in South Korea.
- Dr. Kenneth O. Rachie, program leader for grain legume improvement, joined the staff in June. A plant breeder long experienced in the tropics, Dr. Rachie's most recent post was at Makerere University, Uganda.
- Dr. R.A. Briggs resigned in July, to return to the University of Minnesota as acting secretary, Board of Regents and executive assistant to the president of the University.
- Dr. John L. Nickel succeeded Dr. Briggs as associate director in July. Dr. Nickel came from Makerere University where he was dean of the Faculty of Agriculture.
- Dr. Sang Ki Hahn, plant breeder, joined the IITA staff in July as leader of the root, tuber and vegetable improvement program. He was a member of the faculty of Seoul National University, Korea.
- Dr. William F. Lalor, agricultural engineer (mechanization), joined the staff in August.
   Dr. Lalor came from Auburn University.
- Dr. George F. Wilson, vegetable breeder, joined the staff in August. He completed graduate studies at the University of Illinois in June 1971.
- Mr. Walter G. Rockwood became head of IITA communications and information in August. Mr. Rockwood worked with USAID in several francophone African countries, but his most recent post was at the University of Illinois.
- 10. Dr. Loy V. Crowder, visiting scientist on leave from Cornell University, started a

one-year research program with soil conserving and improving crops in September.

#### TRUSTEES

Dr. Stuart S. Peters, Canada, resigned from the Board in March when he left the Canadian International Development Agency. Dr. Peters is now with the Outdoor Recreation Division, Department of Lands and Forests, Province of Ontario.

Dr. H. George Dion succeeded Dr. Peters on the Board in September. Dr. Dion, now on the staff of CIDA, is past Dean of Agriculture, MacDonald College, Montreal.

M. Abdoulaye Sawadogo joined the Board late in the year. He is Minister of Agriculture, Republic of the Ivory Coast.

Dr. Armando Samper also became a member of the IITA Board late in 1971. He is a past member of the Board of Centro International de Agricola Tropical (CIAT) in Colombia, a former Minister of Agriculture of Colombia, a past director general of the Inter-American Institute of Agricultural Sciences, Organization of American States (IICA) and was a member of the faculty of the University of Bogota.

Dr. John J. McKelvey, Jr., associate director, Division of Agricultural Sciences, The Rockefeller Foundation, succeeded the late Dr. Will M. Myers as a member of the Board in 1971.

#### FINANCES

The budget for IITA operations during 1971 was \$2,170,000 from the following sources:

The Ford Foundation	\$ 534,443
Rockefeller Foundation	534,443
Canada (CIDA)	534,443
United States (USAID)	534,443
Other	32,228

\$2,170,000

The IITA capital fund requirements for buildings and site development to completion are estimated at \$18,541,000. Funds paid to 31 December, 1971 plus those committed in 1972 are:

The Ford Foundation	\$16,175,000
The Rockefeller Foundation	107,000
Canada (CIDA)	310,000
United State (USAID)	1,020,000
The Netherlands	43,500
United Kingdom (ODA)	57,500
	\$17,713,000
Still required	88,000
Estimated Total Cost	\$18,541,000

IITA and the FAO, in cooperation with the University of Wageningen and with funds provided by the Government of The Netherlands, initiated a three-year project on rice mechanization in January Mr. Harrie Curfs, associate expert, FAO, is assigned to the project.

An agreement was concluded in 1971 with the Overseas Development Administration to launch cooperative research in grain legume physiology and root development research in 1972. The root development work is in cooperation with the Letcombe Laboratories and the grain legume physiology work with the University of Reading. Additional grain legume research projects are being developed with the University of Durham.

#### COOPERATIVE PROGRAMS

Program assistance during 1971 went to the governments of Zaire (maize, in cooperation with CIMMYT), Sierra Leone, Ghana and Liberia (rice) and Togo (land use). IITA scientists participated in the work of the task force planning the Nigerian Accelerated Cereals Production Program and the research and training plans of the West African Rice Development Association (WARDA).

### Farming Systems Program

The Farming Systems program is the integrating and synthesizing unit among IITA's research units. The program's research is directed towards combining the improved plant materials and aspects of their culture derived from the crop improvement programs with the environmental and management factors determined by the scientists in soils, agronomy, engineering and economics.

A farming system is defined as the specific organization operation and resource combination of an agricultural production unit. It includes the selection of location (soils and environment), selection of crops and varieties, cultural practices, plant protection, harvesting, processing and marketing including the economic costs and returns to the operation of the farm. The term farming system is chosen in contrast to two others frequently used - agricultural systems, a broader term reserved to refer to state, national, regional or zonal systems that operate as combinations of several farming systems, and cropping systems, a nearly synonymous but narrower term used principally to describe the cropping sequence, rotations and cultural practices within a farming system.

The environment of the total agricultural system of concern to IITA is the humid tropics at less than 600m elevation between 23° 27'N. or S. of the equator and in which evaporation is less than precipitation for at least six months of the year.

The farming system program's broad objective is to provide adequate food of good quality, fiber, housing and living standards at the highest level compatible with the resources available and the competing objectives for the people in the environment.

#### Detailed objectives are:

- To identify optimum systems of cropping for a long-term, sustained-yield rotation for the humid tropics.
- To identify adapted crop varieties and examine their yield potentials in continuously cropped tropical soils.
- To identify solutions to problems of soil fertility, chemistry and management resulting from continuous, intensive cropping in comparison with traditional methods.
- To identify pest and disease limitations under traditional and intensified cropping and to develop control methods.
- To develop mechanical techniques for upland agriculture and to identify machines suitable for continuous cropping systems including tillage, spraying, weeding, harvesting and drying equipment.
- To identify optimum combinations of crops and maximum economic return from land cropped in technical and conventional systems.

A series of generalized model agricultural systems representing points on a continuum of intensities of land and resource utilization has been drawn up. This list is the basic framework within which specific systems will operate as experimental treatments. The shifting cultivation system will serve as control and the others will be related to it. The most complex system, multiple cropping, will serve as the control at the technical end of the spec-

trum where presumably the most scientific agriculture will be practiced and the greatest productivity will result.

#### IITA'S PHYSICAL ENVIRONMENT

Situation and Topography, IITA is north of Ibadan at 3° 54'E and 7° 30'N latitude and occupies an area of about 1000 ha. The general topography is rolling with dominant slopes ranging from 3 to 10%. Flat areas with slopes of 1% or less are confined to the wider valley bottoms and to the upper parts of the ridges and plateaus. Rarely do these flat to gentle sloping uplands occupy consolidated areas of more than five hectares.

The highest point at IITA (243m) is a small quartzite hill immediately north of the entrance. The lowest point, slightly below 185m is situated along the south boundary in the Ona river valley. Valleys in IITA form a trellis pattern. The central valley of the Ona river, which bisects the site, is south oriented following the general strike of the country tock.

Compared with the general ecological area in the Western State of Nigeria, IITA's topography is steeper than average. This is mainly related to the presence of the incised valley of the Ona river from which a consequent system of side valleys has developed.

Geology. IITA soils overlie crystalline metamorphic basement rocks of pre-Cambrian to upper-Cambrian age. Three major types of rock occur, notably banded gneiss with associated schists quartzites and quartz schists, and granite gneiss. All can be found in rock outcrops but the banded gneiss, and especially the associated schists, are usually deeply weathered. The quartzites and quartz schists, being resistant to weathering and erosion, occur mainly in ridges. Granite gneisses are

often visible in rock outcrops and rocky ledges.

Present IITA land forms are mainly a result of quarternary morphogenesis. A series of gently sloping pediment plains were formed under fluctuating climatic conditions during the quarternary. Under arid conditions pediment gravel accumulated on the surface giving rise to stone lines found in most upland soils at IITA. Late and post-glacial rejuvenation of the drainage system eroded the pediment plains near the river moving much of the pediment gravel along the slope. Only small amounts of the original quarternary pediment plains remain on some of the higher, flatter ridges and plateaus. Weathering of the bedrock proceeded under more humid climatic conditions of the later geological periods. Depth of weathering is moderate, and saprolite is found at a shallow depth in most upland soils. A superficial, stone-free deposit was formed at the surface of the upland soils due to the action of termites and earthworms.

Valleys at IITA, though belonging to a mature drainage system, are young and the thickness of the alluvial deposits is usually less than 4m in the center of the valleys. Colluvial movement on slopes is an on-going process and most lower slopes and minor drainage ways are covered by gravel-free colluvial deposits.

Hydrology. Deep underground water is rare in basement rock areas, and is mainly confined to local fractured strata of faults and joints. IITA has no deep underground water resources of any importance. Surplus water infiltrates and moves laterally by interflow to valleys and drainage ways. Permanent or intermittent groundwater occurs in the alluvial deposits in the deeper valleys and drainage ways.

Streams and creeks are fed by interflow and run-off from the uplands. The interflow water, which surfaces on the lower slopes in intermittent springs, provides regular flow of rivers and creeks from about the end of May until December. of the rainbelt. This period is characterized by low intensity rains, heavy cloud cover and relatively low temperature. Dry days occur frequently in this period, and are reflected in the bimodal rainfall pattern with a lower average rainfall in August. As the ITCZ moves south-

#### CLIMATIC DATA FOR THE IBADAN AREA

	J	F	М	À	М	1	J	A	S	0	N	D	Year
Rainfall (mm) Av. daily	10	23	92	133	151	187	155	82	178	157	45	10	1226
Max. 8C Av. daily	32.3	33.9	32.7	32.4	31.1	29.7	27.8	27.2	28.6	29.7	31.2	31.8	30.7
min. 8C Pot, evapo-	20.9	21.9	22.5	22.2	21.7	21.8	21.1	20.6	21.3	21.1	21.6	20.7	21.4
transp. (mm) Rel. humidity	134	155	135	117	100	81	65	60	73	83	102	122	1228
09.00 GMT	81	78	81	82	84	86	. 89	88	88	86	83	83	84
15.00 GMT	48	73	54	61	68	73	7.7	77	74	69	68	52	63

The rainfall pattern in the Ibadan area is largely determined by the interaction between high pressure zones over the Sahara and over the Atlantic Ocean. The boundary bewteen the two systems, the inter-tropical convergence zone (ITCZ), moves toward the equator from August to January and toward the north from January to August. Dry, cool harmattan winds reach Ibadan in December and January. The dry rain-free period is followed by a nearly rain-free period of high humidity. The rainbelt reaches the Ibadan area in March-April.

Early rains are characterized by thunderstorms occurring as line squalls. Rainfall reaches a first peak in June, with the passage of the monsoonal rainbelt and from mid-July to late August Ibadan is in the moist zone south ward rainstorms increase in trequency and intensity, causing a second rainfall peak in September-October. By mid-October rains diminish rapidly and the area again comes under the influence of the dry easterly winds. Whereas the general rainfall pattern is stable, there are year-to-year variations. Total annual rainfall varies from about 950mm to 1600mm.

The frequency of rains in the wet season, or alternatively the frequency of dry periods bringing about drought stress in shallow-rooted crops is of great importance for agriculture.

Periods of five days with less than 2.5mm of rainfall are common throughout the rainy season. The probability of occurrence of such dry periods is more than 55% for most months, except during June and September. The temperature regime of Ibadan is characterized as equatorial, with no great variation throughout the year. The daily range in temperature is moderate, reaching its peak in December and January, and its minimum in July and August Diurnal fluctuations of soil temperature, as influenced by soil management and vegetative growth, are considerable.

Vegetation and Land Use. The southern Nigerian forest belt falls into the ecological zone of moist lowland forest. The climax forest of this zone has a closed stand of three layers of trees consisting of lower and middle layers and a discontinuous layer of taller emergents. In the climax forest, grasses are uncommon, whereas lianes and epiphytes are abundant. This ecological zone is further subdivided and the Ibadan area is labelled as moist, semi-deciduous forest with abundant Sterculiacear, Morecede and Ulmaceae.

According to a vegetation survey in July 1967, no primary or climax forest remained at IITA. About 30 ha of scattered secondary forest was recorded and more than 500 ha was in use for cocoa growing. The remaining land was mostly under shifting cultivation.

Soils. Parent materials of IITA soils are grouped into four distinct categories according to their origin. These are:

- Sedentary parent material, derived from solid rock, weathered in situ.
- Stoneline material that originated as pediment gravel of late glacial age, but at IITA at least, often has been moved and mixed with fresh material subsequent to its formation as a desert payement.
- Biogenetic surface material and colluvium derived from this material.
- Alluvial material deposited in valley bottoms from streams and rivers.

The solum of most IITA upland soils shows a superposition of the materials mentioned in 1, 2 and 3. In eroded soils such as at old village sites, the biogenetic material may be absent and in some places the sedentary parent material does not form part of the solum proper. Our valley soils are formed mostly or entirely on alluvial parent material.

Terminology used in field studies at IITA is taken from the USDA Soil Survey Manual (1951 and from SCS Soil classification: A Comprehensive System (1961). Series names and definition closely follow the current ones used for soil surveys in western Nigeria.

Most IITA upland soils belong to the order of the Alfisols. Entisols and Inceptisols are found on lower slopes, in valleys and in isolated spots with shallow bedrock,

The most important series occurring at IITA are:

 The Egbeda series, found on about 10% of the IITA area. Soils of this series occupy mainly the gently to moderately sloping sites at high elevations of the topography. The series is derived from fine grained biotite gneisses, and schists. Weathering is deep and in normal profiles no unweathered rock is found.

Modal Egbeda series soils have a mediumtextured surface, usually sandy loam or sandy clay loam, developed in the biogenetic layer. The surface soil may be as deep as 20 cm, but is usually shallow and sometimes absent as a consequence of erosion. The surface soil is underlain by a gravelly horizon that varies in thickness from 20 to 70 cm. The texture of the fine soil in this gravel layer is clayeysandy clay loam or finer. The gravelly horizon is underlain by dark teddish brown to dark red clay, passing into a multi-colored mottled clay in which no or little tock structure is visible other than occasional resistant quartz veins. Weathered rock and eventually bedrock is reached at depths of 200 cm or more.

2. The Iwo series, occurring on 33.5% of IITA's area. Three variants or phases were mapped – Iwo normal (21.3%), Iwo sandy (10.2%) and Iwo concretionary (2%). Iwo series soils occur in the higher parts of the topography, both on the gently sloping uplands and on the steeper, convex upper slopes.

The Iwo series is derived from granites and coarse grained gneisses with the latter being the most common. Weathering rock with visible residual rock structure is usually reached at a depth of less than 150cm, and fresh rock occurs commonly at a depth of 2-4 meters.

Modal Iwo series soils have a medium-tolight-textured surface, sandy loam for the normal variant, and loamy sandy for the sandy variant. The surface layer is at most 25 cm deep, but usually shallower and sometimes absent in badly croded spots. This layer is followed by a gravelly horizon (stoneline), which may contain important quantities of hard laterite concretions, a concretionary variant.

The texture of the fine earth in this layer is medium sandy loam in the upper part, but becomes rapidly finer below. The underlying clayey horizons are reddish brown or brown. At a depth of 70 cm or more, the horizons contain an increasing amount of weathering feld-spars and the moderately mottled weathering gneiss with residual rock structure is reached between 100 and 200 cm.

3. The Ibadan series, mapped on 8% of IITA's land, with 3.5% in the normal variant, and 4.5% in the sandy variant. It has been found, however, that in a number of places, soils mapped under this series do not conform with the definition of the Ibadan series. Soils on

quartzite shale belong to the Okemesi association, and should be separated from the Ibadan series soils.

Ibadan soils at IITA are mainly found on moderately to steeply sloping uplands. The modal Ibadan series soils have a sandy texture in the first 50 cm or more. Associated with this, the content of gravels in the layer below the topsoil is usually high to very high, with coarse quartz and quartzite gravels dominating. The deeper horizons are similar to those of the Iwo series soils since the Ibadan series is also developed on coarse grained gneisses.

4. The Gambari series, comprising a large variety of distinctly different soils, each of which should be separated at the series level according to modern soil classification systems. These soils are found on slightly more than 5% of the IITA area, mainly isolated small strips on the lower slopes along valleys and drainage ways and occasionally on middle slopes. These soils are common along all valleys and drainage ways where they are situated at the break of slope at a low level in the topography.

The Gambari soils are characterized by the presence of abundant laterite at a shallow depth or at the surface. At IITA the laterite is mostly of the concretionary type, but a few spots with consolidated laterite sheets (iron pan)were observed. It is noted that at IITA the laterite of the Gambari soils has formed in those parts of the topography where iron-rich interflow water reaches the surface. The formation is a slow process, extending over hundreds or even thousands of years, Hence, the dangers of active 'lateritization' of the soils at IITA is considered negligible since laterite now present has been there for a long time, and new laterite or plinthite is forming at a rate so slow it cannot be measured with present analytical methods.

5. The Apomu soil series, together with the Iregun series, occupying about 22% of the surface of IITA. The two series are mapped together since they occur side by side and can only be separated in detailed surveys. The Apomu series soils are formed on sandy colluvium washed from the higher slopes and accumulated on the lower concave slopes along valleys and depressions. In the minor depressions, they may fill the whole lower portion, but in the larger valleys the valley bottom is usually occupied by soils of the Jago association.

Apomu series are composed of sandy slope colluvium, sandy or loamy sand for at least 50 cm. Frequently the sand layer is thicker than 100 cm. The Apomu soils show a variety of subsoils, according to the nature of the soil on which the colluvial material was deposited. In the lowest position, the subsoil may be alluvial-Jago association, Higher up the slope, subsoil characteristics of the Gambari, Ibadan, Iwo and Olorunda series are noticed.

6. The Iregun series, discussed under the Apomu series. The Iregun soils mainly occupy lower slopes, as do the Apomu soils, but Iregun soils may be found at higher levels on gentle slopes. Occurrence seems to be related to soil conditions on the higher slopes. Where the surface soil of the higher slopes is medium to fine-textured – the normal variants of the Iwo and Egbeda series – soils on the colluvial portion of the slope normally belong to the Iregun series. For this reason, certain valleys have an asymmetric aspect with Iregun soils on one slope and Apomu soils on the opposite slope.

The Iregun series soils have more than 50 cm of colluvial material, with a texture finer than loamy sand or coarse sandy loam occurring at less than 50 cm depth, but excluding clayey colluvial soils. The colluvial cover usually is considerably thicker than 50 cm, and often contains gravel and concretions in the lower parts. Drainage varies strongly according to topographical position. The lower Iregun series soils may be somewhat poorly drained, showing brownish colors and distinct subsoil mottling. A temporary water table is found in most of these soils during most of the rainy season.

7. The soil series of the Jago association, which occupy approximately 16% of IITA's surface. They are confined to valley bottoms and the lowest portions of the adjacent slopes. The parent material is classified as alluvium but may be partly of colluvial origin, notably in the zone adjacent to the valley bottom proper. The series of this association occur in an extremely intricate pattern and can be mapped separately only in a detailed soil survey. The series are defined according to natural drainage and textural profile.

#### Soil Physics

Research activities in soil physics during 1971 were primarily oriented toward water management and plant-water relationships. Physical properties of the soil profile that inhibit root development of cereals were also investigated.

#### WATER MANAGEMENT IN RICE

We investigated the effects of eight water regimes on two rice varieties in a greenhouse experiment using top soil packed in 20-liter containers. The soil was loamy sand consisting of 80% sand and 10% each of silt and clay fractions. The soil held 25% moisture by weight at zero suction and only 11% moisture by weight at 0.3 atmosphere pressure. The soil was pH 6.3 and contained 1.3% organic carbon.

One of the rice varieties used was a locally recommended variety, OS-6. The other was IR-20.

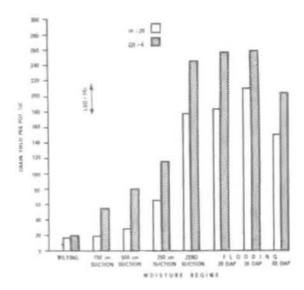
The eight water treatments included continuous flooding 20 days after planting (DAP), 35 DAP, and 55 DAP; zero suction; 250 cm 500 cm and 750 cm of water suction at 15-cm depth, and one treatment of irrigation up to 250-cm suction only when plants showed wilting at 2 p.m. We measured daily plant water consumption, tiller count, leaf area, growth, dry matter production, root development, nutrient uptake and grain straw yield. The experiment was replicated four times and the data statistically analyzed as a completely randomized design.

The grain yield data in Figure 1 indicate that OS-6 yielded more than IR-20 for all the water treatments. The highest grain yield was from the treatment flooded 35 DAP. Maximum straw yield, however, was from the zero suction or flooding 20 DAP.

Continuous flooding favored vegetative growth while a stress imposed until the panicle initiation stage, and then flooding, favored reproductive growth. Root development was seriously inhibited by high soil moisture stress.

A field experiment similar to the greenhouse study used a circular plot. Iron rings 50cm deep and 3m in diameter were buried 30cm in the ground with minimum soil disturbance and pre-soaked seed of IR-20 was planted in a moist soil. Six water treatments consisted of flooding 20 DAP, 35DAP, 55DAP, zero suction, alternate flooding every two weeks and a rainfed treatment. In addition to the plant parameters such as tiller count, plant growth, dry matter production and grain

Figure 1. Effect of soil moisture regimes on grain yield of 1820 and OS- 6.



and straw yield, weather parameters such as solar radiation, wind velocity, evaporation, evapotranspiration, humidity and temperature were measured.

Grain and straw yield data from the field experiment show that grain yield for flooding treatment 55 DAP was significantly higher than that of 20 DAP. However, straw yield was greater for the 20 DAP treatment.

#### ROOT STUDIES

Investigations on the effect of physical characteristics of soil profile on root development of maize and rice indicate that widespread occurrence of stone lines in tropical soils may be responsible for inhibited root development.

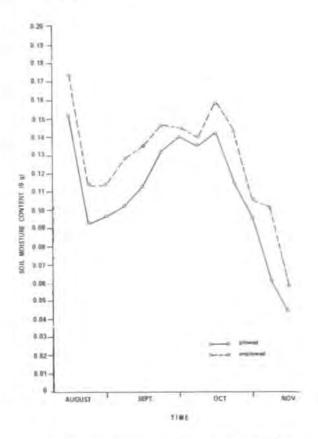
Maize is normally grown during an early season, from April to June, and during a second season from July to October. We investigated the effect of three factors — fertilizer, irrigation and plowing — for maize during the second 1971 season. There were two levels of each factor, irrigation vs rainfed, normal dose of fertilizer vs no fertilizer and plowing with disc plow vs no plowing, or zero tillage. Weed control for zero tillage plots was with Paraquat sprayed at the rate of 1.5 l/ha and a premergence application of Atrazin at 4 kg/ha. The bulk density of the surface soil to a 15-cm depth was 1.37 g/cm<sup>3</sup> for zero tillage plots as compared with 1.30 g/cm<sup>3</sup> for the plowed treatments.

Plant height and root development were conspicuously retarded for the first two weeks in the zero tillage plot as compared with plowing treatments. Plowing induced more root hairs in the initial stages. These differences, however, were not visible at later stages of growth.

Soil moisture content measured at the 0- to 10-cm depth was consistently higher for the zero tillage plots as shown in Figure 2. This increase in moisture storage was probably due to the mulch cover of weeds killed by Paraquat. Soil shifting and erosion was noticeable only in the plowed plots.

The analysis of variance test for grain yield showed a significant effect of plowing and fertilizer. Since the rains were frequent in the second season, irrigation had no significant effect on yield. The interactions between plowing and fertilizer, and irrigation and fertilizer on yield were significant (Table 1). Root weight and length, observed during the silk stage, was not affected by any of the treatments. There was no difference in the yield among the zero tillage plots with fertilizer, and plowed plots with and without fertilizer (Figure 3). The experiment will be repeated for at least two more seasons.

Figure 2. Effect of plowing on soil moisture in the surface 15 cm of soil.



Preliminary investigation on sub-soiling and incorporation of organic matter to a depth of 50 cm shows decreased maize yield as compared with a control plot. Surface incorporation of organic matter, however, significantly increased maize yield. The increase in yield by organic matter is attributed to increased soil moisture storage in the surface layer.

#### SOIL TEMPERATURE

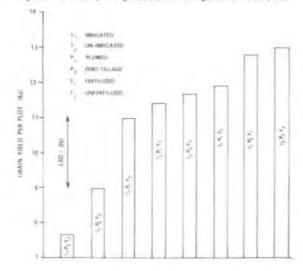
The effect of tillage practices and ground cover on soil temperature measured at 5-cm depth is shown in Figure 4. It is apparent that diurnal fluctuations in temperature for a bare

Table 1. Analysis of variance table of the Fratios.

Stern co.	Grain Yield	Weight of 1000 grains	Root wt/plant silk stage	Root length silk stage	Plant height silk stage
Pluwing (A)	37.0*	NS	NS	NS	NS
irrigation (B)	NS	25.0-	NS	NS	NS
Fertilizer (C)	9.28*	40.36%	NS	55.3*	NS
AB	NS	NS	NS	NS	NS
AC	12.8*	65.3	NS	11.8*	NS
BC.	8.7*	NS	N5	17.4*	NS
ABC	NS	NS	NS	19.8*	NS

Statistically significant at 5% level of confidence

Figure 3. Effect of plowing, fertilizer and irrigation on maize yield.



soil are of the magnitude of 15 to 20 C from December to mid-May. High soil temperature, therefore, may affect plant growth in the initial stages and its effect is further aggravated if plants are also subjected to soil moisture stress.

A preliminary investigation studied the effect of surface mulching on soil temperature and its effect on maize. Soil temperature measurements at 5-cm depth for mulched and unmulched plots of maize showed a temperature difference of 3 C to 7 C in the initial stages of maize growth. Soil moisture content though higher in the mulched plot was not significantly affected. Plant growth and vigor for the mulched plot were superior to those of the unmulched plot. Grain yield for the unmulched treatment was 10.5 kg/plot of 30 m<sup>2</sup>, compared with 16.2 kg/plot for the mulched treatment. Damage by termites was significantly higher on the mulched plot.

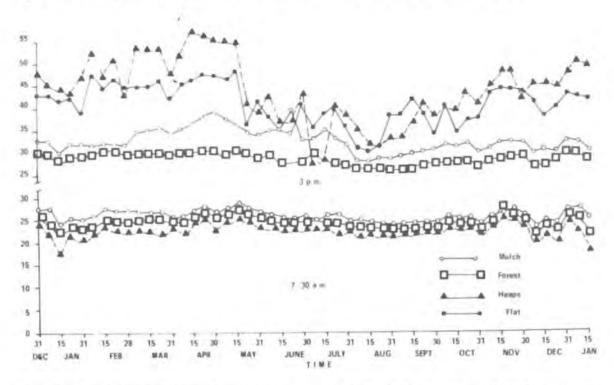
Similar investigations for yam show that yam germination is significantly improved by mulching on a flat soil surface.

#### SOIL AND WATER CONSERVATION STUDIES

Twenty-four runoff plots were established during 1971 with the following objectives:

- To investigate water-use efficiency under various crop rotations.
- To study soil erosion and soil physical characteristics under various tillage, crop rotation and cultural practices.
- To study surface and sub-surface movement of agricultural chemicals.





Runoff and soil loss will be evaluated for the following plot treatments during a three-year period:

- Continuous maize with stover plowed in.
- Continuous maize with zero tillage and stover left on the surface.
- Maize cowpeas maize.
- Maize stylo maize.
- Bare ground.
- Bush.

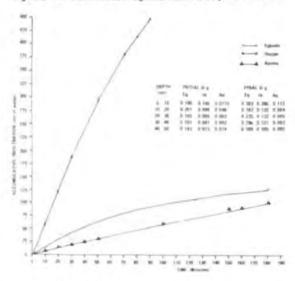
# PHYSICAL PROPERTIES OF SOME NIGERIAN SOILS

Egbeda, Ibadan and Apomu soils are not well graded since 60 to 70% of the soil material falls in the coarse fraction. Gravel content is highest for the Ibadan profile.

Penetrometer readings of Egbeda, Ibadan, Iwo and Gambari series increase for the lower horizon indicating the compactness of these layers. Except for the Egbeda sub-soil, none of the soils exhibits plasticity or shrinkage.

The data in Figure 5 show the accumulative infiltration for the Apomu, Egbeda and Ibadan soil series. Infiltration rates were determined using a double ring infiltrometer and a Mariotte bottle technique with a constant water head of 5 cm maintained in the inner ring. Infiltration rates at one hour after starting the experiment are 30, 40 and 150 cm an hour respectively, for Apomu, Egbeda and Ibadan soils. The low rate for Apomu soils may be due to high contact angle and non-

Figure 5. Infiltration rates of Egbeda, Ibadan and Apomu soil series.



wettability of the sand.

Moisture characteristics for the Egbeda, Iwo. Olorunda. Gambari and Iregun series are similar. The moisture retention at 0.3-atmosphere pressure varies from about 15 to 20% and from 8 to 12% at 15-atmosphere pressure. In general water-holding capacity for Apomu and Ibadan, Balogun, Mataka and Ekiti soils is low. This is due to predominance of the coarse fraction in these soils.

Though the moisture-holding capacity of Egbeda soils is high, a majority of the pores for both soils drain at about 0 1-atmosphere pressure. Wetting moisture characteristics for Egbeda soil show that inter-aggregate pores start filling at about 30-cm suction. Non-wettability of the coarse sand fraction for Apomu soil is evident on comparing its wetting and draining moisture characteristics.

Moisture characteristics for the soils of Danggappe, Alagba and Owode series are alike. In general, these soils have low water-holding capacity and a majority of pores drain at 0.1atmosphere pressure. Humic gley soil from the Niger Valley and Funtua series from Samaru have a greater water-holding capacity than the coarse soils of Alagba and Owode series. The moistureholding capacity at zero potential varies from 42 to 48% and majority of pores drain at 9.3-atmosphere pressure with water content varying from 17 to 25%. Humic gley soil holds more water than that of the Funtua series. The water retained at 15-atmosphere pressure for both soils is about 5%.

#### Soil Chemistry

Five areas of soil chemistry research were initiated during 1971. They were phosphorus retention, fixation and availability; dynamics of iron, aluminum oxides and organic matter in tropical soils; soil chemical environment and root growth; chemical characteristics of West African soils as related to soil fertility capability, and behavior and effects of pesticides in soil and water. The last area is not reported.

#### PHOSPHORUS RETENTION, FIXATION AND AVAILABILITY

Experiments on phosphorus retention and fixation by tropical soils, and soil chemical factors affecting the availability of various forms of phosphorus fertilizers to plants were conducted in laboratory and greenhouse during 1971. Following are some preliminary results:

Phosphorus sorption and fixation by soils. Sorption of phosphorus by soils from different parts of Nigeria was studied by equilibrating 5 g of soil in 100 ml of 0.01 M CaCl<sub>2</sub> solution containing various concentrations of KH<sub>2</sub>PO<sub>4</sub> at 30C for 24 hours. Phosphorus remaining in the equilibrium solutions was determined colorimetrically. Phosphorus sorption isotherms

were plotted according to Langmuir adsorption equation:

$$C/x/m = \frac{1}{kb} + \frac{C}{b}$$

where C is the equilibrium P concentration in moles per liter, x/m is mg P sorbed per 100 g of soil, b is the sorption maximum, and k is a constant related to the bonding energy of sorbed P. The P sorption maxima and k values of Langmuir sorption isotherm for the five Nigerian soils are given in Table 2. Chemical properties and sample location of the soils are given in Table 3.

Egbeda, Funtua and Alagba soils showed moderate P-sorbing capacity whereas the acid Nkpologu soil from eastern Nigeria showed a high P-sorbing capacity. The P-sorption maximum of the highly weathered Danggappe soil

Table 2. Phosphorus sorption maxima (b) and k values of five Nigerian soils.

No.	Soil	Langmuir Constants b mg P/100 g soil	k × 10 <sup>-4</sup>
001-1	Egbeda	13.5	1.65
007-1	Funtua	10.8	1.03
011-1	Danggappe	4.1	1.28
028-1	Alagba	13.3	1.25
024-1	Nkpologu	44.4 ,	2.25

from Mokwa, central Nigeria is lower than the other four soils studied.

The bonding energy of sorbed P as indicated by the k values for the soils are in the order of Nkpologu > Egbeda > Danggappe > Alagba > Funtua.

Sorption of added P by soils is believed to be mainly controlled by the amorphous Fe and Al oxides, organic matter and soil pH, as well as the silicate minerals present in the clay fraction. This relationship shows in Table 3.

P fertilizer retained by soils under certain favorable conditions may not be rapidly converted to fixed form. We believe that added P retained at the surface of amorphous Al oxide or sorbed by the Al associated with soil organic matter is relatively more available to plant than that retained by amorphous Fe oxides.

Condensed phosphate as a source of P for plants. The value of pyrophosphate as P source for crops in tropical soils was evaluated by determining its rate of hydrolysis and its retention characteristics by soils as compared with orthophosphate.

The rate of hydrolysis of pyrophosphate

Table 3. Soil properties and extractable Fe and Al in soils used for P sorption studies.

Soil No. Soil Series	Call Carles			0 0	Claure	Al in Soil	as Al <sub>2</sub> 0 <sub>3</sub> ,%	Fe in Soil as Fe,03.%	
	Location	pH (H <sub>2</sub> 0)	Org. C %	Clay %	Oxalate	Dithionite	Oxalate	Dithionite	
001-1 007-1	Egbeda Funtua	IITA Samaru	6.7 5.8	1.82 0.68	27.0 24.0	0.32	2.21 1.47	0.27 0.26	4.22 1.08
011-1	Danggappe	Mokwa	6.7	0.59	20.0	0.13	1.42	0.06	0.87
018-1	Alagba	Benin	5.6	1.10	21.0	0.19	3.02	0.10	1.59
024-1	Nkpologu	Nsukka	5.1	1.23	26.3	0.39	3.48	0.21	4.04

was studied in several selected Nigerian soils. To a series of 5-g samples, 0.5 ml of Na-pyrophosphate solution containing 6.72 mg of P was added and the soil incubated at 30C at field moisture capacity, Orthophosphate content in the soil was then analyzed after 2, 4.8.16.32 and 64 days of incubation. Hydrolysis of pyrophosphate as a function of time was shown to be in exponential form for all the surface soil and subsoil samples studied. Therefore, the rate of hydrolysis can be expressed as half-life where 50% of the pyrophosphate was hydrolyzed to orthophosphate. The pyrophosphate half-lives of the eight soils studied and their relation to some soil properties are given in Table 4.

In general, hydrolysis proceeded readily in the four surface soils whereas the hydrolysis proceeded at a slower rate in the subsoil samples. The rate of pyrophosphate hydrolysis in soils is mainly governed by the microbial activity, optimum soil pH, and organic matter content.

About 20 to 30% of the pyrophosphate was "permanently" retained by the soil and temained unhydrolyzed in the surface soil

sample, and approximately 40 to 60% of the pyrophosphate remained unhydrolyzed in the subsoil samples. This portion of non-hydrolyzable pyrophosphate is apparently associated with the clay content of the soil as shown in Table 4, presumably associated mainly with amorphous Fe and A1 oxides in the soil. Further investigation is needed with regard to the retention characteristics of pyrophosphate on various soil components in tropical soils.

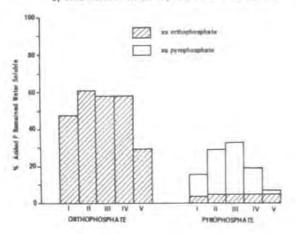
A preliminary experiment was conducted to study the retention of pyrophosphate of five surface soils as compared with orthophosphate. An equal amount of P as Na-pyrophosphate and mono-sodium orthophosphate (6.72mg P) was added to a series of 5-g soil samples, which were later incubated at 30C at field moisture capacity, Orthophosphate and pyrophosphate soluble in 1N NH4Cl were determined after a two-day incubation period, (Fig. 6). The surface soils retained more pyrophosphate (70 to 94% of added P) although the relative amounts of pyrophosphate and orthophosphate retained by the five soils follow a similar trend. The acid Nkpologu soil from eastern Nigeria retained the highest amount of pyrophosphate and orthophosphate

Table 4. Half-lives of pyrophosphate in relation to some soil properties.

Soil		Depth	Location	Pyrophosphate Half-life days	pH (H <sub>2</sub> 0)	Organic C %	Clay %
Egbeda Egbeda	A B	0-17 42-78	IITA	9	6.7	1.82 0.31	27.0 61.0
-	Á	0-10	IITA	6	5.9	2.06	21.0
regun Iregun	В	94-148	IITA	75	7.7	0.38	37.0
Funtua	A	0.27	Samaru	Б	5.8	0.68	24.0
Funtua	В	27-75	Samaru	15	6.0	0.38	41.0
Alagba	A	0-14	Benin	11	5.6	1.10	21.0
Alagba	В	34-75	Benin	37	5.0	0.40	48.0
Vkpologu	i	0-43	Nsukka	-	5.1	1.23	26.3

(94% and 71% of added P respectively). However, the first experiment showed that more than 70% of pyrophosphate added to the surface soil was subjected to hydrolysis within 20-day period. A relatively constant level of NH4C1-soluble orthophosphate from the pyrophosphate treated soils is maintained after correction for original soil orthophosphate content (Fig. 6).

Figure 6. Comparison of the retention of pyro- and ortho-phosphate by soils incubated for two days at field moisture capacity.



The results indicate that pyrophosphate may be a more effective source of P for plants than orthophosphate. The relatively greater amount of pyrophosphate retained by the surface soils prevents further downward movement of P beyond the root zone in these coarse-textured surface soils. Moreover, in soils with high orthophosphate-fixing capacity, the pyrophosphate retained is subjected to gradual hydrolysis to orthophosphate form during the cropping period. Such process may act as a "slow-release" process in supplying plant-available P in soils having high orthophospnate-fixing capacity.

However, laboratory data alone are not sufficient. Greenhouse experiments are being conducted comparing the effectiveness of the various forms of condensed P fertilizers to the conventional orthophosphate fertilizers in a range of selected Nigerian soils.

#### DYNAMICS OF FE, AL OXIDES & ORGANIC MATTER IN TROPICAL SOILS

The rapid deterioration of physical and chemical conditions of soils after forest clearing is a major problem in the management of tropical soils for continuous food crop production. Amorphous and crystalline Fe and Al oxides and hydrous oxides are among the predominant components in the clay fraction of tropical soils. The importance of Fe oxides in stabilizing the structure of tropical soils is recognized.

There is evidence that soil properties such as cation and anion sorption, swelling and specific surface area are significantly modified by the presence of Fe oxides. The effect of Al oxides on soil aggregation as well as other soil physico-chemical properties has received little attention by tropical soil researchers.

Further understanding of the physicochemical characteristics of these compounds in tropical soils is of great importance for the development of effective soil management practices for food crop production.

#### Our objectives are:

- To characterize the forms and content of Fe, Al oxides and organic matter in tropical soils.
- To study the interaction of Fe and Al oxides with soil organic matter and its effect on soil micro-aggregation.

 To study the changes of physicochemical status of Fe, Al oxides and organic matter under different vegetation cover and their influence on phosphorus retention, cation and anion sorption capacity and soil moisture characteristics.

Forms of Fe and A1 in soils, Fe and A1 in soils can be classified into three major forms: Fe and A1 associated with soil organic matter in the forms of complexes, amorphous oxides and hydrous oxides of Fe and A1, and crystalline oxides and hydrous oxides of Fe and A1. These three groups in soils can be approximately differentiated by methods of selective extractions. It was found that 0.1 M Na4P207 mainly extracts organo-A1 and organo-Fe complex salts from the soil. Acid ammonium oxalate extracts the amorphous forms of Fe and Al oxides and extraction with dithionite-citrate-bicarbonate removes both amorphous and crystalline-free Fe and A1 oxides from the soil. These extraction methods are generally successful in differentiating forms of Fe in soil.

Oxalate and dithionite extractable Fe and A1 in 12 soil profile samples from various parts of Nigeria were analyzed. Results of four selected profiles are given in Table 5.

Varied contents of Fe and A1 in the soils were obtained. In general the contents of dithionite extractable Fe and A1 oxides (total free oxides) increase with depth and the amounts of these oxides in the soil are directly proportional to the clay content of the soil. These relationships are more pronounced in the case of Fe and A1.

Amorphous forms of Fe and A1 oxides as determined by NH<sub>4</sub>-oxalate extraction constitute only a small portion of the total free Fe and A1 oxides in all the soils studied. There seems to be no definite correlation between amorphous Fe and A1 content and the content of clay within each profile.

The relative proportion of amorphous forms of Fe and A1 to the total free Fe and A1 oxides can be expressed as the active Fe and A1 ratio calculated by:

Active Fe (or A1) ratio  $= \frac{\text{Oxalate Fe}_20_3 \text{ (or A1}_20_3)}{\text{Dithionite Fe}_20_3 \text{ (or A1}_20_3)}$ 

and results are also given in Table 5.

The active Fe ratio for all soil profiles decreases with the increase of depth within the profile. This clearly suggests that the proportion of crystalline Fe oxides increases with increased depth within the profile. Nevertheless the same relationship does not hold true in the case of A1. The active A1 ratios in all soils are generally greater than the active Fe ratios within each profile for all soils studied.

# SOIL CHEMICAL ENVIRONMENT AND ROOT GROWTH

Recently, increasing attention is being given to chemical environment at the root-soil interface and its relation to root development and plant growth. The development of plant roots in soil is greatly influenced by the available nutrient status, concentration of toxic ions in the soil solution, soil physical conditions and the ability of roots to modify the chemical and biological conditions at the root-soil interface.

Supply of nutrients to plant roots. A greenhouse pot experiment was conducted on the change of chemical environment at the root-

Table 5. Extractable Fe and A1 contents in soils from Nigeria

Depth	pH	Clay	Fe203	in soil, %	A1203 i	n soil, %	Active Fe	Active At
cm	(H <sub>2</sub> 0)	%	Oxalate	Dithionite	Oxalate	Dithionite	Ratio x 10 <sup>3</sup>	Ratio x 10 <sup>3</sup>
			Profile 00	1 Egbeda/IIT	A (Alfisol)			
0 - 15	6.8	21.3	0.27	4.22	0,32	2.21	64	145
5 - 15	6.7	25.3	0.23	4.89	0.36	2.46	47	146
15 - 45	7.1	37.3	0.22	7.08	0.40	2.10	31	190
45 - 65	6.7	56.3	0,21	10.20	0,49	4.20	21	117
65 - 95	6.3	64.3	0.21	9.68	0.49	4.35	22	113
95 -110	6.1	65.3	0.21	10.27	0.49	3.76	20	125
			Profile 018	Alagba/Ben	in (Oxisol)			
0 - 14	5.6	21.0	0.10	1.59	0.19	3.02	63	63
14 - 34	5.6	38.0	0.17	2.98	0.30	3.21	57	93
34 - 75	5.0	49.9	0.19	4.17	0.38	3.82	46	99
75 -175	5.0	48.0	0.17	3.67	0.32	3.02	46	106
125 -175	5.0	47.0	0.15	3.72	0.38	3.08	40	123
			Profile 024	Nkpologu/Ns	sukka (Oxis	ol)		
0 - 43	5.1	26.3	0.21	4.04	0.39	3.48	52	112
43 - 70	5.2	25.7	0.19	4.30	0.39	3.21	44	121
70 - 93	5.3	29.3	0.23	5.44	0.43	3.08	42	140
93 -170	5.2	36.3	0.23	6.09	0.42	3.21	38	131
			Profile 00	7 Funtua/San	naru (Alfiso	1)		
0 - 27	5.8	24.0	0.26	1.08	0,09	1.47	241	61
27 - 75	6.0	41.0	0.16	2.06	0.17	1.42	78	120
75 -166	6.1	45.0	0.14	2.54	0.21	2.12	55	99

soil interface as related to nutrient uptake of several varieties of maize and upland rice growing in two IITA soils: Egbeda and Apomu soils with 27% and 10% of clay, respectively.

Nine varieties of maize and 10 of rice were used for this study. Two plants of maize and four of rice were grown in both fertilized and unfertilized soils. After four weeks (maize) and five weeks (rice) of growth, the plant tops were clipped, dried at 60C and the uptake of P, Ca and K analyzed. The pH values of the rhizoplane soil, rhizosphere soil and bulk soil were measured immediately after harvesting, and the neutral NH<sub>4</sub>0Ac soluble P, Ca and K contents in rhizosphere and bulk soils were determined.

No significant differences among varieties of the same plant species in pH changes and nutrient content in rhizosphere soil were obtained. Therefore, results may be presented as the average values. When rice and maize plants were growing in non-fertilized Egbeda soil with a pH of about 6.9, the plant roots seemed to lower the pH of the soil consider-

ably, particularly in the soil immediately adjacent to the root surface as indicated by the pH of the rhizoplane soil plus roots (6.6 and 6.3, respectively). The maize roots produced a more acidic environment than the rice roots.

As a result of NPK fertilizer applications, the pH values of Egbeda and Apomu soils were lowered to about 5.3 and 4.8 respectively. Rice plants growing in these acidic soils were found to be able to modify the pH values of the soil environment surrounding the roots slightly to higher pH values (5,5 and 5.3, respectively). However, in the case of maize, different conditions of pH changes were observed. When maize grew in the fertilized Egbeda soil with a pH value of 5.4 in the bulk soil, the pH value of the soils near roots was lowered slightly to 5.1. But the maize plants grown in fertilized Apomu soil with a pH of 4.7 increased the pH of the soil surrounding the roots to 5.1.

These results indicate that the ability of maize and rice roots to alter the pH at the root-soil interface depends upon the pH value of the bulk soil. Plant roots may raise and lower the pH condition at the root-soil interface and thus favorably modify the environment for root growth and nutrient uptake.

The average contents of P, Ca and K in the rhizosphere soil and bulk soil were also measured immediately after harvesting.

When maize and rice were grown in the non-fertilized Egbeda soil with high levels of soil K and Ca, low levels of soil P and N, and a near neutral pH value, the supply of K was a mass-flow controlled process as shown by the accumulation of K in the rhizosphere soil. The supply of Ca and P under such conditions was diffusion-controlled as indicated by the depletion of Ca and P in the rhizosphere soil. In

cases where NPK fertilizers were applied, the soil pH values of the Egbeda and Apomu soils were lowered to about 5.3 and 4.8 respectively as a result of fertilization. Under such conditions, the supply of K to plant roots became a diffusion-controlled process while the supply of Ca to plant roots became a mass-flow controlled process. The supply of P to plant roots remained diffusion-controlled as in the case of non-fertilized soil regardless of the decrease in soil pH and the increase of soil P level. This is shown by the depletion of P in the maize and rice thizosphere soils. The results demonstrate that soil chemical and physical conditions may alter the mechanism and the rate of supply of certain nutrients to the plant roots. Studies of the effect of surface and subsoil nutrient status on root development are being conducted.

Aluminum toxicity. Crops are generally classified according to their preferences to soil pH conditions. However, the direct effect is the tolerance of the crop to the concentrations of certain toxic ions existing in the soil. Al toxicity has been frequently reported to be one of the major limiting factors affecting crop growth in acid tropical soils.

In many tropical soils, crop growth responds to lime in proportion to the amount of extractable A1 in the soil. The critical level of extractable A1 in soils varies by crop species as well as soil characteristics.

Preliminary studies conducted on soil acidity and extractable A1 content in some selected Nigerian soils indicate that soils from Ibadan, Ife, Akure and Samaru contain relatively small amounts of N KC1 extractable A1 (0.01 to 0.2 me/100 g). Greenhouse pot experiments have shown that the application of acidifying fertilizers may cause soil pH to drop to below 5. However, addition of a rela-

able 6: Analysical data of an Egbeda series soil No. 001 (Alfisol). Location: IITA, Western State.

Depth	Mecha	Mechanical Analysis %			Gravel pH*			CECH	
cm	sand	silt	clay	g/kg	H <sub>2</sub> 0	Kel	%	me/100 g	
0-5	66.9	11.8	21.3	100	6.6	5.7	1.54	5.36	
5-15	57.9	16.8	25.3	430	5.4	5.5	1.50	6.99	
15-45	48.9	13.8	37.3	40	6.5	5.8	0.76	5.26	
45-65	29.9	13.8	56.3	60	5.6	5.3	0.28	4.24	
65-95	29.6	6.1	64.3	20	5.7	5.3	0.26	4.06	
95-110	20.2	14.4	65.3	20	5.6	5.4	0.18	4.47	
Depth			Exchange	able Cation	s. me/100	g		Bray 1-P	Non-Exch K
cm	Ca	Mg	K	Na	Mn	A1	H	ppm	ppm
0-5	3.50	1.20	0.39	0.10	0.09	0.01	0.16	14.9	283
5-15	5.20	1.31	0.15	0.05	0.11	0.01	0.16	6.3	183
15-45	3.52	1.35	0.12	0.05	0.05	0.03	0.14	2.5	157
45-65	3.05	0.89	0.10	0.10	0.02	0.04	0.13	0.7	157
65-95	2.90	0.75	0.11	0.10	0.03	0.06	0.11	0.7	157
		0.68	0.10	0.73	0.04	0.06	0.11	0.7	

<sup>\*</sup> pH was determined in soil paste

tively small dosage of lime brings the pH quickly back to normal.

Soils from Shagamu, Benin and eastern Nigeria contain relatively large amounts of extractable A1 (0.2 to 1.21 me/100 g) and the percentage exchangeable A1 saturation in these soils is much higher (40 to 70%).

# CHEMICAL CHARACTERISTICS OF CERTAIN NIGERIAN SOILS.

A thorough chemical and physical analysis of some representative Nigerian soil profiles is being made. This study is a part of the joint project with soil physics, soil fertility and soil classification in evaluating the soil fertility capability of major West African soils. These data are too voluminous for this report and will appear as a special publication. The Egbeda series analysis is included (Table 6) as an example.

#### Soil Fertility

Greenhouse and field trials during 1971 were as follows:

- A maximum yield trial with maize to study the influence of several cultural factors that influence yield potential.
- (2) A study of crop response to various fer-

<sup>#</sup> CEC was calculated by summation of all exchangeable cations in the spil-

tilizers on some major soils of Western State, Nigeria.

- (3) Evaluation of various forms of new, highanalysis fertilizers.
- (4) A study of the influence of nitrogen and inoculation with various Rhizobium strains on cowpeas and soybeans.
- (5) A study of soil microvariability.

Maize Maximum Yield Trial. Maximum yield trials during 1969-71 studied the influence of cultural factors, which individually or combined were expected to influence the maximum yield of maize at our experimental site. The studies included plant population, fertilizer application, weeding and crop protection. The results for the 1971 first season trial are in Table 7.

Highest yields during all 1969-71 trials were obtained when all limiting factors were reduced. This demonstrates the superiority of the multi-factorial approach in maximizing maize yield. Comparing the influence of the four main factors, crop protection gave the highest significant effect on yield, followed by plant population, weeding and fertilizer application. The effects of the four factors vary from year to year. The trial will continue for at least two more seasons to study seasonal influence on the magnitude of the four cultural factors.

Crop Response to Fertilizers. Preliminary house studies were conducted on the response of maize to additions to macro-secondary and micro-nutrients. The Egbeda and Olorunda series surface samples, collected from the forest zone regardless of vegetation, showed a P> N> S> K order of response with no appreciable potassium response. In the Woro series collected from the savannah area nitrogen and

Table 7. Dry grain yield of maize Composite AxB as influenced by plant population, fertilizer application, weeding and plant protection, 1971. LSD 0.05 = 0.77

	Treatment	Yield (ton/ha)
1.	Low population, no weeding	3.39
2.	Low population, weeding	3.25
3.	High population, no weeding	3.25
4.	High population, weeding	3.79
5.	Low population, no weeding, fertilizer	
6.	Low population, weeding, fertilizer	3.36
7.	High population, no weeding, fertilizer	3.76
8.	High population, weeding, fertilizer	4.04
9.	Low population, no weeding, protection	3.94
10.	Low population, weeding, protection	4.64
11.	High population, no weeding, protection	n 4.96
12.	High population, weeding, protection	5.83
13.	Low population, no weeding, fertilizer, protection	4.10
14.	Low population, weeding, fertilizer, protection	4.95
15.	High population, no weeding, fertilizer protection	5.74
16.	High population, weeding, fertilizer, protection	5,38

- High population 53,200 plants/ha, low population 26,600 plants/ha
- \*\* Fertilizer rate 120 N-90 P2 05-60 K20 kg/ha
- \*\*\* Hand weeding
- \*\*\*\* Plant protection, regular spray program with Dithane M-45 and Thiodane

sulfur were more limiting, with an order of response of N> P> S> K.

Table 8 shows a distinct response to sulfur of soils collected from forest and savannah areas. All soils tested gave a response to sulfur but the response was greater in the savannah soils. Studies of soil factors that may contribute to the differential response to sulfur between the soils of the forest and savannah zones are in progress.

Table 8. Response of maize cultivar NS-5 grown on various soil series collected from forest and savannah areas to addition of sulfur in pot trial.

Sample	Soil	Ecological	Dry matter weigh (grams)	
Location	Series	Zone	NPK S	NPKS
Ikenne	_	Forest	7.0	10.1
Eruwa	Apomu	Savannah	3.0	6.8
Hora	Shante	Savannah	4.1	7.1
Ogbomosho	Apomu	Savannah	2.4	6.8
Sepeteri	Woro	Savannah	1.9	7.6
Kishi	Omo	Savannah	1.6	6.6

Phosphorus Field Trials. A phosphorus rate and residual study was initiated on the Egbeda soil series in 1971. In the first season maize yield increased significantly with application 60 to 120 kg P/ha.

The second season yields were lower. With fresh dressing the yield increased significantly with 60 kg P/ha. Except at the highest rate, all treatments of the fresh dressing series gave slightly higher yields than the residual series. After one season there seems to be a good residual response of the applied phosphorus. The experiment will continue a few more seasons with two dressing series added.

Sulfur Field Trials. Field trials based on the greenhouse results studied the response of maize to addition of sulfur at three locations (Table 9). Significant sulfur responses were obtained only in the savannah locations. In Ogbomosho application of 60 kg S/ha nearly doubled yield. Sulfur application on both locations besides increasing yield also improved grain quality. The kernels from no-S plots were small, pale-yellowish and dull in color as compared to large, bright darkish-red kernels from the adequate S plots.

Tissue analysis of ear leaf samples indi-

cated that at Ogbomosho, where the highest S response was obtained, the sulfur content of tissue increased with sulfur application. A sulfur content of 0.12% in the ear leaves appeared to be adequate for good yield. The Ogbomosho samples also showed a significant increase in N, Fe and Mn content in the leaves with S application while the concentration of P, A1, Zn and Cu was not affected.

Zinc Field Trials. There are indications that zinc may be a limiting factor in certain soil series of Nigeria. Maize field trials were conducted in 1971 at six locations showing low soil zinc values. Data on available zinc in the soil profile are in Table 10. Response to zinc was observed only in the savannah zone. Zinc application significantly increased 0.lN hydrochloric acid extractable Zn and the Zn concentration of the ear leaf tissue.

Table 9. Influence of application of various sulfur rates on yield of maize NS-1 and Composite AxB grown on three soil series.

D	ry grain yie	Id (ton/ha)	
Sulfur rate (kgSO2/ha)	lbadan* Egbeda series	Ogbomosho** (Apomu series)	Kishi*** (Omo series
0	2.3	1.8	5.9
15	2.1	2.4	6.8
30	2.4	2.9	6.2
60	2.5	3.5	6.7
120	2.4	3.2	6.8
LSD 0.05	ns	0.9	0.9

<sup>\*</sup> Forest zone

It was also observed that with the same Zn level in the soil, the ear leaf Zn concentration of maize plants in the savannah was half that of plants in the forest zone. A com-

<sup>\*\*</sup> Savannah zone

<sup>\*\*\*</sup> Composite AxB only planted at Kishi

Table 10. 0.1 N HC1 extractable zinc (ppm) from various horizons at the six experimental sites.

Ikenne	(Shante series)	(Shante series)	Ogbomosho (Apomu series)	(Omo series)	(Woro series)
Forest zone	Savannah zone	Savannah zone	Savannah zone	Savannah zone	Savannah zone
1.70 (0-15 cm)	0.50 (040 cm)	0.50 (0-24 cm)	1.00 (0-30 cm)	0.60 (0-10 cm)	0.90 (0-13 cm)
0.50 (1					
1,70 ( 0 - 15 cm)		0.50 ( 0 - 24 cm			
0.50 (15- 30 cm)	0.75 (40-100 cm)	0.35 ( 24 - 40 cm			
0.60 (50- 75 cm)		0.35 ( 40-105 cm	1 0.45   49 - 86 c	m) 1.10 (22 - 50 c	m) 1.25 (28 - 44 cm
0.40 (75-100 cm)		1.00 (105-130 cm	0.55   86-108 c	m)	2.10 (44-65 cm
0.20 ( + 100 cm)			1.30 (108 -145 c	m)	1.50 (90-120 cm
					1.85 (120 - 150 + cm

plete nutrient analysis of the tissue did not suggest any nutrient interactions with Zn in the plant. It is speculated that the decreasing Zn concentration from forest to savannah zone may relate to increasing solar radiation.

Copper Yield Trials. Strip trials designed to detect possible maize response to copper were run simultaneously with the zinc trials at the same locations.

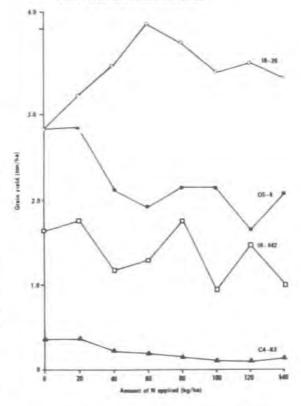
Although soil treatment with Cu significantly increased 0.01 M EDTA extractable Cu at all the sites, no significant effect of the Cu on growth, grain yield or tissue content of Cu and Zn was observed.

#### FERTILIZER WORK WITH UPLAND RICE

Nitrogen Field Trial. A 1971 field trial tested the response of four rice cultivars to nitrogen application. The experiment was under rainfed upland conditions on a soil of the Egbeda series. Figure 7 gives grain yield data.

All cultivars showed differences in yield response to N. IR-20 had a positive response until the rate reached 60 kg N/ha. No explana-

Figure 7. Influence of nitrogen rates on dry grain yield of rics cultivars. IR20, IR442, OS6 and C4-63.



tion can be given for the decrease in yield at

higher nitrogen rates. OS-6 gave a yield similar to IR-20 at zero N, but yield declined at higher rates, partly due to a higher degree of lodging. IR-442 yields varied between treatments because of variable damage to plots by Helminthosporium brown spot. C4-63, which showed severe leaf and neck blast infestations had the lowest yield.

Sulfur Pot Trial. A sulfur rate test was carried out with the Apomu soil series using OS-6 and IR-20 grown under upland conditions. Both cultivars showed significant response to sulfur and the experiment is still in progress.

Evaluation of New High-Analysis Fertilizers. Greenhouse trials were started in 1971 to evaluate the agronomic value of new nitrogen fertilizers received from TVA for tropical soils. Preliminary results were obtained from sulfurcoated urea sources (SCU) with different release rates compared to urea and ammonium sulfate used on upland rice. From the five nitrogen sources tested, urea was the least efficient and ammonium sulfate gave the best yield. SCU-D, which has an intermediate release rate, gave results comparable to ammonium sulfate. Split application of the ammonium sulfate in three equal parts - at planting, at tillering and at boot stage - increased panicle weight significantly at low nitrogen rates.

Inoculation and Nitrogen Rate Studies. A nitrogen rate test was carried out on three cowpea cultivars with different growths. The cultivars tested were Pale Green (prostrate type) Mala Local Brown (semi-erect type) and Prima (erect type). Trial results are presented in Table 11. Grain yields and yield components of Pale Green and Prima were not significantly affected by N application at rates up to 160 kg N/ha. Pale Green gave a higher yield than Prima. Mala Local Brown appeared photo-

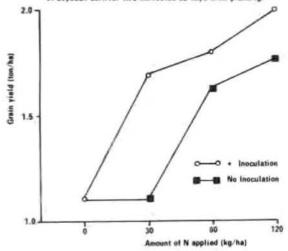
sensitive in the first season and did not produce grain.

Though natural nodulation with cowpeas is excellent, seeds in this trial were inoculated with Nitragin inoculum. Root examination showed no differences in nodulation between cultivars and treatments.

Inoculation and Nitrogen Rate Study on Soybeans.

Results of a field trial with four nitrogen rates, with and without inoculation, are presented in Figure 8. This indicates that inoculation only on low-nitrogen soil did not contribute significantly to the yield of cultivar TK-5 harvested 82 days after planting. There was a delay in scenescence of the plants from inoculated seed.

Figure 8. Influence of inoculation and nitrogen rates on dry grain yield of soybean cultivar TK5 harvested 82 days after planting.



Periodic root observations showed insignificant and irregular natural nodulation of uninoculated treatments. Inoculation increased nodulation significantly as shown in Figure 9 but application of N greatly depressed nodule weight. Observation of nodule numbers indicated that the application of N reduced nodule

Table 11. Influence of nitrogen rates on nodulation, grain yield and other yield components of cowpea cultivars Pale Green, Prima Green, Prima and Mala Local Brown.

Cultivar	kg N/ha	Nodules per plant 30 DAP	Grain Yield (ton/ha)	Pods per plant	Grain/Poo ratio
Pale Green	0	23	1.58	22	0.73
	20	15	1.59	22	0.73
	40	19	1.52	21	0.71
	80	23	1.65	22	0.72
	160	24	1.86	27	0.72
Prima	0	38	1.44	23	0.72
	20	26	1.34	24	0.70
	40	29	1.43	23	0.72
	80	31	1.36	21	0.70
	160	32	1.48	26	0.64
Mala Local	0	46	0		-
Brown	20	29	0		
	40	34	0		
	80	38	0		-
	160	49	0	~	

weight rather than nodule number.

Influence of Mulching and Inoculation Method. Data from a field trial to study the influence of mulching and inoculation method on nodulation of soybean cultivar TK-5 are presented in Table 12. The experiment was conducted at the end of the dry season and the plots were irrigated daily. Mulching increased nodulation. This may be due in part to a lower soil surface temperature under mulching. All three methods of inoculation gave good nodulation. Mulching with inoculum applied to seeds and broadcast gave the best nodulation.

# Evaluation of Effectiveness of Rhizobium Sources

A greenhouse test with soybean cultivar TK-5 evaluated the effectiveness of three inoculum sources, Nitragin, IAIR and CB 1809, on an Egbeda soil series. Nitrogen rates and a molybdenum treatment at 1 kg Mo/ha were included in the trial. Root observations indicated excellent nodulation with all three rhizobium

Table 12. Influence of mulching and inoculation method on nodulation of soybean cultivar TK-5 (Nodules counted at 63 DAP).

Inoculation Method	Mulched	Unmulched	Average
1. Uninoculated	57.3	40.3	48.8
<ol><li>Inoculum applied with seed</li></ol>	602.3	268.0	435.2
<ol> <li>Inoculum half ap- plied with seed, half broadcast</li> </ol>	737.0	197.7	467.4
4. Inoculum broadcast	562.3	258.7	410.5
Average	489.7	191.2	

strains. Application of molybdenum tends to increase nodule dry weight.

Study on Soil Microvariability. Localized variations in soil characteristics that influence crop growth and yields, to a considerable extent, occur in many tropical upland soils. Annual crops show a highly irregular growth under low level of management, but even with a high level of management including fertilizer application, the effects of soil microvariability are often striking for a considerable period of time after initial clearing. This soil microvariability is a severe limiting factor in field experimentation and in the statistical analysis of results of many types of experiments.

#### Forage Crops

Forage grasses and legumes may offer an alternative for bush fallow in the forest zone. Limited data from trials in West and Central Africa show that certain forage crops such as Stylosanthes gracilis and Pennisetum purpurem when used in cropping sequences, maintained or improved soil fertility conditions as well as bush fallow, and within less time.

Most studies of cropping patterns were conducred at low soil fertility levels. With increased inputs for accelerated field and food crop production, greater benefits from other forage species can be expected.

Adaptability studies are needed in selecting suitable forage species and cultivars for more intensive evaluation. Characteristics such as growth habit, extent of ground cover, seasonal growth pattern, drought tolerance, total dry matter production — above and below ground — and seed availability are important.

Some forage grasses and legumes were grown late in 1971 for such evaluation. Plant quarantine restrictions placed serious constraints on seed importations of the forage legumes. A few species were obtained from several introduction nurseries within Nigeria but none of the more recently developed cultivars was available.

Seeds of forage grasses and legumes are

not commercially available in West Africa, which requires production of adequate experimental seed stocks at IITA. Many forage crop species in the 1971 introduction nursery development into the dry season harvest of sufficient seed for 1972 research trials was possible.

Undoubtedly, greater benefit in terms of soil improvement from the use of forage as a part of the cropping system would accrue with the use of animals for recycling plant nutrients to the soil. Few cattle exist in the forest zone because of serious problems of pests and diseases. Some goats and sheep are kept but they browse and scavenge. As larger areas of the forest are cleated, cattle numbers will increase as in the derived savannah. Although major emphasis will be given to the use of forage as soil-conserving and soil-improving crops, it is anticipated that preliminary trials with cattle can be initiated.

A seminar on Forage Crops in West Africa was held at the University of Ibadan in April, 1971 sponsored by the Ford Foundation, L'Institut de Recherches Agronomiques Tropicales et de Cultures Vivrieres (IRAT) and IITA. This was the first time that torage researchers in West and Central Africa had ever convened. The gathering prompted keen interest in future conferences and in developing a coordinated regional forage program.

#### Nematology

By December 31, 1971, more than 10,000 soil and root samples were collected (5,880 for 1971) and examined for plant-parasitic nematodes. Fifteen kinds of plant-parasitic nematodes were found at IITA. The root lesion Pratylenchus sp., the root-knot, Meloidogyne

incognita, and the spiral nematode, Helicotylenchus pseudorobustus, are the predominant forms.

Changes in plant-parasitic nematode populations. The objective of a continuing study is to determine the kinds of plant-parasitic nematodes present on selected sites with different farming and abandonment histories and to follow the population trends from land clearing through subsequent croppings.

Based on aerial photographs and ground observations 19 plots representing five traditional farming and abandonment histories -Theobroma cacao L., Dioscorea rotundata Poir, Manibot esculenta Crantz, thicket and secondary forest - were identified prior to clearing. Surface soil texture was sandy clay loam in all plots. The land was hand-cleared in February, 1970 and planted to maize Zea mays L. in May, 1970, cowpen Vigna unguiculata (L) Walp in August, 1970 and maize in April, 1971. Ten 200 cm3 soil samples were taken monthly from each plot before clearing, January 1970 through July, 1971. Nematodes were isolated using the combined screening-Baermann funnel technique.

Nematodes found were Pratylenchus sp., Meloidogyne incognita, Helicotylenchus pseudorobustus, H. cavenessi, H. erythrinae, Paratylenchus curvitatus, Scutellonema bradys, S. clathricaudatum, Xiphinema americanum, X. ebriense, X. ifacolum, X. nigeriense, Xiphinema sp., and Criconemoides sp.

Population densities of plant-parasitic nematodes declined 85% within two months of clearing. However, the densities increased at each cropping and declined during fallow between crops. Pratylenchus sp., M. incognita, and H. pseudorobustus were the principal species that increased during cropping. Pratylen-

chus sp. was rarely found prior to cropping but became dominant, being 96% of the total population after 19 months of cultivation.

H. pseudorobustus was the dominant "wild" species (41%) prior to clearing and became the second dominant (3%) under cultivation. M. incognita, infrequently found prior to clearing, also increased under cultivation, H. cavenessi, H. erythrinae, P. curvitatus, S. clathricaudatum, X, ifacolum and X. nigeriense were rarely found after the first two months. The other named species of nematodes eventually disappeared from cultivated soil or declined to low levels and were not detected. No clear relationship was determined between population changes and preclearing cropping history. However, soils previously under cocon cultivation had fewer of the three dominant species.

These data suggest that under the traditional farming system of shifting cultivation the several plant-parasitic nematode species are able to survive, albeit in small numbers, and that modern farming practices favor the increase of certain species of nematodes to the detriment of others.

Time of planting after soil fumigation. To determine the optimum planting time after soil fumigation with D-D Mixture under IITA conditions, the soil was prepared to the seedbed condition for soil fumigation and D-D Mixture applied at the rate of 300 1/ha. The fumigant was injected on level ground using the broadcast method by hand-operated fumiguns. Maize and cowpea plots were arranged in a randomized complete block design with four replications for cowpea and six replications for maize.

None of the maize or cowpea plantings suffered any toxic effect from D-D Mixture on Egbeda soil from any of the planting times after fumigation. Prima cowpeas planted immediately after fumigation gave a higher yield than the planting on the 18th day after fumigation (Table 13). The yield differences between dates of planting are considered a date of planting effect independent of treatment.

Maize, NS-5, planted immediately after soil fumigation did not yield differently from maize on non-fumigated soil.

Plant response to soil jumigation on nonnematode injested soil. To determine the degree of plant-growth response on Egbeda soil fumigated with D-D Mixture where plant-parasitic nematodes are not a limiting factor, the soil was prepared to seedbed condition for soil fumigation. D-D Mixture was applied at the rate of 325 1/ha.

Table 13 Yields in kg/ha of Prima cowpea and time of planting after soil fumigation with D-D Mixture.

1st	18th day planting	
Fumigated soil	2830 a 2/	1382 a
Control (Non fumigated soil)	2580 a	888 b

<sup>1/</sup> Means of 4 replications.

Prima cowpea showed no significant differences in yield between fumigated and non-fumigated plots on Egbeda soil. The effect of D-D Mixture soil fumigation on nitrogen nodule formation was not inhibitory as nodulation was not significantly different between control and treated plots (Table 14). The root-knot nematode, Meloidogyne incognita, was rarely found. The root-lesion nematode,

Table 14. Yield nitrogen nodule index and root-knor nematode index on Prima cowpea grown on D-D Mixture fumigated and non-fumigated Egbeda soil.

	Yield*	Nitrogen nodule index**	Root-knot nematode index***
Fumigated soil	2381	1.23	0.07
Control (non - furnigated soil)	2543	1.42	0.08

. Means of 6 replications in kg/ha.

\*\* 0 = no nodules, 4 = maximum nodules, Means of 6 replications of seven samples each.

\*\*\* 0 = no galling, 4 = maximum galling. Means of 6 replications of seven samples each.

Pratylenchus sp., and the spiral nematode, Helicotylenchus pseudorobustus, were not a limiting factor.

Maize, NS-5, showed no significant difference in yield between fumigated and nonfumigated plots. The root-lesion nematodes were recovered in small numbers and did not affect the yield.

We conclude from the two soil fumigation trials on Egbeda soil planted to maize and cowpea that there is no stimulatory effect resulting from D-D Mixture treatment alone.

Lakeside and paddy sampling. The IITA lake and paddy areas were sampled to detect the introduction and buildup of plant-parasitic nematodes commonly tound in soils disappeared after submersion. No wet habitat plant-parasitic nematodes were found in 1971, more than one year after inundation.

Upland Rice. Fifty 200 cm3 soil samples were taken atrandom from the rhizosphere of several cultivars of upland rice in August. The

<sup>2/</sup> Statistical significance. Means followed by the same letter are not significantly different. Vertical columns only.

spiral nematode, H. pseudorobustus, was found in all samples at a mean of 263 nematodes per sample. Numbers of H. pseudorobustus ranged from 2 to 1140 nematodes per sample. M. incognita larvae were found in five samples with a mean of 30 larvae. Pratylenchus sp. were found in three samples (mean 2) and Paratylenchus curvitatus were in one sample (mean 3).

Pigeon Pea. Two plantings of pigeon pea, Cajanus cajan, were sampled in September with 100 root and soil samples examined. H. pseudorobustus was found in 74% of the soil samples in small to moderate numbers, Meloidogyne sp. larvae in 4% and Pratylenchus sp. in 2%. No nematodes were recovered from root samples. This is an interesting observation as C. cajan has been shown to be an excellent host plant for Helicotylenchus sp. and Pratylenchus sp. in Nigeria.

Soil Fumigation. The rapid increase of the root-lesion nematode on newly cleared land illustrated the need for protection of experiments such as maximum yield trials. Seedbed prepared soil was fumigated at the rate of 200 1/ha of D-D Mixture and excellent control of the nematode obtained. Three nematodes were recovered from 50 root samples of 10 g each from the entomologist's maize plot. The maize breeder's plot had four infected plants out of 50 with a mean of 21 nematodes per 10 g of roots. Maize plants from non-fumigated plots were 88% infected with 6,164 nematodes recovered from 10 g of roots.

#### Weed Research

The IITA weed research program expanded during 1971 with experiments on upland rice, soybeans, cowpeas, maize and soil sterilization.

Upland Rice. Two herbicide trials were conducted with upland rice (IR20) on land recently cleared from forest. The land for the first trial had a maize crop in 1970, and was fallowed until April 1971. Lack of rain for about 10 days following rice planting delayed emergence and probably reduced the effectiveness of some preemergence treatments. Weed growth was so profuse that the untreated control plot produced no yield. Lack of rain at panicle initiation and during grain filling also greatly reduced the crop yield.

No herbicide treatment provided good weed control. Compounds that look promising and warrant further investigation are 0.75 kg a.e. /ha 2,4-D plus hoe weeding, 3 kg a.i./ha fluorodifen 3 days after rice emergence plus 0.75 kg a.e./ha MCPA 28 days after rice emergence, and 2 kg a.i./ha butachlor plus 2.25 kg a.i./ha propanil 14 days after rice emergence. Oryzalin caused stunting of the crop.

In the second trial, rice was planted on land not cropped previously by IITA. There was a 36-hour delay between application of the preplant incorporated treatment and incorporation, thereby reducing their effectiveness.

Grain yields were greatly reduced because of lack of rain and insufficient irrigation. Promising herbicide treatments were 6 kg a.i./ha of propanil, 2 kg a.i./ha of A 70-345, 0.5kg a.i./ha 2,3,6-TBA plus 1.5 kg a.i./ha MCPA, and 2 kg a.i./ha of chloramben. Rice stands were greatly reduced by nitralin, by linuron at both 1 and 2 kg a.i./ha and slightly reduced by U-27,267 at 4 kg a.i./ha.

Soybeans. A soybean herbicide trial was conducted with the Kent variety. Total weed growth in the unweeded control plots at harvest was 3250 kg/ha dry weight. Excellent weed control and best yield was obtained with linuron at 2 kg a.i./ha (Table 15).

Cowpeas. A weed crop competition trial was conducted to determine when weeds cause the greatest reduction in yield in cowpeas. Treatments - weed free and weed infested - were changed at weekly intervals starting seven days after emergence.

The trial was conducted with Westbred cowpeas planted in April, June and July. In the April trial the plots were weeded daily until harvest. In the other trials the plots were weeded daily until 35 days after emergence and then weekly until harvest.

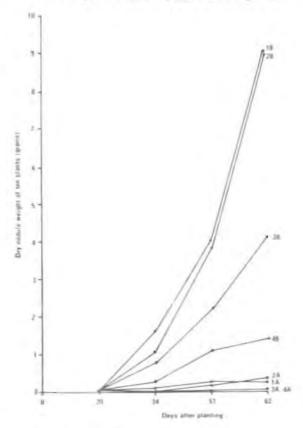
Yields from the three crops were averaged and expressed as a percentage of the weed-free control (Fig. 9). Weeding cowpeas once 20-30 days after emergence should be sufficient to obtain yields close to the maximum.

Three herbicide trials were conducted in cowpeas in 1971. Westbred was the test variety in the first two trials and W-112 the test variety in the third trial.

In the first trial planted in April 1971, meager rainfall for 10 days after planting delayed emergence of cowpeas and weeds and probably reduced the effectiveness of some preemergence treatments.

Total weed growth in the unweeded control plots at harvest was 3320 kg/ha dry weight, comprising 79% grasses, 19% broadleaved weeds and 2% sedges. The best herbicide treatment was trifluralin plus linuron. Other promising treatments were nitralin, ala-

Figure 9 Influence of inoculation and extrogen rates on nodulation of soybean cultivar TK 5, (A – uninoculated, B – inoculated, N rates 1, 2, 3 and 4 respectively 0, 30, 60 and 120 kg N/ha).



chlor, and alachlor plus linuron. Chlorbromuron caused stand reductions.

In the second trial weed growth was less than in the first trial - 2930 kg/ha dry weight in the unweeded control plots. Grain yields were extremely low due mainly to severe insect attack. Chloramben at 3 kg a.i./ha was the best herbicide treatment and a mixture of 2 kg a.i./ha of diphenamid and 2 kg a.i./ha of chlorpropham showed promise. Stand reductions were caused by acetochlor, terbutryn, and terbutryn plus GS 13529.

In the third trial, the best treatments

Table 15. Weed Control in Soybeans, 1971

TREATMENT	RATE (kg/a.i./ha)	TIME OF* APPLICATION	YIELD kg/ha 14% MOISTURE
Linuron	2	PE	1404
Chloramben + alachlor	1.5 + 1	PE	1340
Alachlor	2	PE	1244
Alachlor	3	PE	1204
Trifluralin	1	PPinc	1169
Trifluratin + linuron	0.5 + 1	PPinc + PE	1161
Alachlor + linuron	1 + 1	PE	1130
Chloramben	3	PE	1111
Weed free	*	Weekly	1070
No weeding		12	1025
Nitralin	2	PPinc	988
Nitralin	1	PPinc	954

\*PE - preemergence

PPinc - preplant incorporated

from the April 1971 trial were compared at varying rates. Also included were some new compounds not tested previously in cowpeas at IITA. All treatments that had yields less than yields in the no-weeding treatment caused stand reductions. Treatments that included linuron at more than 0.5 kg a.i./ha and alachlor at a rate higher than 1 kg a.i./ha were particularly damaging to the crop. Nitralin at both rates caused stunting of the crop.

Total weed growth in the unweeded control plots at harvest was 4540 kg/ha dry weight. None of the herbicide treatments that had yields higher than the no-weeding treatment provided adequate weed control.

There appears to be a genotypic difference between cowpea varieties in reaction to different herbicide treatments. Thorough examination of the problem in the greenhouse and in the field must be carried out before recommendations can be made.

Maize, In an herbicide trial conducted in maize during the second growing season, weed growth was light, probably due to residual atrazine because the area was planted to maize treated with atrazine at 2 kg a.i./ha in the first season. There was little difference in grain yield between the best herbicide treatments – atrazine + oil, atrazine, and cyprozine. Bladex and propachlor provided little if any weed control.

Soil Sterilization Herbicides were used in an attempt to obtain total weed control for the duration of the wet season. The herbicides were applied to cut plots on March 15 and to uncut plots on March 16. No rain fell during

the application period. Rapid growth of weeds required harvesting of weeds in all the plots six and nine months after herbicide application.

Only two treatments, sodium chlorate (361.3 kg a.i./ha) plus diuron (31 kg a.i./ha) and bromacil (7.5 kg a.i./ha) plus diuron (25 kg a.i./ha) and surfactant (1%) performed well on both cut and uncut vegetation. Generally treatments containing diuron were superior to the others.

# Agricultural Economics

During 1971 a number of studies were conducted in Nigeria within the framework of agricultural economics, with the study of farmers and their farms dominating the time and budget allocated.

The following studies were conducted:

- Decision-Making Processes of Yoruba Small Holders.
- Characteristics of Farm Labor Supply.
- The Role of Farm Gate Middlemen in Maize Marketing.
- The Coordination of Inputs and Information in Farming Systems.
- Price-Quality Variations in Maize.

Studies of factor and product relationships, and broad issues relating to agricultural development policy received increased attention. The following studies were initiated and should be complete in 1972.

- Economics of Water Resources.
- Economics of Fertilizer Distribution in Nigeria.

 Maize-Fertilizer Price Relationships in Zaire,

Decision-Making Processes of Yoruba Small Holders.

Field work — recording daily input and data, completing questionnaires and plot surveying for 100 smallholders sample — terminated in May 1971,13 months and two cropping seasons after initiation.

The cross-checking aggregation and coding of information took longer than anticipated owing to the large amount of data taken in the project. The nature of the farming system at the smallholder's level is such that many other activities, directly affecting the system, play an important role in the system's composition. The effect of risk on decision making is a case in point. All decision makers take risks and one of the factors influencing a decision maker's attitude to risks is the resources available to him should the risk fail. The resources available to the Yoruba smallholder are determined to a large part by his relationships with his wife or wives and their financial situation. It thus became necessary to' investigate the financial dealings of the wives of our sample. This added considerably to the amount of data necessary.

While data processing was done at IITA, the theoretical framework with which to investigate farming systems was formulated at Reading University, U.K. The simulation technique is employed because it is felt that the technique is the most suitable for a system that is essentially dynamic, incorporates changes over time and has both backward linkages and forward flows.

The model separates into two related parts. The first part structures the process in which the long-term planning is evolved - the plan consisting of the types of crops the decision maker will use in a season, the quantities of each he will plant, and the quantity and timing of labor he will use. This plan or over-all strategy may exist either consciously or subconsciously in the farmer's mind and may change during time due to changes in the values of any of the various factors influencing the plan's evolvement. The other part of the model structures the smallholder's daily decision process that results in each day's action, a process affected, among other things, by the smallholder's long-term plan.

The completed model may be inspected for a typical smallholder. His overall strategy is first evolved and then his daily decisions are simulated to give a series of actions and outcomes during a required period. Changes may then be made in values given to the characteristics of the crops so that a comparison may be made of the effect on income generated and different possible types of technology.

# Characteristics of Farm Labor Supply.

The supply of farm labor in Nigeria's Western State has changed rapidly during the last few years. Migration to urban areas, increased opportunity for education and major changes in relative farm product prices combined to alter the composition and the characteristics of the labor supply. Samples of households were drawn from each of six villages in Western State to identify the characteristics of the labor supply and to investigate the implications of changes over time in the composition of the labor force.

Three villages selected for the study, Ilua, Ilero and Okeho, are located in the derived savannah area in Oyo Division. Three other villages, Alaho, Akinlalu and Imo-Lisa are located in the forested area east and south of Ibadan. The 148 farmers interviewed were divided nearly equally among the six villages.

Modal farmsize of the farmers interviewed was 6 to 10 acres. However, 60% of the farmers each cultivated 10 acres or less. About 25% of the farmers had more than 15 acres each. There was no significant difference in the distribution of farm sizes between the derived savannah and forested areas.

Farm area was divided into food-crop and cash crop areas. The frequency of large cashcrop holdings was considerably higher in the forested area than in the derived savannah areas as expected.

The family farm labor supply for each village varied from four to sevon persons per household. This included both adults and children. The educational level and age distribution of the farm family members are shown in Table 16.

Each of the families interviewed was asked to indicate the number, age and educational characteristics of nuclear family members who had moved away from the farm. The characteristics of these individuals can be compared to the characteristics of the farm family. One-third to one-half of all those family members in the 11 to 20 age group have left the farm, and about one-fourth of those in the 21 to 30 age group have left the farm (Table 17).

The educational characteristics of the off-farm migrants are shown in Table 18. The high proportion of the migrants from the derived savannah area with West African School Certificate can most likely be attributed to a secondary school located near Ilero.

Occupations of off-farm migrants and rate

Table 16. Education levels and age distribution of farm family labor in six villages.

		Village					
		Hua	Hero	Okeho	Alaho	Imo-Lisa	Akinlalı
Education							
Percentage with:							
No schooling		84	77	88	75	91	77
Primary school Students		16	17	8	21	7	14
Primary school Completed	+		2	1	4	1	6
Secondary modern Students		-	4	3	-		+
Adult education		-	*		-	3	3
Age Group							
Percentage in group:							
1 - 10		11	26	28	27	32	24
11 - 20		15	14	23	14	24	30
21 - 30		23	21	14	14	-11	18
31 - 40		25	22	15	18	12	13
41 - 50		21	15	15	18	9	5
50 or more		5	2	5	9	12	10
Average labor force per household		7	4	6	5	6	б
Number of family members surveyed		172	81	179	116	169	116

Table 17. Percent of family members migrating out of the farm family by age group.

Age Group	Three Savannah area villages	Three forest area villages
1 - 10	10	8
11 - 20	35	49
21 - 30	30	19
31 - 40	11	1
41 - 50	1	11.0
50 or more		
f migration b	y educational leve	el are shown

The results indicate that education is the vehicle for migration out of the farm family. In this regard, it is important to note that

Table 18. Educational characteristics of family members migrating out of the farm family

Educational level	Three Savannah area villages	
3	of all migrants	
No. schooling	39	24
Primary school		
non-graduate		4
Primary school		
graduate	26	60
Secondary school		
non-graduate	2	3
Secondary school		
graduate	18	8
W. A. S. C.	15	1

in Tables 19 and 20.

a major product from the agricultural sector is educated people. This out-migration of the educated from the farm families represents a major export of the agricultural sector. The value of this export from agriculture cannot be estimated with precision. Another aspect of the out-migration from agriculture is that rural people are left behind with relatively low education levels.

Table 19. Rate of migration off the farm of those in each education level.

Rate of migration for those with:	Three Savannah area villages	Three forest area villages
No. schooling	6	7
Primary school non-graduate		5
Primary school graduate	B4	75
Secondary school non-graduate	11	100
Secondary school graduate	100	100
W. A. S. C.	100	100

Table 20. Occupations of off-farm movers by percent of migrants.

Occupation	Three Savannah area villages	Three forest area villages
14	of all migrants	
Unskilled labor	52	36
Apprentice	8	15
Skilled labor	13	7
Self employed	5	7
Unemployed	7	15
Students	10	10
Others	5	10
Number of migrants	61	71

In an attempt to relate farm size to family size by age group and proportion of total acreage in arable food crops, the following regression was estimated:

$$Y_i = B_0 + B_1 X_{i1} + B_2 X_{i2} + B_3 X_{i3} + B_4 \chi_{i4} + B_5 X_{i5} + E_i$$

whereY; = total crop acreage.

X<sub>i1</sub> = number of persons in the 7-14 age group multiplied by the ratio of arable crop acreage to total acreage.

X<sub>12</sub> = number of males in the 15-65 age group multiplied by the ratio of arable crop acreage to total acreage.

X<sub>i3</sub> = number of females in the 15-65 age group multiplied by the ratio of arable crop acreage to total acreage.

X = number of in-school children multiplied by the ratio of arable crop acreage to total acreage.

X is a value of hired labor (annual) multiplied by the ratio of arable crop acreage to total acreage.

The over-all results were significant for only one pair of the six villages studied -Ilero and Ilua. The estimated regression for Ilero and Ilua is:

$$Y_i = 14.862 - 0.577 X_{i1} + 0.907 X_{i2} + 2.921 X_{i3}$$

$$(0.490) \quad (0.606) \quad (0.806) **$$

$$-2.661 X_{i4} + 3.349 X_{i5}$$

$$(0.708) ** \quad (0.422) **$$

$$R^2 = 0.89$$

$$\pi = 40$$

\*\*Regression coefficients significantly different from zero at 99 percent level.

For a farm with only arable food crops, children in the 7-14 age group have no significant influence on total farm size. Adults in the farm family are associated with larger farm size. Hired labor is also associated with larger farm size. School children are associated with smaller farm size. An additional woman in the family is associated with an increase in farm size of nearly three acres, while an additional man is associated with only a one-acre increase in farm size. As the proportion of arable crop acreage to total acreage declines — an increase in extent of cash crops — the magnitudes of the greater farm size associated with more adults and hired labor decline in the same proportion.

The estimated regressions for the other groups of villages showed no overall significance. The estimated coefficients corresponding to the independent variable X<sub>5</sub> (value of hired labor multiplied by the ratio of arable crop acreage to total acreage) were statistically significant at the 5% level and positive in all cases. However, the simple correlations between the variable, X<sub>1</sub>, X<sub>2</sub>, X<sub>3</sub> and X<sub>4</sub> were too high to permit significant and reasonable estimates of the corresponding regression coefficients.

The Role of Farm-Gate Middlemen in Maize Marketing.

The objective of this study is to examine the existing marketing facilities, the marketing structure and the functions of the farmgate middlemen for maize. The study was carried out in one of the major maize producing zones in Nigeria,

Forty-four farm-gate middlemen were interviewed during July and August 1971 in five willages. There were about 140 farm-gate middlemen identified altogether in the five villages. A farm-gate middleman is that person in the marketing chain who deals directly with the farm. The farm-gate middlemen who trade in maize do not confine their activities to maize. They also trade in other foodstuffs such as yam, yam flour, cassava flour, beans, rice, onions, guinea corn and pepper. The capital of farm-gate middlemen is not tied to maize and the crops they buy and sell vary throughout the year depending on harvest periods. Few of the farm-gate middlemen interviewed had maize and rice in stock in June and early July but most had yam flour and cassava flour at that time.

By August, however, all farm-gate middlemen had most of their inventories of foodstuffs in the form of maize and rice.

There were marketing organizations in each village to which about two-thirds of the interviewed middlemen belonged. Entry into the organization required a membership fee and sometimes a three-year apprenticeship. In three of the villages, the organizations fixed prices for foodstuffs purchased from farmers and policed their members to maintain the fixed prices. All of the organizations provided an informal method of disseminating pricing information at both producer and consumer levels. The organizations could grant loans to members although rarely were these loans given. The organizations also played a social role in each of the villages.

The farm-gate middlemen obtain maize from farmers in one of three ways:

- Buying maize on the field before harvest.
- Giving production loans to farmers and later obtaining the maize at harvest at a lower price than exists in the market.
- Buying maize at the harvest season.

None of the interviewed traders used the first method, although nearly one-third commonly gave production loans to farmers. The price of maize is established when granting the production loan. The farmers' interest cost for this credit is about 500% expressed on an annual basis. A major portion of the maize obtained by farm-gate middlemen is obtained at the harvest season. Measurement of the volume of maize purchased by the middlemen in this manner was not possible.

The growth of capital resources available to the farm-gate middlemen varies considerably within the five villages. In the larger villages, capital growth on the average appears considerably higher. There does not seem to be any distinction between personal and business capital. In the smaller villages particularly, the older traders appeared to be depleting their capital over time by personal consumption.

The Coordination of Inputs with Information in Farming Systems

The objective of this study is to examine the coordination of inputs and information for fertilizers and for pesticides.

Tentative conclusions are that the use of fertilizers is not widespread in the Western State but considerable gains have been made in the last few years. Fertilizer use is concentrated in certain geographical areas, and appears to be crop-specific. The Ministry of Agriculture and Natural Resources has been the chief source of information on fertilizers. The Ministry prepared radio broadcasts concerning fertilizer use and direct farmers' general and technical inquiries to the local extension agents.

Of the farmers who currently use fertilizers, most appear satisfied with the returns and, barring supply difficulties, will continue using it. There have been serious inadequacies in the supply and distribution of fertilizers. Ministry personnel attribute supply difficulties to lack of funds for salaries and transportation, but have continued to maintain a subsidy for the input.

Although good use is made of the radio, more could probably be done. The study reveals that the majority of the farmers sampled listen to radio with special attention given to programs carrying agricultural information.

### Price-Quality Variation in Maize

During the dry season of 1970-71, 30 samples of maize were purchased in several local markets in Nigeria's Western State to determine whether or not the price of maize reflected indentifiable quality characteristics. Each sample of maize was purchased in the local market in local measure. Measurements taken on each sample were: moisture content, kilograms per hectoliter, weight of sievings per kilogram, percent of insect-damaged grains and 1000 grain weight.

The simple correlation coefficients between price and each of the five measurements were low. The relationship between the quality measurements and price was inspected by regressing price on each of them. The F-statistics of overall regression were significant.

As expected the correlation between price and the kilograms per hectoliter was positive. On the other hand, the correlation between price and moisture content was positive while a negative correlation is expected.

The low correlations are in conflict with the maize-quality information found in talking with traders. Part of this may be explained by the difficulty in establishing a price in the local market, where it was obvious to the trader that the enumerator's interest was academic rather than a desire to purchase food. The enumerators often found either of two conditions — excessive heaping of the basin because of the interest shown in the trader, or an excessive price based on the enumerators' apparent ability to pay.

This work will continue on a limited basis to either confirm or reject the tentative results.

Rainfall Probability and Irrigation Economics.

Crop production in West Africa depends on rainfall as the major source of water. The annual rainfall in the moist forest zone of the south varies from 1.14 to 3.81 meters, while the savannah zone of the north has an average of from .08 to 1.14 meters. In general, the distribution of this rainfall in the forest zone is bimodal, and that of the savannah zone is unimodal.

Droughts can occur during the wet season causing serious loss in the crop yields, with annual crops being most seriously affected.

Recent interest in economic evaluation of supplemental irrigation, especially for rice, in the higher rainfall areas, prompted study of probabilities of rainfall, implications for supplemental irrigation on farms, and possible economic gains due to irrigation in crop production. The long-run objective of the study is to determine the economic benefits from supplemental irrigation and related production practices, given a specific rainfall pattern.

Although knowledge of the effects of water stress on grain yield at different physiological growth stages would help decide the optimum allocation of limited irrigation water for improved varieties, the length of time the plant is subjected to stress is more important in determining the amount of yield reduction than the particular growth stage at which the stress occurs.

Generally, rainfall of 5 to 7.5mm/day is considered adequate for optimum yield of rice. Depending on the rainfall distribution and rice variety, the yield would be reduced if a dry period occurs at any growth stage. A dry period is defined here as any seven days or more during which the total rainfall is less than 35mm. The rainfall pattern during the main crop period is analyzed to determine the most critical period during which supplemental irrigation is considered necessary. The daily rainfall record during 19 years (1953-1970) for May through September was obtained from the Geography Department, University of Ibadan, for the analysis. These daily rainfall data are grouped into different periods, and for this analysis, the four-day period records are used. Assuming a rainfall requirement of 5mm/day for rice, a minimum of 20mm of rain is required in any four-day period of optimum vield.

The probability of obtaining a certain level of rainfall was calculated and, with given probability levels, the expected minimum rainfall at each probability level was calculated for each of the 38 four-day periods involved in this study.

The amount of rainfall that can be expected at different probability levels are shown in Table 21. At 10% probability level the rainfall expected throughout the crop period ranges between 26.3 and 76.5mm. The expected rainfall decreases at higher probability levels. From 40 to 90% levels, for example, the amounts of rainfall expected, in general, are less than the 20-mm level.

Despite the shortness of the four-day period, it is difficult to assume independence

Figure 21. Rainfall Levels (mm) with Equal Probability, in four-day periods - (May-September).

PERIOD	10%	20%	30%	40%	50%	60%	70%	80%	90%
1	54.8	38.2	28.7	21.8	16.6	12.3	8.5	5.5	2.6
2	40.7	28.4	21.3	16.2	12.3	9.2	6.3	4.1	1.9
3	47.2	32.9	24.7	18.8	14.3	10.6	7.6	4.7	2.2
4	49.1	34.2	25.7	19.6	14.9	11.1	7.7	4.9	2.3
5	64.6	45.0	33.8	25.7	19.6	14.5	10.0	6.4	3.1
6	32.3	22.5	16.9	12.9	9.8	7.3	5.0	3.2	1.5
7	32.2	22.4	16.8	12.8	9.7	7.2	5.0	3.2	1.5
8	54.3	37.8	28.4	21.6	16.5	12.2	8.5	5.4	2.6
9	56.5	39.6	29.5	22.6	17.0	12.5	8.8	5.4	2.7
10	76.5	53.3	40.1	30.5	23.2	17.2	11.9	7.6	3.6
11	43.6	30.4	22.9	17.4	13.2	9.8	6.8	4.3	2.1
12	68.6	47.8	35.9	27.3	20.8	15.4	10.7	6.8	3.8
13	46.8	32.6	24.5	18.6	14.2	10.5	7.3	4.7	2.2
14	47.6	33.2	25.0	19.0	14.4	10.7	7.4	4.7	2.3
15	58.4	40.7	30.6	23.2	17.7	13.1	9.1	5.8	2.8
16	35.7	24.9	18.7	14.2	10,8	8.0	5.6	3.6	1.7
17	48.4	33.7	25.4	19.3	14.7	10.9	7.5	4.8	2.3
18	65.3	45.5	34.2	26.0	19.8	14.7	10.2	6.5	3.1
19	49.8	34.7	26.1	19.8	15.1	11.2	7.8	5.0	2.4
20	32.8	22.8	17.2	13.1	9.9	7.4	5.1	3.3	1,6
21	39.1	27.2	20.5	15.6	11.8	8.8	6.1	3.9	1.9
22	26.3	18.3	13.8	10.5	8.0	5.9	4.1	2.6	1.3
23	30.0	20.9	15.7	11.9	9.1	6.7	4.7	3.0	1.4
24	26.3	18.3	13.8	10.3	8.0	5.9	4.1	2.6	1.3
25	26.3	18.4	13.8	10.5	8.0	5.9	4.1	2.6	1.3
26	41.0	29.8	21.9	16.6	12.6	9.4	6.5	4.2	2.0
27	30.1	20.9	15.7	12.0	9.1	6.8	4.7	3.0	1.4
28	42.6	29.7	22.3	16.9	12.9	9.6	6.6	4.2	2.0
29	48.5	33.8	25.4	19.3	14.7	10.9	7.6	4.8	2.3
30	47.4	33.0	24.8	18.9	14.4	10.7	7.4	4.7	2.3
31	34.2	23.9	17.9	13.6	10.4	7.7	5.3	3.4	1.6
32	67.3	46.9	35.2	26.8	20,4	15.1	10.5	6.7	3.2
33	33.5 55.0	23.3	17.5	13.3	16.7	7.5	5.2 8.6	3.3 5.5	1.6
35	36.4	25.4	19.1	14.5	11.0	8.2	5.7	3.6	1.7
36	74.1	51.6	38.8	29.5	22.4	16.7	11.5	7.4	3.5
37	58.6	40.8	30.7	23.3	17.8	13.2	9.1	5.8	2.8
38	48.3	33.7	25.3	19.2	14.6	10.9	7.5	4.8	2.3

between rainfall amounts in successive periods. Furthermore, there is no reason to believe that the probability distribution would be symmetric when models involving five-day periods are utilized. The use of the normal distribution is thus probably not appropriate in this case. For further analysis the gamma distribution will be utilized.

Fertilizer Distribution in Three States of Nigeria.

To examine the present methods and problems in the distribution and use of fertilizer, a study was initiated in three states of Nigeria – Western, Benue and Kano. Some secondary information is being obtained from the other nine states. Three groups of people were interviewed in each state – sales agents, farmers using fertilizer and farmers not using fertilizer. Information was also obtained from Ministries of Agriculture and Natural Resources concerning subsidy policies, distribution systems, transportation arrangements and levels of fertilizer use. The study is to form part of a graduate thesis for a Nigerian student at Cornell University.

Ma ze-Fertilizer Price Relationships in Zaire.

A study of maize-fertilizer price relationships in the Republic of Zaire was initiated at the request of the Zaire National Maize Research and Production Program.

The objectives were: to determine the constraints on increased maize production and fertilizer use in Zaire, and to suggest changes in policy which would promote the expansion of maize production.

The fertilizer-maize price ratio in Zaire is approximately 10:1 or 12:1 and increased maize production using fertilizer-responsive varieties is dependent on lowering this ratio considerably. Some reasons for this high ratio were identified:

- Price legislation and enforced cropping patterns in Zaire have contributed to major distortions in pricing and production of maize. In general this legislation, coupled with inflation, has tended to drive smallholders out of the market economy and back into a subsistence agriculture, leaving commercial production for those in the paysannal system.
- The transportation system in Zaire is organised around the Voic National, a government-controlled, privately-owned set of monopolies. Transport costs are high on this national system. Feeder roads are few and usually in bad repair.
- Fertilizer costs are extremely high, in part due to the high transport costs from North Europe to inland cities, in part due to the 18% import and customs duties and in part due to the oligopolistic position of the distributors. Distribution networks at the farm level do not exist.

During 1972, further work will be done to complete the analysis and develop a set of policy recommendations for the Zaire government.

Estimation of Plot Size and Shape for Maize Field Experimentation from Uniformity Trial On Egbeda Soil Series.

A major problem in conducting field experiments on recently cleared land at IITA is the high micro-variability of the soil. Observations are that previous land use and other factors still under investigation influence the magnitude of the micro-variability of the soil.

The most widely used estimate of soil

variability is the regression coefficient b for the regression of the logarithm of plot variance on a per unit basis against the logarithm of the number of basic units. Though this method with and without adjustments has been used successfully for a number of crops under tropical conditions, no published data are available for newly cleared forest land in the humid tropics.

The purpose of our study was to obtain an estimate of soil variability after forest clearing and determine the most efficient plot size and shape for maize field experimentation. In addition, effect of fertilizer application was also evaluated.

Data for this study were obtained from a uniformity trial with maize grown on Egbeda soil series in 1970. The experimental site was hand-cleared from secondary forest four months prior to planting. Maize cultivar NS-5 was planted in rows, spaced 80cm between tows and 25cm within rows.

Fertilized blocks received 40 kg/ha N, 40 kg/ha P and 50 kg/ha K broadcast before planting. Four unfertilized blocks and two fertilized blocks, each consisting of 36 rows 30m long were selected for this investigation. In each block maize yield was determined from 2.5m x 0.80m unit plots, giving a total of 432 (2m<sup>2</sup>) basic units per block. Grain yield was adjusted to 12% moisture content.

The coefficient of soil variability was calculated:

$$Var (y_x) = \frac{Var (y_i)}{\times \beta}$$
 ----(1)

where: Var (y<sub>x</sub>) = variance of yield estimated using observations on all plots of x basic units.

Var (yi) = variance of yield esti-

mated using observations on each basic unit.

number of basic units.

β = coefficient of soil variability.

 $\beta$  is estimated using two alternative least square methods which provide linear unbiased estimates of  $\beta$ , the coefficient of soil variability. Estimates of  $\beta$  are given in Table 22.

Table 22. Regression estimate for coefficient of soil variability.

Block	All Plots	One-row Plots	Two-row Plots
1	0.696	0.715	0.647
2	0,907	0.952	1.068
3	0.655	0.803	0.648
4	0.958	0.864	1.077
5	0.697	0.709	0.656
6	0.902	0.922	0.914

One of the estimates of  $\beta$  is significantly larger than one (1.077) which indicates that in at least one of the six blocks, the variance of yield increased as plot size increased. The conclusion is that the soil variability is high, confirming the suggestion that soil microvariability is a serious problem in the design and layout of field experiments.

The number of basic units (x) required to achieve a given c.v. (y) was then calculated from the mean yield per unit area.

The estimates of x can be transformed directly into plot sizes required to obtain given coefficients of variation. They are shown in Table 23 Table 24 shows the plot sizes required for given coefficients of variation when one- and two-row plots are used. The estimates of plot sizes are averaged

Table 23. Estimated plot size (m<sup>2</sup>) needed for various coefficients of variation.

c.v. (x)	Unfertilized	Fertilized
10	82.2	57.8
12	49.6	35.4
14	32.5	23.5
16	22.6	16.5
18	16.4	12.1
20	12.4	9.2
22	9,6	7.1
24	7.6	5.7
26	6.2	4.6

Table 24. Comparison of plot sizes (m<sup>2</sup>) needed for various coefficients of variation for onerow and two-row plots (No fertilizer).

c.v. (x)	One-row Plots	Two-row Plots
10	39.1	43.6
12	27.2	30.3
14	20.0	22.3
16	15.3	17.0
18	12.1	13.5
20	9.8	10.9
22	8.1	9.0
24	6.8	7.6
26	5.8	6.5

across the four unfertilized blocks and two fertilized blocks.

These results indicate that soil variability is high on the Egbeda soil series at IITA and that relatively large plots are needed in experiments.

## Agricultural Engineering

The agricultural engineer joined the staff on September 1 and devoted his time entirely to planning research and ordering research equipment and supplies. Farm equipment needs of the research farm were also studied and recommendations made.

## Power-and-Machinery Engineering Research.

Mechanization research is coordinated with the farming systems field research. Functional-design-requirements research will study the mechanical properties of soils in the context of tillage and traction. The broad objectives will be to identify the correct tillage-tool types and how best to apply them in working tropical soils and to identify the traction elements best suited to the prevailing soil types and service demands.

# Rice Mechanization (FAO)

A three-year rice mechanization project started in February and concentrates on soil tillage and weed control, and harvesting and threshing. Work in 1971 was limited to the first area. Data of the experiments are still in the processing stage and the following results are preliminary.

Irrigated Rice. A combined tillage-planting methods experiment was established early in the wet season. Yield data for rice following dry tillage and wet tillage are in Tables 25 and 26.

No significant differences were found in yields. However, there are indications that dry tillage results in higher yields than wer

Table 25. Yields in kg/ha of IR 20 rice grown in a flooded field following two methods of dry tillage and three methods of sowing, wet season, 1971.

		Handhoeing	1		Rotary Tille	r	
	Drilling	Dibbing	Broadcasting	Drilling	Dibbing	Broadcasting	Mean
REP.	3640	4330	4640	4080	3540	3320	3925
REP. II	4220	4320	4950	3550	4180	4850	4345
REP. III	5350	5540	3870	5270	4810	4980	4970
MEAN	4403	4730	4487	4300	4177	4393	4413

Table 26. Yields of IR 20 rice grown in a flooded field following two methods of wet tillage and four me thods of sowing, wet season, 1971.

		Handh	oeing			Rotary	Tiller		
	Drilling	Dibbing	Broad.	Transp.	Drilling	Dibbing	Broad.	Transp.	7
REP. 1	4280	5030	3250	3020	3350	4930	4360	3200	3928
REP. II	4270	4080	3820	3580	4150	3440	3370	3380	3761
REP. [1]	4600	3470	4710	4330	3860	3640	4030	3970	4076
MEAN	4383	4193	3927	3643	3787	4003	3920	3517	3922

tillage. Handhoeing gives higher yield following both dry and wet tillage methods than does rotary tilling, and planting methods do not produce differences in yield, except for transplanting following wet tillage (+400 kg/ ha less).

The IRRI-designed, hand-pulled, six-row seeder for pre-germinated rice was tested and used in some fields. Results were not outstanding because:

- The seed rate is difficult to adjust and keep constant because of variables involved such as seed size, moisture content of the seeds, length of sprouts, brush setting, the bush itself and working speed.
- Since the machine is pulled backwards,

it is difficult to maintain a constant speed, resulting in uneven seeding, and difficulty in making straight rows.

It is difficult to make a soft puddle in our sandy loam and sandy clay loam soils. This prevents the seeder from penetrating enough to get the seeds in a row. A wide band is sown instead, which looks more like broadcasting and results in poorly defined rows.

Plant counts were made in one paddy after dry drilling with a linkage seed drill. The coefficient of variability, mainly due to soil variation, of two-meter strips was 25%. Strips of 0.5m, 1m and 1.5m gave coefficients of variation of 43%, 29%, 29% respectively.

Table 27. Yields (kg/ha) and weed weights at harvest from IR 20 rice grown as upland following various tillage and weed control treatments, wet season 1971.

			RAIN YIE	LD	Manufacture California	a at bassade
		Weed	Control Pr	actice	weed weight	s at harvest
_	Tillage Treatment	No weeding	Hand weeding	Chemical Preforan	Non-weeded plots	Preforan treated plots
1	No tillage	191	937	423	2,179	592
2	Manual hoeing, 7-8 cm	451	1,184	859	1.363	251
3	Hand tractor with rotary tiller, 12 cm	378	995	776	1,088	185
4	Hand tractor with reversible plow, 12 cm	644	1.187	893	760	74
5	Mouldboard plow, 10 cm	441	1,032	844	1.026	99
6	Mouldboard plow, 25 cm	576	1,031	766	633	8.4
7	Disc plow, 10 cm	453	958	827	1,117	64
8	Disc plow, 25 cm	494	1,202	851	1.469	158
9	Rotavator, 20 cm	491	974	929	606	25
10	Subsoiler + rotavator, 50cm + 20 cm	385	999	816	1,671	103
	MEAN	450	1,051	798	1,191	164

Upland Rice. A tillage experiment with upland rice was carried out on sandy clay loam soil during the rainy season. The study consisted of 10 tillage treatments, two planting methods and three weed control practices, with five replications. Yield data and weed weights at harvest are given in Table 27. Because there were no differences between planting methods, the data presented are the means of drilled and broadcast plots together.

Hand-weeded treatments were better than a spraying with Preforan and no weeding was an inferior treatment as clearly demonstrated in the experiment. Weed control is urgently needed even in the first year after clearing. This is contrary to statements in the literature. The yields in general are low, resulting from a two-week too early start of the dry season at a time that the grains were just filling.

When all the data are plotted on a semi-

logarithmic scale, the equation found is (with a regression coefficient between Y and Y of  $R^2 = 0.85$ )

In Y = 
$$6.864 - 0.000671$$
 W  
(R<sup>2</sup> =  $0.87$ )  
with Y = yield (kg/ha)  
W = weed weight (m<sup>2</sup>)

This shows that the higher the level of Y, the more reduction in Y results if W increases. In other words at high yield levels an increase in weeds does more harm than at lower yield levels.

The upland rice experiment will continue for three years on the same plots to compare tillage treatments and to see if there is a cumulative effect of a given treatment.

# Cereal Improvement Program

The Cereal Improvement Program concentrates on rice and maize because of their production potential for the African forest zones of the humid tropics. By close cooperation with our sister institutes, IRRI and CIMMYT, the program is developed as an integral component of their global research as well as their regional outreach for Africa.

Specialized in-depth basic research on maize and rice is the global responsibility of CIMMYT and IRRI. However, IITA is attempting two major "breakthroughs" important for high yield levels of rice and maize in Africa:

- 1. IRRI designed a "new" rice plant. In Africa most rice is grown on rain-fed upland soils and for this, in addition to the new morphology, a new design in metabolism is needed. Root studies by the physiologist and agronomist, together with leaf studies in relationship to drought tolerance, should provide the breeder with parameters and screening techniques to develop a plant for high yield performance under upland conditions.
- There is much speculation about the factors that limit yields of maize in the humid tropics. The HTA multi-disciplinary team approach is to study the limiting factors and their interactions, and to replace speculation with precise knowledge.

#### Factors studied are:

- (a) ambient air night temperature effect on respiration losses.
- (b) soil temperature effect on rate of seedling growth.

- (c) effect of limited light, both short-day effects and effects of frequent overcast.
- (d) soil moisture effects.

#### MAIZE BREEDING AND AGRONOMY

The start of the maize breeding program was with Nigerian composites A and B, formed by the Federal and Western State Ministries of Agriculture. Composite A, formed by the Western State in 1968-69, has 12 components. Composite B was started in 1968 by the Nigerian Federal Department of Agricultural Research with 18 components. Twenty-three other components, supplied by CIMMYT via Kenya were included in the first generation as females only.

To achieve thorough mixing, four generations of random mating accompanied by mild 25% mass selection, were carried out in the formation of the composites during the two rainy seasons of 1968 and 1969. Results of Federal and State variety trials, including West African regional variety trials, showed that before the start of improvement by intensive selection, the two composites were equal in yield to the best improved material in Nigeria and West Africa.

IITA began intensive recurrent selection in the two composites early in 1970. The selection method used is by yield trial evaluation of S<sub>I</sub> lines, a method requiring three generations to complete a cycle. By the end of the 1971/72 dry season the first cycle was completed in composite A and the second cycle in composite B.

Selection is based predominantly on yield but progress on yield, though considerable, will be less than indicated because of experimental error and low heritability of yield. However, progress in the trials generation on other characters will be close to that indicated. There is considerable, though not always consistent, progress on reducing rust and blight leaf diseases, ear rots, and lodging presumably because all these characters influence high yield. Unfortunately other undesirable characters - late flowering, high ears and ears exposed at the tip - also tell on yield. However, there are exceptions by individual lines to this general trend so that even in the yield trials generation it was possible to avoid serious deleterious drift on these characters.

Superior germplasm was identified from the Central American regional variety trials and the best of it merged into composite A and composite B. The composites are openended and continual improvement will be made by adding such superior material as identified in addition to the improvement from regular breeding cycles. In the second season of 1970 four replications of the Central American regional maize trials were grown - two replications as regular yield trial plots without irrigation, one replication inter-planted in irrigated composite A and grown as female only by de-tasseling to give crossed seed, and similar replication in irrigated composite B. There were 14 commercial entries and 33 experimental entries in the trials. From the 47 entries 23 were selected at harvest for further work. The crosses were selfed and selected S1 lines were included in the recombination cycle of the composites.

At the same time a yield trial of the crosses to both composites was grown at Samaru, Nigeria and at IITA. The results showed that among this material we had considerably higher yields, good leaf disease resistance, and plant types less prone to lodging (Table 1). The best selections from this material are, therefore, expected to contribute greatly to improvement of the composites as from the next cycle.

Back-crossing to incorporate the Opaque-2 gene for high lysine into both composites reached the third generation in most of the material being used. Numbers are now big enough and further back-crossing is not needed.

Training and Regional Cooperation. Three visits to Zaire during 1971 led to the establishment of the Zaire National Maize Research and Production Program. Action proposals were made to the Government of Zaire during the first visit in March and during the second visit in July proposals were approved and budgets, staffing patterns, training plans, and initial research plans developed. An October visit was made to arrange implementation. The first six trainees from Zaire were in Mexico within 12 months of the Government of Zaire seeking advice.

The contract is between Zaire and CIMMYT with IITA participation to increase as our program develops. The Government of Zaire has allocated \$2.25 million to its maize program during the next 10 years. This is the first IITA involvement in a national program.

Cooperation was continued with O.A.U. Project 26, the West African regional cereals crops research project. IITA participation in this is expected to increase rapidly.

#### MAIZE ENTOMOLOGY

The main objectives of IITA's initial maize entomological investigations were to

Table 1. Results of Central American entries crossed with composites A and B. All characters at Ibadan and Samaru, 1971.

	Yield kilos/ha	Days To 50% Tasse	Ear He	ight cms.	Lod	ging ntage	Bligh	t Score	Rust
ENTRY	of BOTH CROSSES at BOTH locations	Average, 2 Crosses and 2 locations	Entry Alone Ibadan	Avge. 2 Crosses & 2 lo- cations	Entry Alone Ibadan	Avge. 2 Crosses & 2 lo- cations	Entry Alone Ibadan	Avge. 2 Crosses & 2 lo- cations	Avge. 2 Crosses Ibadar
Honduras 10 x 11	7085	56	57	175	13	7	2.2	1.4	1.8
Honduras Sin Tuxpeno	7020	58	60	178	19	10	2.2	0.8	1.6
E. S. H5	7015	56	53	163	20	6	2.0	2.0	1.7
Paey T 88	6852	57	61	165	15	10	2.0	1.3	2.4
Panama SM 1	6761	55	57	167	2	4	20	1.0	2.4
Poey T 25	6612	57	61	165	10	6	2.0	1.1	1.4
Proneer x 332 B	6590	56	48	156	9	6	1.5	1.1	1.6
Poey T 86	6472	58	58	167	11	В	2.0	1.1	1.8
Pioneer x 306	6465	55	52	154	33	6	1.5	0.9	1.8
Rocumex H 507	6445	59	61	172	21	7	2.2	1.2	1.4
Honduras 18 x 21	5224	56	50	163	31	8	1.7	1.3	1.6
Poey T 80	6083	55	57	159	15	6	2.2	0.9	1.8
Proneer x B 101	6020	56	50	154	7	4	2.0	1.0	1.8
Honduras 6 x 7	5989	57	55	163	10	5	2.0	1.5	1.6
Poey T 82	5917	57	58	172	14	5	2.0	1.0	1.9
Honduras H 5	5872	56	57	163	20	7	2.2	0.8	1.5
Honduras 8 x 10	5843	57	57	163	1.1	7	2.0	0.8	1.6
Control, Comp. A x Co	тр. В								
average of 3 entries	5834	55		164		7		0.9	2.0
Pioneer x 332	5706	55	46	151	10	6	1.5	0.9	1.6
Pioneer x V 103 B	5696	55	48	149	12	8	1.5	1.2	1.7
Poey T 27	5432	57	58	160	13	6	1.7	0.8	2.1
Pioneer x 330	5362	57	50	155	13	7	1.5	1.1	1.7
Pioneer x 306 A	5064	56	50	150	17	6	1.5	0.8	1.7
Pioneer x 342	4945	56	46	152	9	7	2.0	1.0	2.0

determine which insects cause the major problems, to assess the magnitude of losses due to insect attack, to compare the susceptibilities of several maize selections and to measure the efficacy of some insecticides. Untreated observation plots were established in 1969 and repeated in 1970. Insecticide trials were conducted in 1970 and 1971 and insect damage was assessed and correlated with yields in three cultural trials. Insect Populations and Types of Damage. The most obvious plant pests are the lepidopterous stalk borers, especially the noctuids Busseola lusca (Fuller) and Sesamia spp. and the pyralids Coniesta ignefusalis Hmps. and Eldana saccharina Wlk. Borer attack in young plants seriously reduces stand. Older plants are weakened and lodging is increased. It is not unusual for 100% maize stalks to be infested at harvest. Preliminary correlation analysis indicates that grain yields are reduced 1% for each 1% of the length of a stalk bored. The incidence of borer attack is significantly greater (1.6 times) in the upper half of stalks. Differences between infestation of top versus bottom halves were consistent and not affected by age of plants, plant variety, plant population density, fertilizer, weeds or sprays.

Other important pests comprise a heterogenous group of insects that inflict direct injury or spread plant diseases. For example the leafhoppers, Cicadulina spp., are vectors of maize streak virus. Among the heterogenous group are aphids, armyworms, budworms, cercopids, coreids, delphacids, derbids, grasshoppers, leaf beetles, leafworms, lygaeids, meloid beetles, mirids, pentatomids, plataspids, termites and thrips.

Relative Susceptibility of Maize Varieties. Six varieties planted in untreated observation plots during 1969 and examined at harvest showed no differences in stalk borer susceptibility. Nine varieties evaluated in 1970 showed interesting differences in susceptibility. Further selection work under controlled artificial infestation is planned.

Insecticide Evaluations and Avoidable Losses Field trials were conducted to estimate the importance of insects as a limiting factor in maize production. The first trial (1970 late season) included 12 insecticide formulations applied to NS-5 at 10 and 20 days after plant emergence. Results showed significant differences in stalk borerdamage but due to termite damage, non-uniform lodging caused by wind and rain, soil variability and insufficient replication, yields ranging from 2,702 to 3,876 kg/ha were not statistically different.

The second trial (1970 late season) was conducted to compare different spray schedules with carbaryl 85% WP at 1.5 kg a.i./ha per treatment date. Three 37-125 m<sup>2</sup> plots of NS-5 maize were used for each schedule. Results of borer damage counts and yields are shown in Table 2.

Table 2: Effects of timing and number of carbaryl sprays(1.5 kg a.i./ha per spray)on maize stalk borers and grain yields, 1970.

Sprayed at — days after emergence:	Total No. of sprays	Borer damage (% of stalk length bored)	Yield (kg/ha)
10, 30	2	1.33	3333
10, 20, 30	3	1.43	2709
10, 20, 3080	8	1.53	3164
10	1	1.63	3055
10, 20	2	1.73	3359
Untreated check	0	1_87	2615
30	1	2.37	3095
20, 30	2	2.40	2901
20	1	2.60	2811

 a/ Figures not connected by same line are significantly different at 0.05 level.

The third trial, planted with NS-1 in April and May 1971, compared the following treatments:

		Treatment at -	weeks after pl	ant emergence	
Insecticide	1 waek	2 weeks kg a	3 weeks	4 weeks	Tota
Carbaryl 85% WP	1.0	1.0	1.5	1.5	5.0
DDT 10% Dust*	1.0	1.0	1.5	1.5	5.0
Endosulfan 50% WP	0.7	0.7	1.0	1.5	3.9

<sup>\*</sup> The first application on the first planting was a 0.2% a.r. DDT spray made from a 25% EC. This produced local burning of the plants where it accumulated in the leaf axils and in the whorl, therefore, subsequent DDT applications were made with the dust formulation.

In the April planting, counts were made on plants damaged by armyworms (Spodoptera spp.), leaftiers (Marasmia trapezalis Ghesq. and Prodotuala grisealis Guenee) and leafeating coccinellids (Epilachna sp.). Populations of homopterous insects (mainly leafhoppers Cicadulina triangula Ruppel, Deltocephalus schmidtgeni Wagner, Empoasca spp., Austroagallia caboverdensia (Lindberg), Balclutha spp. and others, and planthoppers Peregrinis maidis (Ashmead), Sogatella spp. and others estimated with a D-Vac suction sampler. All treatments gave significant reductions in damage and insect populations. Carbaryl and DDT were more effective than endosulfan in reducing damage by Epilachna sp.

Signs of boter damage at six weeks after the May planting were reduced by all treatments:

- At harvest, borer-damaged stalks were fewer in the endosulfan and DDT treatments.
- Termite damage reached an average of 29% in the check plots and was reduced by all treatments in the April planting but only by DDT and endosulfan in the May planting.
- \_ Lodging averaged 20% in the April plant-

ing and 51% in the May plantings. Treatments did not affect the incidence of lodged plants.

Fewer of the ears from the April planting were damaged by earworms in the untreated check plots than in the plots sprayed with carbaryl. Carbaryl plots and the checks had more damaged ears than DDT or endosulfan plots in the May planting. Number of larvae per ear at harvest was not affected by treatment.

Yields from the April planting were about double those from the May planting. In the April planting, the check plots yielded 4,600 kg/ha and the treatments gave the following yield increases: endosulfan 9%, carbaryl 7% and DDT 5%. In the May planting, the check plots yielded 2,310 kg/ha and increases were: DDT 14% and endosulfan 5%. Carbaryl plots produced 5% less than the check. Plots previously occupied by termite mounds produced 1% and 10% less than the check plots in the April and May plantings, respectively.

Cultural Practices Study The role of plant protection was assessed during 1969-71 in connection with three studies on cultural practices and factors which limit maize productivity.

A September - December 1969 experiment

with four maize varieties at 62,000 plants pe hectare included the following:

- fertilizer seed dressing with aldrin and thiram, five sprays with 0.25% carbary and 0.25% Dithane M-45 applied to the total plant during the pre-silking period and three 0.25% carbaryl sprays applied to developing ears,
- (2) fertilizer and
- (3) untreated plots.

The four varieties tested (H-503, Diacol V-153, NS-5, and NS-1) did not differ in regard to stalk borer damage or lodging assessed six weeks after planting. The two treatments, fertilizer and fertilizer plus plant protection, however, did reduce the signs of borer attack. Plant protection reduced lodging and increased yields.

In the April - July, 1970 trial with NS-5 the following parameters were assessed in a factorial design:

- (1) Plant protection consisting of aldrin plus thiram seed dressing and sprays of 0.25% carbaryl April 22 and 30, 0.20% malathion plus 0.25% Dithane M-45 May 28 and June 1 and 0.25% Dithane M-45 June 19.
- (2) Weeds versus no weeds.
- (3) 26,000 versus 53,200 plants per hectare.
- (4) Fertilizer versus no fertilizer.

Plant protection was associated with increased yields (Fig. 1), however, sprayed plots had significantly more stalk borers at harvest. The relative abundance of borer species was also affected by spraying. The number and species distribution of ear insects at harvest were not affected by sprays. The outstanding item demonstrated in this experiment was the beneficial interaction of incorporating plant protection with other desirable agronomic practices.

A May - September 1971 cultural trial with maize composite A x composite B was conducted with the same parameters as used in 1970 except that the plant protection schedule consisted of weekly sprays with 0.15% endosulfan and 0.25% Dithane M-45. Sprayed plots, except for treatment 16 (high plant population, fertilized, no weed control), had significantly fewer borer-damaged stalks and less extensive damage within the stalks that were damaged (Table 3).

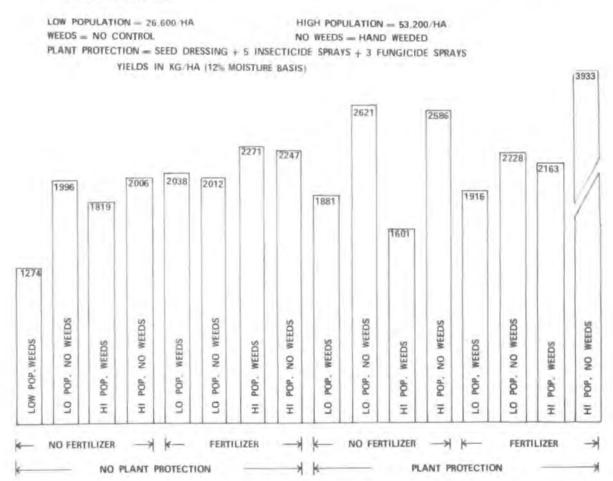
Borer damage was significantly correlated with lower yields. When all plot results were analyzed together by linear regression of yields on percentage of the length of stalks bored, the equation showed about 1% reduction in yield for each 1% of the length of stalk bored.

The six highest yields were all from sprayed plots. Eight of the nine highest yields were also from sprayed plots. Increases in production associated with plant protection ranged from 16% (0.55 tons/ha) to 54% (2.04 tons/ha).

## MAIZE PATHOLOGY

Steady progress is being made by the breeding team in building into the populations greater degrees of resistance to both the major leaf diseases, rust (Puccinia polysora Underw.) and blight (Cochliobolus beterostrophus (Drechsl.) Drechsl.). Selection is in progress for lines resistant to the stalk rot complex. Several potential pathogens isolated from rotted stalk include Cephalosporium acremonium Corda agg., Macrophomina phaseoli (Maubl.) Ashby and several Fusarium spp. Bacteria isolated include Pseudomonas fluorescens Migula, Erwinia berbicola (Geilinger)

Figure 1 Maize cultural trial (April - July 1970) grain yields as affected by population density, fertilizer, weeds and plan, protection. Variety NS.5



Dye and a saprophytic Corynebacterium sp. Severe stalk rot was induced in green-house grown maize (Lagos White) when 5-week-old plants were inoculated with a conidial suspension of Cephalosporium acremonium.

A severe incidence of maize streak virus (100 percent infection) decimated a dry season planting of composite A,cycle 1 recombination. A second crop in an adjacent field, planted one month later had only about 50% infection.

#### RICE IMPROVEMENT

During 1970-1971, 1,093 varieties or advanced lines of rice from 47 countries were added to the IITA collection. This number of accessions is relatively low because of concentration o. upland materials of lowland varieties that have promise under upland conditions. This expanding germplasm collection forms the foundation for rice breeding and selection activities.

Table 3. Maize cultural trial (May-Sept. 1971): Effects of various combinations of cultural practices on stalk borer damage at harvest and yield.

YIELD b/	OF LENGTH OF STALK		ENT	REATM	T,	
(kg/ha) (Y)	% OF LENGTH OF STALK WITH BORER DAMAGE (X)	PLANT POPULATION	WEEDS	FERTI- LIZER	FUNGICIDE	No.
376	30.8	HIGH	+	+		7
403	29.3	HIGH	1.0	+	-	8
378	27.8	HIGH	+		-	4
335	26.0	LOW	-	+		6.
325	25.0	HIGH	+	-	-	3
324	21.8	LOW	-	2	7	2
337	21.3	LOW	+	Ğ.	-	5
338	20.8	LOW	1.4.1	3		1
538	13,0	HIGH		+	+	6
410	8.5	LOW	+	+	+	13
464	7.0	LOW	-	-	1.6	0
394	6.3	LOW	+	-	+	9
496	6.0	HIGH	- 4		*	11
495	5.8	LOW	197		. +	4
574	5.8	HIGH		141	1.67	5
583	5.5	HIGH	(44)		- t	2
LSD= 77	D.001 <sup>a</sup> /					

<sup>8/</sup> F significant at 0,001 level; means connected by same line do not differ according to Duncan's multiple range test.

Material received in 1971 was planted in the paddy for seed multiplication and general observations under irrigation.

Upland Nurseries. Most of the collection was grown under upland conditions in 1970 with 969 entries planted in single row plots. In 1971, after screening and additions, 387 entries were included in the nursery. Data taken on each entry included seedling stand, leaf blast score, days to first heading, days to 50%

bloom, days to maturity, height at harvest, lodging percent, drought score, neck rot percent, and plot yield.

Paddy Nursery And Observational Yield Trial. In 1970, 841 entries were continuously flooded and observed. Sixty-eight upland entries were grown in an observational yield trial in 1971 dry season. Yields and other data for the 15 highest ranking entries are presented in Table 4. These are from two replications with the

b/ Linear regression shows r=0.55; Y=5061.98-50.736X; F for overall regression = 27.21 (sig. at 0.001).

Table 4. Observational Yield Trial Results, Paddy E4 and 5, Jan. June 1971.

RANK	ACCESSION/VARIETY	BLAST SCORE Leaf-Neck	DAYS TO 50%	HEIGHT At H	LODGING	YIELD
		Rot	FLWRG			
				cm	%	kg/ha
1	488/IR587-95-1-3	1-1	97	114	0	8455
2	44/1R400-5-12-10-2	1-1	90	102	0	8366
3	42/IR665-79-2	1-1	90	115	0	8311
4	124/IR578-95-1-3	1-1	92	90	0	7995
5	534/IR878 B2-73-3-2	1-1	96	109	60	7988
6	49/IR127-80-1-10	2-4	86	115	0	7978
7	120/IR661-1-170-1-3	1-1	86	97	0	7940
8	188	1-1	107	102	0	7700*
9	111/IR95-42-13	1-1	85	106	0	7577
10	58/1R382-7-2-2	1-1	74	83	0	7291
11	46/IR305-3-17-1-3	1-1	84	108	.0	7171
12	87/IR626-1-110-2-2	17	100	114	70	7083
13	52/IR630-27	2-2	92	100	0	6354
14	836/Colombia 1	1-1	92	153	50	6229
15	135/IR332-2-10-1	1-1	96	145	100	6183

Yields computed only on one replicate

exception of 14 plots. Yields ranged from 1,557 kg/ha BG 79, recommended in Nigeria, produced 2,800 kg/ha because of blast and 60 percent lodging. Nineteen of the best 20 varieties were from IRRI.

Replicated Yield Trials. In June 1971 three replicated yield trials were planted. They are: cooperative uniform upland trial, consisting of 20 entries, with eight replications; an upland trial having six replications with 26 entries, and a similar yield trial sent to Senegal, Ghana, Somalia, Sierra Leone and Badeggi, Nigeria.

Poor rainfall distribution and early cessation of rain in Ibadan adversely affected yields and other characters recorded. Yields ranged from 438 kg/ha to 3,072 kg/ha. The top entries were IR305 and IR20 with yields of 3,072 kg/ha and 2,261 kg/ha respectively. OS6, the locally recommended upland variety, ranked third, yielding 1,855 kg/ha (Table 5).

Results of a paddy trial are presented in Table 6. IR269-26-3-3-3 yielded highest, 6,999 kg/ha and Agbede lowest, producing 2,325 kg/ha. Although Agbede is an upland variety, it is included to compare its performance when flooded. The high yields of IR578-95-1 and IR382-7-2-2 compare well with the strikingly high yields obtained in the dry season observational yield trial (Table 4) because dry season yields are usually 1-2 tons/ha higher than the wet season yields. The lew yields of IR400-5-12-10 in this trial was due to high roguing.

#### RICE UNIFORMITY TRIAL

A yield uniformity trial with 208 rows of

Table 5. Co-operative uniform upland rice variety trial, 1971.

Rank	Variety	Average Yield kg/ha	Stand	Leaf Blast	% Neck Rot	Days To 1st Heading	Days To 50% Blooming	Maturity (DAS)	Height (cm)	Lodging %	PAN Pan/ Meter (	(length
1	IR 305	3072	95	22	32	94	103	126	66	O	112	20
2	IR 20	2261	90	22	8	95	107	128	85	61	92	22
3	OS 6	1855	80	22	4	85	98	119	143	0	54	26
4	IR 503	1711	95	2	8	102	114	130	77	0	83	22
5	63-83	1634	90	2	7	81	95	115	121	0	53	24
6	NILO 3 <sup>A</sup>	1574	75	2	- 1	87	104	129	132	45	52	30
7	MOROBEREKAN	1463	80	2	6	97	109	130	156	77.	48	28
8	IR 8	1372	90	5	75	96	105	121	74	0	102	26
9	II KONG PAO	1188	95	2	75	78	88	104	70	0	113	19
10	IR 528-1-6	1135	80	2	87	74	84	103	63	0	109	.21
11	IR 5	1133	95	4	38	87	115	130	94	0	82	26
12	IR 400	1124	85	2	47	83	93	117	63	0	110	20
13	IR 81-105	992	90	3	27	95	112	130	104	0	58	25
14	IR 878B <sub>2</sub>	856	85	2	0	106	105	131	81	0	83	22
15	IQUAPECATETO	798	85	2	29	85	101	118	127	.0	28	26
16	DV-98	551	95	5	100	70	76	91	92	35	80	19
17	C4-63	473	90	5	100	88	103	120	92	.0	90	24
18	MI-48	(364) 424	90	3	86	90	104	118	112	D	56	26
19	Td-49	339	90	4	98	67	85	95	118	90	79	23
20	IR 127-80	43	90	5	88	84	98	117	84	0	58	25

the OS6 was planted under upland conditions. Each row represented 1.80 m<sup>2</sup>, and was drilled in dry soil at the rate of about 50 kg seed/ha, Standard errors of yields were calculated for plot sizes ranging from 1.80 to 45 m<sup>2</sup>. Coefficients of variation on the means were calculated for various numbers of replications. Results are shown in Table 7.

The coefficients of variation decrease markedly for increases in plot size up to about 20 m<sup>2</sup>. Larger plots reduce the coefficient of variation but not significantly. Increase in the number of replications is also associated with a decrease of the coefficient of variation in the same proportion as the inverse of the square root of the number of replications.

In general, the area required for one treatment with a constant c.v. (x) declines as the number of replications increases as the plot size increases.

The plot size requirements for rice at IITA are quite large, indicating great variability in the soils. As a standard, therefore, until more information is developed upland rice experiments will be conducted with 20 m<sup>2</sup>

Table 6. Yield and other data on the 1971 wet season paddy yield trial.

					%	DAY	STO		AT H	ARVEST	0-1-1-
Rank	Acc. No.	Varieties	Yield kg/ha	Blast	Neck		50%	Maturity		%	Panicle No/Hil
					Hot	Heading	Blooming		in cm	Lodging	
1	(78)	IR 269-26-3-3-3	6999	-1	0	96	111	137	111	20	23
2	(232)	SML-140/10	6876	1	0	110	127	153	165	50	17
3	(143)	IR 5	5626	2	1	105	115	139	146	0	18
4	(124)	IR 578-95-1-3	6617	3	15	96	108	133	114	0	24
5	(52)	IR 630-27	6387	2	0	100	111	137	106	0	21
6	(58)	IR 382-7-2-2	6217	1	Ü	92	98	123	101	.0	19
7	(508)	IR 442-2-50-2-3	6108	1	0	97	107	133	126	0	15
8	(490)	IR - 20	6061	1	0	73	108	133	110	0	20
9	(488)	IR 587-95-1-3	6019	2	0	98	110	134	122	0	19
10	(448)	Improved Dima	6018	3	O	96	109	134	109	0	16
1	(141)	IR 532-E-576	5976	2	0	92	107	134	123	0	19
12	(42)	IR 665-79-2	5695	1	12	95	105	133	111	0	15
3	(64)	IR 237-43	5601	2	5	107	1.18	141	129	23	21
14.	(211)	ML - 48	5398	0	0	93	101	131	148	0	9
15	(100)	81 B-25	5303	1	0	112	123	151	164	90	16
16	(153)	C4-63	5160	2	6	94	105	133	133	0	17
17	(534)	IR 878B <sub>2</sub> -73-3-2	5151	1	0	104	114	138	111	0	20
18	(87)	IR 626-1-110-2-2	5044	3	44	98	107	131	132	IJ	15
19	(515)	IR 442-10-2-2	5041	3	3	100	120	140	106	0	15
20	(125)	IR 661-1-140-3-2	4882	1	12	92	103	131	91	0	15
21	(118)	IR 66T-1-175-3	4835	1	15	94	120	142	107	5	23
22	(44)	(R 400-5-12-10-2	4834	2	0	86	95	21	84	0	17
23	(553)	IR 503-1-91-3-2-1	4792	1	0	98	111	134	95	D	24
24	(486)	OS 6	3802	2	0	86	93	118	169	0	8
25	(49)	IR 122-80-1-10	3761	4	38	92	100	120	109	0	10
26	(665)	Agbede	2325	1	0	87	94	119	165	0	9

plots of harvested area with six replications. The same levels of precision could be achieved with 15 m<sup>2</sup> and eight replications but the lower replication number is advantageous regarding simplicity of layout and handling while the net land area used remains constant.

#### BREEDING PROGRAM

To accomplish breeding objectives crosses were made to combine desirable traits from the promising parents. Forty crosses, designated ITA1 to ITA40 resulted from breeding. In 1971 several lines of the F<sub>3</sub> generation of five upland crosses were received from IRR1 for selection in the 1972 wet season. Selections were also made from the F<sub>2</sub> segregations of ITA6, ITA9 and ITA7 for further F<sub>3</sub> selections in 1972.

Spacing experiments. Three rice spacing experiments were conducted in 1971 — one in the paddy and two with upland rice. The paddy experiment and one of the upland trials used a Bleasdale design which included 19 spacings arranged in a logarithmic progression from 10 plants/m<sup>2</sup> to 400 plants/m<sup>2</sup> such that both spacing between plants and between rows varied but that the rectangularity of arrangement was constant at 4:1. Spacing between plants within rows varied from 16.1 cm to 2.5 cm while row spacings varied from 61 cm to 10.5 cm. IR20 and OS6 were used in all experiments.

For upland rice a second population experiment was run using conventional 2.4 x 6 m plot size and six replications. The five treatments were selected to test the same spacing treatments that were represented by the five treatments in the logarithmic design having plants spaced at 2.5, 3.8, 6.3, 10.6, and 16.1 cm while row spacing remained constant at 30 cm. The upland experiments were planted in May and suffered drought stress in August. Some damage by termites was observed but it was not widespread.

Some of the results of the systematic designs are plotted in Figure 2 for both locations. The grain yield of IR20 was generally higher than OS6 in both locations and both varieties produced higher yields in the paddy than in the upland field. OS6 in the paddy showed a distinct sharp peak in yield at about 40 plants /m² and a marked decline at closer spacing. This shape of curve for spacing is typical of tall, leafy, low-tillering, weak-stemmed varieties.

The high-tillering, stiff, strawed, dwarf variety, IR20, showed a characteristic broad range of population over which yields were well maintained. Spacing is a critical management factor with this type variety and it produces enough tillers to utilize the environment fully when conditions are favorable. The population variable tends to be self-regulating with this type of variety and field management is simplified so long as the minimum population requirement is met.

In the upland experiments IR20 outyielded OS6 at all spacings in the logarithmic design but produced equal yield at one spacing in the conventional design, (Table 8). The logarithmic population curves did not snow the peak characteristic of OS6 since yields were restricted by moisture factor.

Effect of presoaking rice seeds on germination emergence, plant growth and yield. The effect of presoaking of seeds on growth, yield and drought tolerance of the rice plants was studied. Rice seeds of IR-20 were soaked aseptically in water for varying periods, air dried to initial moisture content and stored for four

Table 7. Coefficients of variation about the mean calculated for various plot sizes and number of Replica-

PLOT	Laurey			R	EPLIC	ATIONS	S		
SIZE	c.v. (x)	4	5	6	7	8	9	10	11
					c.v.	(×)			
1.80	38.5	19.3	17.2	15.7	14.6	13.6	12.8	12.2	11.6
3.60	29.0	14.5	13.0	11.8	11.0	10.3	9.7	9.2	8.7
5.40	27.0	13.5	12.1	11.1	10.2	9.6	9.0	8.6	8.2
7.20	24.5	12.2	10.9	10.0	9.2	8.7	8.2	7.7	7.4
9.00	21.4	10.7	9.6	8.8	8.1	7.6	7.2	6.7	6.5
10.80	20.2	10.1	9.0	8.2	7.6	7.1	6.7	6.4	6,1
12.60	20.2	10.1	9.0	8.2	7.6	7.1	6.7	6.4	6.1
14,40	20.9	10.4	9.3	8.5	7.9	7.4	7.0	6.6	6.3
16.20	18.4	9.2	8.2	7.5	7.0	6.5	6.1	5.8	5.6
18.00	19.6	9.8	8.8	8.0	7.4	6.9	6.5	6.2	5.9
19.80	18.0	9.0	8.1	7.4	6.8	6.4	6.0	5.7	5.4
21.60	18.0	9.0	8.1	7.4	6.8	6.4	6.0	5.7	5.4
23.40	17.1	8.5	7.6	7.0	6.5	6.0	5.7	5.4	5.2
25.20	17.1	8.5	7.6	7.0	6.5	6.0	5.7	5.4	5.2
32.40	17.1	8.6	7.7	7.0	6.5	6.1	5.7	5.4	5.2
36.00	14.1	7.0	6.3	5.8	5.3	5.0	4.7	4.5	4.3
39.60	14.7	7.4	6.6	6.0	5.6	5.2	4.9	4.7	4.4
43.20	13.5	6.8	6.0	5.5	5.1	4.8	4.5	4.3	4.1

Table 8. Grain yield of two upland rice varieties grown in a spacing experiment of "conventional" design, wet season, 1971.

T	REATMEN	Г		VARIETY	
EQUIVALENT SYSTEMATIC DESIGN ROW NUMBER	SEED RATE	PLANT SPACING WITHIN 30 cm. ROWS	IR20	OS6	MEAN
	kg/ha	cm	kg/ha	kg/ha	
1	90	2.5	3455	1469	2462
5	72	3.8	3541	1471	2506
10	55	6.3	3449	1814	2631
15	37	10.6	3335	3247	3291
19	20	16.1	3301	1012	2156
		MEAN	3416	1803	2609

weeks before testing in the laboratory or field.

Laboratory Results. Soaking of seeds in water resulted in seed weight losses (Table 9), probably due to leaching and respiration. The largest loss was obtained following a 48-hour soaking.

Early signs of seed germination started after soaking for 12 hours. This was marked by swelling of the seed coat close to the embryo as a result of coleorhiza growth. Following 24 hours of soaking the coleorhiza ruptured the seed coat, while after 36 and 48 hours the

Table 9. Weight loss of IR-20 rice seeds following soaking in water.

Duration of soaking hours	Mean weight loss (% Dry Weight)
6	8.50
12	8.93
24	9.23
36	9.94
48	10.59

radicle protruded from 2 to 3 mm. Following drying of the seed the protrusion of the radicle disappeared as a result of desiccation.

Presoaking of seeds had a two-fold effect on seed germination. It shortened the time to germination as well as the time required to achieve maximum germination (Fig. 3). Nonsoaked seeds required the longest time to germinate and to achieve maximum germination. The effect of seed presoaking on the speed of germination can be seen in Table 10 by comparing the effect of treatments on the number of hours necessary to reach 70% germination

Radicle and seedling height. Radicle length and seedling height increased as a result of increasing the soaking duration up to 24 hours (Fig. 5). Following that there was an adverse effect on radicle and seedling growth and development. In the 36- and 48-hour treatments a large number of primary leaves and radicles were necrosed.

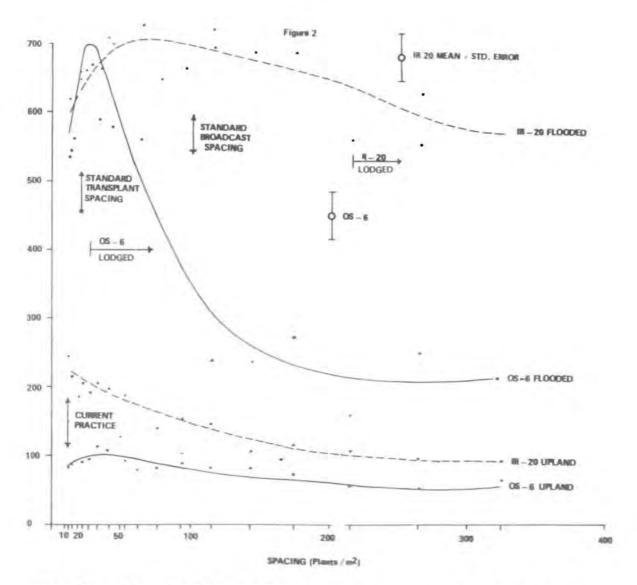
Table 10. Effect of seed soaking duration on the speed by which IR-20 rice seed attain 77% germination.

Duration of soaking hours	Mean Number of hours to achieve 70% germination
0	64
6	47
12	37
24	26
36	17
48	7

Greenhouse studies. Seedling emergence was first observed in the 24-hour presoaking treatment, followed respectively by the 36, 12 and 48 hours presoaking treatment (Fig. 4). The onset of emergence was slowest in the 0-and 6-hour treatments. Seedling emergence in all treatments was high except in the 48-hour treatment where in spite of an early start, emergence later slowed. This is evident considering the time required to achieve 50% or 70-% emergence (Table 11). Despite the early emergence resulting from presoaking, the effect disappeared after 12 hours except in the case of the 48-hour treatment where not more than 64-% emergence took place.

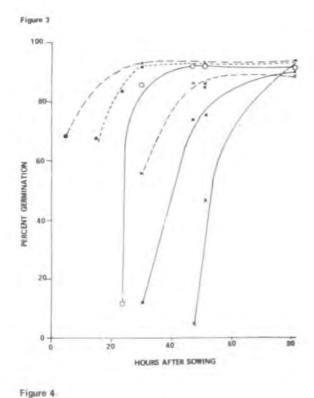
Despite the early germination and emergence resulting from the presonking treatment there were no differences between heights of plants of different treatments 64 days after planting.

The number of tillers in the first six weeks



was significantly lower than the mean resulting from a 48-hour seed soaking (Fig. 6) This difference, however, was of lesser magnitude after nine weeks of growth. Tillering capacity was not improved as a result of soaking to any period of time.

Field studies. Presonked seeds of OS-6 and IR-20 had faster germination and seedling emergence than non-treated seeds. Germination of treated seeds started 12 hours after sowing while emergence took place in 48 hours. The height of seedlings was greater in the treated seeds as a result of the early germination and emergence. The treatment effect persisted for two weeks after which the differences disappeared. Yield difference as a result of the treatment was 540 kg/ha in IR-20, but no dif-





terence in yield was found for OS-6 because of soaking (Table 12). The yield of IR-20 was

HOUSE AFTER SCHOOL

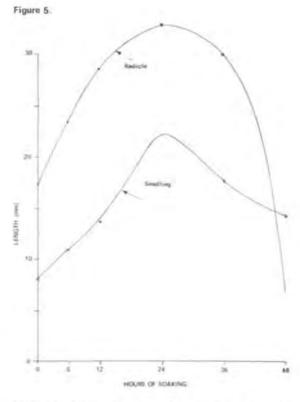


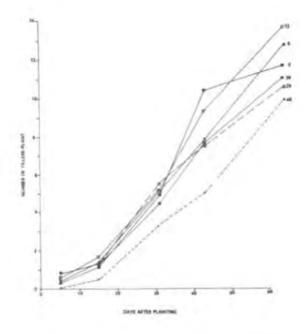
Table 11. Effect of seed soaking duration on seedling emergence following 144 hours.

Duration of soaking (Hours)	Mean Number of hours after planting to achieve	
	50% emergence	70% emergence
0	77	101
6	69	84
12	57	64
24	45	52
36	54	64
48	94	-

more than twice that of OS-6 under conditions of this experiment.

Conclusion. Soaking of rice seeds for more than 24 hours has an adverse effect on plant

Figure 6.



development. Speculation is that the adverse effects of prolonged soaking results from an irreversible injury to the embryo as a result of hydration and dehydration. In addition to the mechanical injury to the developing embryo the availability of food reserves will be less because of the earlier growth and leaching during soaking.

#### RICE ENTOMOLOGY

Representatives of most of the families of notorious rice pests reported from the well established rice growing areas of the world are present at IITA. But on the positive side numerous predaceous and parasitic insects are also present. This may account for the generally low incidence of entomological problems in our rice.

Insect Populations and Damage. Lepidopterous stem borers, including Sesamia spp., Maliarpha separatella Rag., Chilo spp. and Scirpophaga sp., usually infest a small percentage of the stems. In August 1969, however, unit at a dupland plots of mature plants (OS-6) has 60% borer-damaged stems with 73 lepidopterous larvae (mainly Sesamia spp.) and 20 diopsid larvae per 100 stems. IR-8 under the same conditions had 46% borer-damaged stems with 43 lepidopterous larvae and 9 diopsid larvae per 100 stems.

Table 12 Effect of presonking on grain yield of two

Treatment	Yield IR-20	kg/ha
Soaked, 36 hours	3006	1245
Nonsoaked	2466	1276

The dipterous stem borers, which are serious pests of younger plants, are mainly Diopsis thoracica West, and a few D. apicalis Dalm.

Several species of defoliators attack rice at IITA with the most serious, although sporadic, being Spodoptera exempta Wlk. Other defoliators of potential significance include various grasshoppers, Haltica sp., Podagrica sp., Epilarbia spp., Nympbula sp., Susmia exigua Bulter and other leaftiers.

A large number of species of sucking insects are associated with rice plants. The potentially important ones include Nezara viridula L. Aspavia armigera F. and other pentatomids which cause serious damage to grains, Leptocorisa spp., Riptortus dentipes F., Nephotettix modulatus Mel., Cicadella spectra Dist., Exitianus spp., Cicadulina triangula Ruppel, Deltocephalus schmidtgeni Wagner and many other cicadellids, Sogatodes cubanus (Crawford), Sogatella kolophon (Kitkaldy), Nilaparvata meander Fennah, Delphacodes spp., Peragrinus spp., Perkinsiella sp. and many other delphacids and Locris maculata F.

Termites, Macrotermes spp., Microtermes spp. and others, cause serious problems by cutting stems of upland rice.

Ripening grains of rice especially when grown near maize and when not harvested promptly, have been heavily field-infested with the storage pests Sitophilus spp. and Sitotroga cerealella Oliv.

Insecticide Trials and Estimates of Avoidable Losses. Responses from insecticide applications indicate that grain yields can be increased 23% in flooded rice and 37% in upland rice by partial control of pests.

In 1970, seed dressings on OS6 rice were evaluated in laboratory germination tests and in flooded field plots. Dressings at 1 g a.i./ 100 g seed with aldrin plus thiram dust, aprocarb WP, carbaryl WP, DDT dust, diazinon GR, disyston GR, Dursban EC and endosulfan WP were safe in regard to seed viability and seedling emergence. Lindane WP, dieldrin EC, pirimphos – methyl dust and trichlorfon SP at 1 g a.i./100 g seed and aprocarb WP, DDT EC diazinon EC, dieldrin EC, Dursban EC and dimethoate EC caused serious damage at 2 g a.i./100 g seeds.

Insect problems were insufficient or assessment of plant protection. Average yields (4 reps.) ranged from 6,812 to 2,002 kg/ha. Reductions in grain yields were associated with poor stands in plots planted with seeds treated with phytotoxic formulations. Yields from plots planted with seeds treated with nonphytotoxic formulations did not differ significantly from untreated plots.

Two post-emergence insecticide trials were conducted in 1971 - one in flooded IR20 rice and one in upland OS6 rice. In the flooded rice experiment carbaryl 85% WP, diazinon 10% GR, endosulfan 3% GR and lindane 50% WP were applied at 2 kg a.i./ha/application. Two treatment schedules were followed: (1) 22, 35, 56, 77 and 98 days after planting and (2) 35,65 and 95 days after planting. Granules were spread by hand in the standing water and aqueous sprays of wettable powder were applied to the water surface with little folinge contact

Insect populations were low in all plots. Only Diopsis spp. were present in numbers sufficient for valid control evaluations. Lindane and diazinon gave excellent control. Yields ranged from 5,461 to 4,000 kg/ha. Regression analysis of yield versus diopsid deadhearts gave a statistically insignificant correlation (r = -0.202). This suggests that the 23% and 17% improvements in yields associated with five applications of lindane and diazinon, respectively, resulted from control of a complex of several minor insect problems.

In the upland experiment aqueous sprays of carbaryl 85% WP, endosulfan 35% EC and lindane 20% EC were applied to the foliage in 400 1 water/ha. The two treatment schedules were:

Days after planting	Kg a.i./ha Treatment 1	Kg a.i./ha Treatment 2
14	0.50	10020
21	0.50	
28	0.75	8
35	1.00	1.00
49	1.00	× .
63	1,50	1.50
77	2.00	
91	2.00	2.00
Total	9.25	4.50

Insect populations were low throughout the experiment and differences in insect damage were not statistically significant. The insolutive to detect significant differences among the various treatments was probably due in part to large variations among the six replicates, e.g. 58% C.V. for damaged stems and 114% C.V. for white heads. Plots receiving three endosulfan applications yielded a significant 37% more than the untreated check. Regression of yield versus borer-damaged stems was significant at the 0.01 level (r = -0.278), but regression of yield versus white heads was not significant.

# RICE PATHOLOGY

The objectives of IITA rice pathology program are:

- to identify and develop stable or broad spectrum (horizontal) resistance to the major African diseases of rice
- to explore methods of chemical control of rice diseases
- to study pathogen variability, ecology and biology, and, with other international bodies, organise and stimulate interest in Pan-African blast tests.

Spectrum of Diseases. Rice diseases encountered in West Africa include blast (Pyricularia oryzae Cavara), brown leaf spot (Corblinbolus miyabeanus Ito et Kuribayashi), leaf scald (Rbynchosporium oryzae Hashioka and Yokogi), narrow brown leaf spot (Cercospora oryzae Miyake), false smut (Ustilaginoidea virens (cke.) Tak.) bakanae (Gibberella fujikurot (saw.) Woolenw.) stackburn disease (Trichoconis padwickii (Ganguly) and sheath blight (Corticium sasakii (Shirai) Matsumoto). The most serious disease is blast, while brown leaf spot, narrow brown leaf spot and leaf scald can cause a great deal of leaf damage

under certain environmental conditions. No bacterial or virus disease of rice has been confirmed in West Africa.

Blast. As much of the rice crop depends on direct precipitation for its water supply and as rainfall is unreliable especially at the beginning of the wet season, rice often experiences periods of drought stress which increases susceptibility to blast. At IITA low incidence of blast is observed in irrigated rice whereas in upland rice collections many varieties develop severe leaf blast. Periods of drought alternate with periods of heavy rains and overcast skies for many days. Rice which is heading in these wet overcast conditions is particularly vulnerable to the rotten-neck phase of blast. Assessments of leaf and neck blast were made in the upland rice collections in both 1970 and 1971. The relative frequencies of reaction types are summarized in Table 13.

Table 13. Incidence of leaf and neck blast in upland rice collections at IITA, 1970-71.

Type	Category	No. of	lines
	en, ege. y	1970	197
Leaf blast	1-2- 3-4	216 78	32 87
	5.6 or 7	189 58	149 35
(Neck blast per cent infection)	0 <1 1-5	503 60 8	24 0 10
	6-10	7	13
	11-25 26-50	8 2	31 28
	>50	9	134

Categories correspond to those used in assessment of incidence in international blast nurseries with 4 indicating very few type 4 lesions.

Immunity to blast (reaction types 1 and 2) is likely to be short-lived because of the ex-

treme variability of P, oryzae. Of the 216 immune lines in 1970, 104 were grown again in 1971 and only 15 remained immune at the second planting.

The variability within the population of P oryzae in West Africa has not been studied fully. The results of three IBN tests at IITA reveal the presence of virulence within the local population of P oryzae to several varieties (E425, Armistsari HR22, DL10, DNJ-60, Rajbohog, DV-73, C17787, C127-3, Tua Sart, 3-month variety [ENTRY 211], C5561 and TD70) that have been consistently resistant in most other parts of the world. Several varieties were highly resistant in one IBN planting and highly susceptible in another, indicating a shifting spectrum of virulence in the local population of P oryzae.

Chemical Control of Neck Blast. An experiment was conducted with rice variety IR22, two fungicides (Benlate and Hinosan) and two treatments. Benlate (0.03 percent a i. at 1000 I/ha) and Hinosan (0.04% a.i. at 1000 I/ha) were applied at early flowering in one treatment, and at early flowering and again 12 days later in a second treatment. Each fungicide-treatment combination was replicated four times. Neck blast data and yield are summarized in Table 14.

Two applications of Benlate gave a threefold increase in yield over the untreated plots but yields were low because even with fungicide application there was still a lot of blast and IR22 is poorly adapted to the conditions of upland rice culture in West Africa.

Leaf Scald. Leaf scald, caused by Rhynchosporium oryzae was first noted at IITA late in

Table 14. Neck blast incidence and yield in plot of IR22 rice treated with two fungicides and two treatments.

Chemical	Rate	No. Appli	of cations*	Mean C Neck Rot per plot	Y)eld kg/ha
Benlate	0.6 kg	/ha	1	504	415.7
Benlate	0.6 kg		2	379	985.3
Hinosan	0.8 1	ha	1	464	707.3
Hinosan	0.8 1/	'ha	2	477	646.3
Control				736	351_3

<sup>\* 1</sup> application at early flowering, 2 applications at early flowering and again 12 days later

1969 on IR8 and OS6. Since then it has been seen on many other varieties of upland and irrigated rice in West Africa. The disease appears to be most severe in cool wet weather in well fertilized rice, and can severely reduce leaf area with its zonate spreading lesions. Studies with leaf scald will include assessment of potential yield reductions due to the disease, determination of optimum conditions for disease development and identification of resistance sources.

Brown Lea/ Spot. Observations on rice in two years at IITA indicate that brown leaf spot may not be a serious disease of well fertilized rice. However, when environmental conditions are optimum susceptible varieties can be severely infected. The optimum environmental requirements for the development of brown leaf spot must be determined and the potential danger of the disease to upland rice must be carefully examined.

# Grain Legume Improvement Program

Considering the potential of grain legumes for improving human nutrition in the tropics, IITA included improvement of these crops as a major project at an early stage of development. Dr. Royce P. Murphy, professor of plant breeding, Cornell University, started the program during 1970-71.

Strategy for Improvement. The GLIP is dedicated to the proposition that improvement of grain legumes represents the most efficient and least expensive means of providing nutritional balance for human diets in tropical regions by virtue of quality protein content – two to five times that of cereals – and comparatively lower requirement for fertilizers. The objective of the program is to improve the production of high-quality foods from appropriate leguminous plant sources in the humid tropics.

There is a particular challenge in the case of cowpea because it has low yield potential and a high degree of susceptibility to diseases and pests but is the preferred pulse in the tropical regions.

Several other legume species show interesting possibilities under humid tropical conditions. Among these, pigeon peas appear to have excellent adaptation with minimal pest and disease problems, except during flowering and early pod development. Lima beans, Phaseolus lunatus: the winged bean, Psophocarpus tetragonolobus; rice bean, Vigna umbellata; yam bean, Pachyrrbizus erosus and jack bean, Canavalia ensilormis appear to be exceptionally well-adapted and singularly free of pests and diseases under humid tropical conditions. International Collaboration. The British Overseas Development Agency (ODA) contributes massive support to the GLIP in addition to establishing major collaborative projects with British universities - at Reading on physiology and at Durham on grain protein quality in the Vigna species. Prof. A.H. Bunting was instrumental in developing these projects, which are expected to provide essential information about environmental influences on growth and development of grain legumes, on mechanisms of protein elaboration in seeds, and efficient methods of assessing storage protein components. Equally as important as the information are the strong links forged with Reading and Durham and their excellent capabilities in several botanical fields. Prof. P.A. Huxley and Dr. A.P. Hughes are responsible for the investigation at Reading.

The project at Durham University, directed by Prof. D. Boulter, head of agricultural botany, is investigating protein quality in cowpeas with special emphasis on the sulfur-bearing amino acids.

# PLANT IMPROVEMENT

Grain legume improvement efforts involving breeding were initiated in 1970. Initially, emphasis was given to assembling and evaluating germplasm, developing field plot techniques, training assistants, making professional contacts, acquiring supplies and equipment, and formulating program strategy. Observation nurseries of cowpeas, soybeans, dry beans, Asian grams and a few miscellaneous species were established on newly cleared land. Growth and development were studied carefully during 1970 making it possi-

ble to establish critical testing and evaluation programs in 1971. Three consecutive crops were planted in 1971-two under predominantly rainfed conditions and a third with sprinkler irrigation.

Scope of Program. Breeding activities during the first season, 1971, covered about three hectares. Most plantings were made in early April 1971. These included two advanced trials each in soybeans, cowpeas and pigeon peas and preliminary testing of elite lines in cowpeas and soybeans as well as germplasm evaluation in cowpeas, soybeans, dry beans (Phowlgaris) and Asian Vignas.

Second season plantings made during August and early September included five acres of the same advanced trials and similar preliminary observation testing of elite lines as in the first season. In addition two experiments on trellising of climbing cowpeas, lima beans and winged beans were conducted; the germplasm collection of 80 lima beans was planted: a selection nursery of 1,195 pigeon pea lines was grown out; the Cajanus representative nursery of 424 genetically diverse stocks for genotype X environment interaction studies was planted and a small varietal trial of Asian grams was conducted. A crossing block for Vignas and soybeans with sequential plantings tosynchronize blooming dates was also planted. but only a small amount of recombination was done in soybeans because first priority was given to crossing in cowpeas.

Growing Conditions. The first rains were unusually scanty and poorly distributed. Most annual crops would have failed without sprinkler irrigation. During the second season heavy showers were received in September, but the rains terminated during the third week of October - three to four weeks earlier than normal - resulting in less than 900 mm for the first 10 months of 1971 or about 70% of the average year's total. The advanced trials and other early plantings were not irrigated in the second season and medium to late maturing entries were affected by drouth at the end of the season.

Several parameters in addition to yield were recorded during both seasons. These included vegetative and reproductive phases of growth; quantitative measurements of leaf areas and mature plant height and spread; numerical data on noding, branching and podding; qualitative assessment of important and identifying morphological traits, and visual ratings on disease and pest reactions, plant vigor and other less easily measured characters. Grain and straw yields were calculated from full plot yields in the first season and from normally bordered samples in soybeans, Asian Vignas, trellis experiments and cowpea experiments in single-row plots (normally spaced 1.5 m apart).

It was not possible to obtain bordered yield samples in cowpeas because of the intertwining vines of prostrate and semi-upright cultivars.

Mean yields in the soybean trials were more consistent between seasons than in cowpeas, which may reflect more uniform and rapid ripening and greater freedom from pod insects. The yields of both soybeans and cowpeas were over-estimated in the first season as a consequence of taking full-plot yield samples. However, these were adjusted from information collected in the second season. It is apparent that tall, late cultivars have a considerable yield advantage when bordered by short, early entries, and the latter are disadvantaged when the reverse occurs.

Irrigated Dry Season. At least three consecutive seasons are possible in one year in the accelerated legume breeding program at IITA. Accordingly, the crop - harvested in February-March, 1972 - was planted under irrigation during November 1971 to advance generations, increase seeds of valuable genetic stocks, and facilitate further crossing. An adjunct to this was a second planting of both hybrids and elite parental stocks in a mesh house constructed for that purpose. Field growth under irrigation and high insolation was exceptionally good. A further advantage of this season is the reduced insect population and moderate weather conditions. However, heavy root knot nematode infestation was observed in certain lines of soybeans and Asian Vignas.

# ASSEMBLING AND EVALUATING GERMPLASM

About 4,500 accessions of different genera and 20 species were assembled from both Nigeria and abroad through local collecting activities and exchanges with other breedings. This collection includes the following crop samples:

CROP				ACC	ESSIONS
Cowpeas (from all source	ces)		н	Tet:	2.040
Pigeon peas (including	sub	-line	is)	100	1.619
Soybeans (including seg	greg	ating	Sto	cks)	498
Phaseolus species (incl	lude	slim	as)		246
Asian vignas (mung bea	ins,	gree	n gra	im	
and others)	line.	100	-	(Dec.)	117
Miscellaneous species			-		15
		TO	TAL		4.535

We will add about 1,250 cowpea lines

obtained from USDA-ARS collections and grown at Santa Marta, Colombia (planted 13 October, 1971) to satisfy Nigerian phytosanitary requirements. This germplasm is expected to increase at the rate of 2,000 to 3,000 accessions a year during the next four or five years with the start of a systematic crop collecting program in West and Central Africa.

Germplasm Evaluation. The entire germplasm collection was grown in uniform nurseries all three seasons for evaluation, selection and maintenance. The first two crops included about 1,500 entries while the third (irrigated dry season) included 2,040 entries. Data were collected on growth habit, duration of growth phases, rate of growth, leaf and fruit character, disease and pest reaction, seed characters and other important traits.

Selection. There has been little scope for selecting within the predominantly self-pollinated stocks of cowpeas, lima beans and Asian Vignas. However, 100 segregating soybean lines provided considerable opportunity for genetic advancement, and the pigeon peanursery from East Africa contained substantial residual heterozygosity. In the first season 199 single plant selections of cowpeas and 433 plant selections of soybeans were made. In the subsequent season 248 cowpea, 941 soybean, 220 pigeon pea, and 34 lima bean single plant selections were made. Selections from late harvests and the irrigated dry season will be added in early 1972, including 109 F.2's from the field and an additional 130 F.2's from the mesh house. A large proportion of these elite selections will advance to preliminary and intermediate field testing in 1972.

Selecting In Pigeon Peas. The pigeon pear yield trials were planted too early and at higher populations than optimum for the season. These were, therefore, abandoned following selection of about 25 promising plants. The major pigeon pea nursery planted in 1971 yielded 186 single plant selections and five elite bulks for further advanced testing. In addition, two germplasm populations were formed from promising lines. The first CDE-1 (Cajanus Dwarf Early Composite) will include 75 entries, and CME-2 (Cajanus Medium Early) will include 182 lines.

Recombination. The relative ease of emasculating and hand-crossing cowpeas is an important asset in a crop with as many diverse problems and inherently low-yielding ability.

A total of about 240 crosses (several pollinations were made of each) were made in cowpeas during the second rains. In addition, an effort was made to merge the cowpea germplasm collection by random mating between all possible lines. A total of 300 such crosses were affected and this project continued during the planned utilizing hand crossing techniques. A search for genetic sterility was made among segregating lines and in the cowpea germplasm collection during the second season but the results were inconclusive.

## PRELIMINARY AND ADVANCED TESTING

Yield samples were taken in some of the observational nurseries and in a double replicated test of 109 elite cultivars grown during the second season.

Within a group of 25 erect selections grain yields were comparatively low ranging from 53-1,387 kg/ha. Only one line (IS 9079) yielded more than 1,000 kg/ha, while two entries exceeded 900 kg/ha and three selections produced more than 800 kg/ha. These results suggest the comparatively poor adaptation of most erect stocks and also reflect a higher incidence of disease - particularly anthrac-

nose - to which a large number of erect lines are susceptible.

In a larger block of 201 unreplicated selections, yield levels ranged from 80 to 1647 kg/ha. In this material four lines exceeded 1,500 kg/ha, five lines exceeded 1,400 kg/ha and 11 entries yielded more than 1,300 kg/ha. These estimates are conservative as the 1.5m row spacings used are wider than optimum.

Yields were even higher in the replicated observation test of 109 elite cultivars. Although wide row spacings were used, two entries exceeded 3,000 kg/ha; two entries yielded more than 2,400 kg/ha, 14 entries exceeded 2,000 kg/ha, and 16 lines surpassed 1,800 kg/ha of grain. Growth was generally vigorous and healthy in this material although the second replication was poorer than the first because of undetermined soil conditions and less effective plant protection.

Cowpea Varietal Trials. Advanced testing in cowpeas identified several superior cultivars during both rainy seasons (Table 1). During the first season grain yields ranged as high as 2,226 kg/ha and averaged 1,660 kg/ha with 62.7 days to ripe pods for the 24-entry trial. In the second season the trial mean yield was only 713 kg/ha with a high of 1,050 kg/ha. Among the different types of cowpeas the following were the highest performers in both seasons at IITA:

# SEMI-UPRIGHT, LONG DURATION:

- IVu 37 Pale Green 38 DFF, 62 DRP; ranked 1st\*
- IVu 74 Kwara ex-Kwoi 40 DFF, 64 DRP; ranked 3rd
- IVu 354 Hanbru 58-123 39 DFF; 58DRP; ranked 4th

 IVu 335 Jebba Pea-A - 39 DFF, 57 DRP; ranked 5th

# SEMI-ERECT, MFDIUM DURATION:

- IVu 57 New Era 41 DFF, 57 DRP; ranked 2nd
- IVu 18 P.C.1 New Era 41 DFF, 58 DRP;
   ranked 8th

### ERECT, MEDIUM DURATION:

- IVu 176 C-5723-11 39 DFF, 58 DRP; ranked 15th (3rd SR)
- IVu 76 Prima approximately 39 DFF, 57 DRP

### CLIMBING/POLE TYPE:

 IVu 530 Ibadan - 2-41 DFF, 72 DRP; ranked 24th (4th SR)

 DFF = days to first flower, DRP = days to first tipe pods. Ranking = as mean for both seasons unless otherwise specified.

Soybean Trials. Adjusted gross plot yields in the IITA trial ranged as high as 2,928 kg/ha, averaging 1,948 kg/ha for first season and to 2,961 kg/ha averaging 1953 kg/ha in the second season. As trial means, maturity averaged 85.9 days (ranged 78-96 days) and mean plant height was 68.9 cm (range 32-119 cm) during the first season. Both duration and plant height were reduced in the second season as a consequence of early cut-off of rain.

Considering different requirements and uses for soybeans, the first year of testingand observation suggests the following cultivars to be best for different purposes:

# TALL-LATE CULTIVARS:

(Exceed 100 cm in beight and require 90-96 days for maturation in first season)

- IGm 1 CES 407 high yield, partly resistant to shattering.
- IGm 9 Improved Pelican high yields, resistant to shattering.

Note: Both strains tend to lodge and are susceptible to bacterial pustule.

# MEDIUM LATE - BOTH RAINFED SEASONS:

(mature in 88-90 days; 60-70 cm tall)

- IGm 80 Bossier excellent yield, no major problems.
- IGm 10 Clark 63 high yielder, no major problems.
- IGm 44 Chung Hsing No.1 excellent, but tends to shatter.

#### MEDIUM-LATE - FIRST SEASON ONLY:

- IGm 381 Hardee 100 days to mature but short (43 cm).
- IGm 39 Davies 95 days to mature and very short (38 cm).
- IGm 12 TK-5 82 days to mature but very short (31 cm).

# EARLY STRAINS - BOTH SEASONS:

- IGm 16 CNS 78 days, 38 cm tall, shatters slightly.
- IGm 58 Amsoy 87 days, 67 cm tall (1st season).
- IGm 67 Kent 85 days, 56 cm tall (1st season).

Preliminary Testing In Soybeans. In addition to visual evaluation and single plant selections in elite soybean lines of the breeding nursery and in the germplasm collection grown out during the second season, 3-meter yield samples were taken from the center of each

Table 1 Advanced Cowpea yield trial conducted during the first and second rainy seasons 1971 at 11TA, Ibadan (Nigeria). Planted on 27/3/71 and 27/8/71 (grain yields).

No.	No.	Pedigree	Grain Yield I	(kg/ha) II *	Rank II	Mean Yield (kg/ha)	Mean Rank
1.	335	Jebba Pea A	2226a	622cdefg	18	1428	5
2.	74	Kwara Ex-Kwoi-C	2219a	760abcdef	9	1490	3
3.	354	Hanbru 58-123	2171a	740abcdef	12	1456	4
4.	57	New Era	2170a	999ab	2	1585	2
5.	37	Pale Green	2131ab	1050a	1	1591	1
6.	72	59-25	2106abc	745abcdef	1.1	1426	6
7.	363	Lalita-2	2019abc	598defg	19	1309	10
8.	18	PC1-New Era	1942abcd	709bcdefg	14	1326	8.
9.	352	C.239	1917abcd	685bcdefg	16	1301	11
0.	256	58-115-3	1911abcd	707bcdefg	15	1310	9
1.	201	Cal. Blackeye	1818bcde	907abcd	5	1363	7
2.	70	58-185	1797cde	395gh	23	1096	16
3.	32	Iran Grey	1634def	904abcd	6	1269	12
4.	702	Matwase-A	1595ef	461fgh	22	1028	17
5.	92	Witzenborg	1594ef	791 abcde	8	1193	13
6.	398	Bechuana-B	1460fg	808abcd	7	1134	14
7.	30	W.112	1360fg	471 efgh	21	916	20
8.	176	C.5723-11	1290g	936abc	3	1113	15
9.	152	68138	1289g	482efgh	20	886	21
0.	163	C.5723-8	1263gh	739abcdef	13	1001	18
1.	316	56-13	1240gh	260h	24	750	23
2.	78	58-C-91-2	1177gh	746abcdel	10	962	19
3.	593	Westbred	973h	667cdefg	18	820	22
4.	530	Ibadan-2	540h	916abcd	4	1186	24
	Trial	Means	1660	713		1186	
		C.V. (.05)	11.7	26.6			

<sup>\*</sup> Yield values followed by the same letter designation are not significantly different from each other.

5-meter row. In the largest lot of 385 lines yields ranged from 107 to 3,905 kg/ha of grains. Five entries exceeded 3,600 kg/ha, 5 entries yielded more than 3,000 kg/ha, 5 entries exceeded 2,800 kg/ha and 15 entries exceeded 2,800 kg/ha. However, these high vields may be attributable in part to the small

samples taken and to lack of uniform competition by bordering plots.

Preliminary Soybean Test At Zaria. A small lot of seeds of nine entries was supplied to Ahmadu Bello University, Zaria. Although seeds were limiting, yields were reported on

Table 2. Trellising Experiment Yield Results.

Seed Yields (K	g/ha)	Mean of	Four	Replication	S
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			Yields Advantage (T:UT)		
	Unsupported	Trellised	Kg/ha	Multiples (X	
1. Vigna unguiculata	720	1.476	756	2.1	
2. V sesquipedalis	658	1.715	1057	2.6	
3. Phaseolus lunatus	36	614	578	17.1	
4. Psophocarpus tetragonolabus	362	841	479	2.3	
MEAN	444	1,162	718		

unreplicated plantings made there in June, and July. Highest yields were obtained from the tall-late cultivar CES 407, which proved equally productive in both plantings, averaging 1,833 kg/ha of grain. Bossier was second with 1,240 kg/ha and Improved Pelican ranked third with 963 kg ha.

Of interest and considerable concern in that region as well as in the second season at Ibadan is heavy shattering in susceptible varieties. CES 407, Bossier, Improved Pelican Clark, Amsoy and Grant proved less susceptible to shattering but the remaining entries shattered 60-100% of their seeds. CNS, TK-5 and Hsih shattered heavily. This observation was confirmed at IITA.

Trellising Experiments. Four different species – semi-climbing cowpea, yard-long bean, lima bean and winged bean – were grown with and without trellising during the rainy season. Trellising resulted in a yield advantage of 2.05 X for cowpea (1,476 kg/ha), 2.61 X for yard-long bean (1,715 kg/ha), 2.32 X for winged bean (841 kg/ha) and 17.06 X for lima bean (614 kg/ha). When supported on wires strung from 10-foot poles, these species fruited more profusely, appeared less affected by pests (better results from spraying), and produced better quality seeds (Table 2).

Asian Vignas Trial. A small yield trial of Asian Vignas was planted in the second season to assess their potential in the IITA environment. The trial was planted late on a poorly prepared area, and growth was considerably depressed. This experiment included Westbred cowpea, six Vigna aureus accessions and one V. mungo line. Highest yields were from V. aureus entries IVau 27, 4, 31 and 40, which recorded 267, 276, 298 and 307 kg/ha of seed respectively. By comparison IVm1 produced 198 kg/ha and Westbred (IVu 593) only 85 kg/ha.

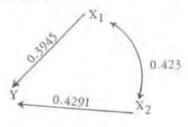
#### CORRELATIONS AND REGRESSIONS

Several parameters assumed to be components of yield were analyzed in both seasons' soybean variety trials and in the trellis experiment. These computations are summarized in the following sections and, where appropriate, path coefficient analysis was applied.

Soybean Yields and Plant Heights. Yields of soybeans were found to be positively correlated with plant height during the first season. In the 15-entry Illinois Regional Trial r value of 0.394 was obtained while in the IITA Advanced Trial made up of 25 entries r = 0.584 for this relationship. The slight discrepancy between the two r values is explained on the basis that

seeding rates in the Illinois trial were higher resulting in about 15% taller plants than in the IITA trial when the same (five) temperate entries were included in both trials. Moreover, the IITA trial included a broader range of germplasm than the Illinois trial.

Soybean Plant Height, Stand and Yield. In a regression analysis of the Illinois trial grown in the first season involving plant height, stand and grain yield (the dependent variable) yield was correlated with both plant height (r = 0.576) and stand at harvest (r = 0.596). Height also was positively correlated with stand (r = 0.423) and could be illustrated as follows:



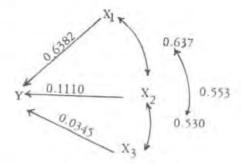
Y = yield

X1 = height

X2 = stand

The same explanation given for the first analysis applies in this situation. The positive correlation between stand and plant height supports the previous argument on relating these two factors.

Soybean PlantHeight. Maturation Period and Yield. The dependence relationship between grain yields and height, and days to first flower and maturity was analyzed in the first season IITA trial. Yield was positively correlated with height (r = 0.728), days to first flower (r = 0.536) and days to maturity (r = 0.553). The multiple correlation coefficient between all characters with yield was r = 0.7345 and mean yields could be estimated as



X1 - Plant height

X2 Days to flower

X3 Days to maturity

Among the parameters in this trial, plant height was most closely associated with grain yields, and also with days to flowering and maturity. However, days to flowering acts both directly on grain yields as well as through plant height and secondarily through maturity.

Soybean pod and seed characters and yield The relationships between pods per plant, seeds per pod, 100 seed weight, seed width, seed length and grain yields were investigated in our second season trial. In this analysis pods per plant were found negatively correlated with yields (r = 0.70) but seeds per pod (r = 0.226) and 100 seed weight (r = 0.587) were positively correlated with yield. However, seed length and seed width - measured on 10 seeds - were highly correlated with 100 seed weight (r = 0.851; r = 0.853 respectively). The negative association between pods per plant and yield is because plant stands were neither comparable nor considered in this analysis.

Heavily podded plants were affected by a late season drouth resulting in poor filling and smaller seeds. Pods per plant and 100-seed weight were negatively correlated (r = 0.754). Agreement between seasons The relationships between four parameters during two seasons were also examined in our soybean trial. The results are:

	MEAN				
	First Season	Second Season	г		
Seed yields	2476	1939	0.582		
Plant height Days to flowering	68. 9	67.3 33.0	0.966		
Days to maturity	85.9	69.8	0.896		

As expected, the correlations for plant height, flowering and maturity are high, whereas there is a negative correlation for grain yields. The best explanation is that late varieties like CES 407, CES 486 and improved Pelican were allected by late season drouth.

Components of yield in other species. The influence of 15 components on yields of cowpeas, winged bean and lima beans in the trellis experiment conducted during the second rains was investigated. A multiple correlation co-efficient of r 0.9784 was obtained and highest positive correlations with grain yield for all species were realized from pods per plant (r - 0.888), duration of growth (r = 0.562), stand count (r = 0.514), number of seeds per plant (r = 0.467) and percent undamaged seeds (r = 0.407). High negative correlations were also obtained between yield and days to first pod (r = 0.667) and days to maturity (r = 0.631). While these relationships could be expected, a negative correlation between 100-seed weight and yield (r = 0.480) was also obtained. This is because the largest seeded species lima beans and winged bean - were the lowest yielders.

### SOYBEAN FOOD PREPARATIONS

Utilizing whole Soybeans for food. A small

project to investigate the direct use of full-far soybeans in Nigerian foods was initiated cooperatively with Mrs. C.E. Williams, Department of Rural Economics and Extension, University of Ibadan. Three local dishes were
prepared and tested by taste panels. One dish
(moin-moin) was rejected outright. The second
dish (simple cooked beans) was accepted by 6
out of 14 tasters. The third dish cooked with
fish, vegetables, groundnut oil and seasoning
was highly relished by all 26 members of the
panel.

## GERMPLASM DISTRIBUTION

The distribution of grain legume seed stocks during the first two years of GLIP establishment is included in 331 separate lots of seed distributed to 12 locations, six of which are in Africa. One-third of all seed lots was given to Nigerians. Other lots went to India, Australia and Colombia.

PLANTING DATE EFFECT ON FLOWERING AND MATURATION OF SOYBEAN AND COW-PEA.

Four soybean and two cowpen cultivars were planted monthly in six replicates in a randomized block design. Each plot contained four 5-meter rows with 0.75 m inter- and 0.15 m intra-row spacings. Plants were considered flowering when 50% of the plants flowered.

Soybean planting date and /lowering. All soybean cultivars planted between May and August responded to increased day length. More days from planting to flowering were required as day length increased to a maximum in June. This was followed by a gradual decrease in number of days to flowering as day length decreased. Outside the period May to August the number of days to flowering depends more on other environmental factors than on day length. This reaction is probably

because all day lengths during September -May are shorter than the critical day length of the four cultivars.

The flowering pattern was similar in all cultivars but there was a difference in the number of days from planting among them. The shorter and precocious cultivars such as Hshi and TK-5 flowered earlier than the taller cultivars such as Improved Pelican and CES 407.

Planting date and maturation. The maturation period was considered from 50% flowering until harvest. The maturation pattern of the soybean cultivars, except CES 407, was similar to that for flowering as longer days delayed maturation. The maturation period of CES 407 decreased as day lengths increased.

Differences in the maturation period of all cultivars were greatest during months of shorter days, and decreased during periods of long days.

Cowpea planting date and flowering. Flowering mode of the two cowpea cultivars is similar to that of soybean. The longest periods from planting to flowering corresponded to increases in day length. The difference in flowering between Westbred and Lalita was not great during the short days of the year, while the differences in date of flowering during the long days were higher. Westbred was less affected than Lalita by changes in day length.

Grain Legume physiology research. In a collaborative program at the University of Reading, Prof. P.A. Huxley, Dr. A.P. Hughes and Dr. R.T. Summerfied studied the effects of day length, day temperature and night temperature on a range of soybean cultivars chosen on the basis of their performance in the initial field trials at IITA. Plants were grown in a greenhouse with controlled day

length, in an inflated plastic "bubble" house and in artificially lighted growth cabinets. With suitable cultural technique, plants closely resembling field grown plants at IITA were obtained.

By the use of contrasting daylengths (11h.40 and 13h.20) together with noninductive photoperiods (natural English long days of ca. 16h or night breaks of 2h duration) it was shown that:

- None of the tropical varieties studied was daylength neutral although Fiskeby, a Swedish soybean cultivar, was. In the case of Fiskeby there was an indication that the time to flower was dependent upon a "heat sum."
- The later a variety flowered in 11h.40 days, the greater was the additional flowering delay for 13h.20 days.
- 3. The later a variety flowered the higher up the stem the first flower and pod appeared, although subsequent flowers developed above and below the first. Later flowering varieties had a higher proportion of pods on branches and they were borne at higher nodes. The final numbers of pods, seeds and seed yields were higher in the later flowering varieties.
- The same pattern of development as in the late flowering varieties could be obtained in an early variety by exposing the plants to a period of non-inductive conditions.
- A juvenile phase during which the plant was insensitive to photoperiod occurred in late flowering varieties but not in the earliest.
- If short days were given for seven weeks from sowing, the performance of even the earliest flowering varieties was still affected by transfer to long days. It is not

possible therefore to accelerate a procedure for screening general morphological and reproductive characters (e.g. components of yield) by giving a short period of induction followed by transfer to natural long day lengths.

In investigations using natural light, the cowpea Westhred was the least sensitive to daylength, but was somewhat indeterminate. New Era and Lalita were both influenced by day length.

In cabinet studies in which day and night temperatures were varied as well as daylength, it was found that for the variety TKS the time to flower was more dependent on night temperature than day length, with the effect of day temperature being negligible. As in the greenhouse/bubble house experiments the later flowering plants subsequently gave the higher vields. Of the components of yield, pods per plant was negatively correlated with night temperature, but this was offset by a positive correlation of mean seed weight and night temperature. Seeds per pod was negatively correlated with day length but the magnitude of the effect was small. However, the final seed vield was best correlated (negatively) with the day temperature.

Planting date and maturation. The maturation of both cultivars took less time during the long days. Their reaction was similar to that of CES 407 soybean. The maturation of the Lalita cultivar was more affected by day length fluctuations than Westbred.

### GRAIN LEGUME ENTOMOLOGY

Insects constitute a major constraint on grain legume production in the tropics. Both quantity and quality of seeds are seriously impaired. IITA's grain legume entomology work consists of

- identification and enumeration of the insect pests,
- estimation of damage and losses due to insect attack,
- screening and selection of plant germplasm for resistance to the major insect pests.
- technical and economic evaluation of insecticides.
- 5. agronomic and cultural insect control and
- observations on the natural enemies of insect pests.

A general appraisal of the legume insect problems, with emphasis on cowpeas, made during 1969 and 1970 provided a basis for pursuing more specific projects aimed at practical control methods.

#### COWPEAS

Insect problems and crop losses. Cowpeas are particularly vulnerable to a vast array of insects throughout the plant growth cycle and during seed storage. Cowpea seed yield losses preventable with insecticide applications are generally at least 50% and often approach 100%. Conspicuous damage by insects such as the defoliators, the large Hemiptera, Maruca testulalis and Laspeyresia ptychora is easily recognized. The magnitude of such damage is indicated in the section "Insecticide Evaluations." A detailed list of significant insect pests of cowpeas at IITA was prepared and is available on request.

Greenhouse cage tests with Taeniothrips sjostedti and Sericothrips occipitalis showed damage to foliage, flowers and pods. Infested plants were severely stunted and seed yield was reduced 50%. The numbers of leaves and flowers produced were not affected by thrips, but leaves on attached plants were severely scarred, deformed and often dried prematurely. Thrips adversely affected plant height, number of flowers during the first week of flowering, number of pods, pod length, percentage of pods with seeds, number of seeds per plant and per pod, weight of seeds per plant, per pod and per 100 seeds, seed-pod ratio and date of maturity.

Screening of Cowpea Plants for Insect Resistance. One of the most attractive means of controlling crop pests is by use of plant varieties that resist or tolerate the pests. As a start 1,173 cowpea entries were planted in September for evaluation of their relative susceptibilities to the major insect pests. Plant protection chemicals were applied only once, when severe insect damage and stem rot threatened to eliminate many plants.

Insect damage to foliage was estimated in the field on four dates.

- 13 October 71 434 entries (37%) showed little damage from leafhoppers, chewing insects or both.
  - 20 October 71 95 entries (8%) showed little damage from chewing insects.
  - 25 October 71 57 entries (5%) showed little thrips damage.
  - 4 January 72 7 entries (0.6%) showed little thrips damage.

Fifteen flowers were collected from each entry to be examined for lepidopterous larvae and their damage and for populations of thrips. A total of 180 entries (15%) showed no lepidopterous larvae and no chewing damage.

A second experiment started when the cowpea germplasm (1,543 entries) was planted on 23-24 November 1971 for seed increase, breeding and observation. At two weeks after planting no sprays had been applied and a heavy thrips infestation, 50 to 200 adult 5. occipitalis per plant, was severely damaging most of the young plants. All entries were evaluated for thrips injury. A total of 380 entries (25%) had little damage. The plants were sprayed on 7 and 13 December 1971 with dimethoate and the thrips practically eliminated. A second thrips-damage rating made on 14 December 1971 to estimate the residual effects of the earlier thrips attack showed that 1,255 (82%) of the plants had recovered. The others (18%) were still stunted and deformed from the thrips damage.

Seed color appears to be correlated with susceptibility to some insects especially *L. ptychora*. Cultivar Pale Green (IVu-37) produces seeds of various shades of brown, the majority being light brown to tan, but some are dark brown. Replicated field trials have shown that the dark seeds are damaged more than light colored seeds.

Each cowpea entry that shows little or no damage by one or more of the major insect pests will be retested in replicated trials to determine whether the absence of damage is due to chance escape or to true resistance.

Insecticide Evaluations. While the few reports of other workers and our own preliminary observations have shown empirically that seed yields can be greatly increased by the application of insecticides, the level of insect control is unsatisfactory.

Westbred cowpeas (IVu-593) were planted in observation plots during 1969 and some were sprayed weekly with insecticides and a lungicide during the period of two to seven weeks after planting. These treatments gave pronounced effects both on date of maturity

Table 3. Yields of seeds (12% moisture) from 10 cowpea cultivars under two spray schedules.

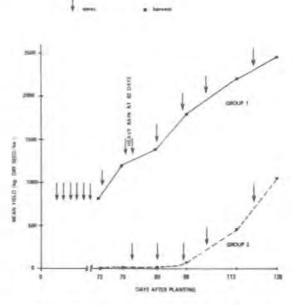
		Yields (	% loss	
IVu No.	Cultivars	13 sprays	5 sprays	(13 vs. 5 sprays)
32	Iran Grey	3,526	1.058	70
34	Lalita - 2	3,412	1,354	60
31	Emma	2,797	1,158	59
37	Pele Green	2,689	1,774	34
35	Mak - 1	2,574	1,427	45
36	New Era	2,449	1,420	42
33	Kawarkwai	2,078	861	59
40	34C395	1,934	565	71
38	SVS-47 (-a)	1,524	123	92
39	No. 19	1,427	84.2	41

and seed yield. In a 1970 experiment similar advancement of plant maturity was shown with carbaryl, diazinon, and lindane but malathion had little influence on maturity date.

In April 1970 ten cowpea cultivars were planted in duplicate plots at a rate of 106,667 seeds per ha. One set of plots was sprayed 13 times with DDT, lindane or both. The other set of plots was intended to be an unsprayed check, but since no pods were developing on these plants at 79 days after planting, these received five sprays of lindane to observe the effect of starting to spray late in the life of the plants.

The plots were harvested six times before the experiment was arbitrarily terminated even though several cultivars were still producing pods. Total seed yields for each cultivar are shown in Table 3. The treatments and cumulative average yields from the six harvests of the two sets of plots are illustrated in Figure 1. Results of pod and seed analysis for insect damage are presented in Table 4.

Figure 1. Effects of insecticide sprays on ten cultivars of cowpeas planted 8 April 1970.



Our 1971 insecticide field tests had the following objectives:

Table 4. Effects of insecticidal sprays and harvest dates on cowpea pod and seed damage by Marnew testulalis and Laspeyresia ptychora. Planted 8 April, 1970

		% Pods dar	% Seeds d	amaged		
Days after	Mai	ruca	Laspey	resia	by Laspe	yresia
planting	13 sprays	5 sprays	13 sprays	5 sprays	13 sprays	5 sprays
72	13	58	32	19	13	No seed
79	22	42	59	40	35	No seed:
						**
89	16	23	73	59	47	57
100	9	11	83	88	49	67
115	10	16	90	90	67	66
127	7	6	88	91	63	60

.. First spray applied to these plots

- Measurement of the types and extent of insect damage in untreated and treated plots.
- Evaluation of several treatment schedules using one insecticide formulation.
- Comparison of the performances of different insecticides applied under the same schedule.
- Economic feasibilities of making a profit by employing various plant protection and cultural practices.

A randomized complete block design with four replicates was used. Planting was 7 April at 83,333 plants per hectare. The treatments and rates of active ingredient and costs per hectare are given in Table 5.

Observations on insect populations were made in the field on four dates before the first flower samples were collected. Flower samples were examined for insects and damage on two dates. Pods were examined for external signs of damage by Maruca and by Laspeyresia. Seeds were examined for damage by Maruca. Hemiptera, Melanagromyza and Luspeyresia. After numerically assessing the specific types of insect damage, the 400 seeds from each treatment and each harvest (4 replications pooled) were subjectively divided into three categories (undamaged, damaged but suitable for human consumption, and too badly damaged for normal marketing) and weighed to estimate the yields in terms of marketable quantities (Fig. 2).

Flower Damage. Although some treatments resulted in fewer lepidopterous larvae, less damage to flowers, or reduction of thrips, results were inconsistent.

Pod Damage by Maruca. Pod damage ranged from 31% in the checks to 4.5% in the best treatment. Degree of control of Maruca with DDT plus lindane was directly related to earliness of the first spray and the frequency of applications. The descending order of efficiency for the four chemical formulations tested under one schedule was endosulfan.

Table 5. Insecticide Treatments used in 1971 experiment.

	TREATMENT 1			INSECTI	CIDE	
Number	Start (DAP)	Days Between	Product(s)	% a.i.	kg a.i./ha <sup>2</sup>	Cost <sup>3</sup>
T .	14	7	DDT Lindane	0.15 0.015	1.48 0.15	5,80
H	28	7	DDT Lindane	0.15 0.015	1.46 0.15	5.75
111	28	14	DDT Lindane	0.15 0.015	1.46 0.15	5.75
IV	56	7	DDT Lindane	0.15 0.015	1.46 0.15	5.60
V	84	7	DDT Lindane	0.15	1.42 0.14	4.90
VI		NO INSECTIO	IDES APPLIED			
VII	49	7	DDT Lindane	0.15 0.015	1.00	3.95
VIII	49	7	Endosulfan	0.15	1.00	5.35
IX	49	7	Gardona <sup>4</sup>	0.10	0.67	5.65
X	49	7	Lindane Dimethoate	0.15 0.0225	1.00 0.15	8.13

- 1. New Era and Iran Grey received I VI. Pale Green received VI X.
- 2. Average kg a.i./ha. Plants sprayed to near run-off and volume recorded.
- 3. Cost per application based on local prices converted to U.S. dollars (\$2.80 per EN).
- 4. Trade name for 2-Chloro -1-(2.4.5-trichlorophenyl) vinyl dimethyl phosphate.

lindane plus dimethoate, DDT plus lindane, and Gardona. Maruca damage in check plots tended to decline with increasing age of the crop (correlations - r-values - of -0.70 to -0.72).

Seed Damage. Results of seed evaluations for damage by Hemiptera and Laspeyresia are presented in Tables 6 and 7. Intensive treatment schedules with DDT plus lindane significantly reduced the level of Hemiptera attack in Iran Grey and Pale Green but not in New Era. Comparisons among the four insecticide formulations applied to Pale Green show that

DDT plus lindane, and endosulfan gave significant reductions in Hemiptera damage compared to the check but Gardona plots suffered greater Hemiptera damage than the untreated checks. In the check plots, Hemiptera damage to Iran Grey and New Era decreased with increasing age of the crop, while damage to Pale Green tended to increase.

Melanagromyza vignalis, the cowpea seed fly, is a relatively minor pest at present, but appears to be increasing. The larvae attack maturing seeds by tunneling through the longi-

Table 6. Cowpea Seeds: Numerical % damaged by insects in 1971 field plots under various treatments (Average of 1st 6 harvests).

- 1	IRAN GREY		AN GREY NEW ERA PA		GREEN				
HEMIPTERA									
v <sup>a</sup>	29.75	111	23.17	ix	20.63				
VI	28.25	IV	21,79	VI	15.17				
V	26.71	VI	21.42	X	13.29				
ш	23.34	V	20.92	VII	11.88				
11	20.67	11	20.58	VIII	10.71				
1	20.17 0.1b	):	17.50 NS		0.001				
thec	×=28.25_	0.0	b_21.79_	0.01	15.17				

LASPEYRESIA								
ī	45.21	IV	31.67	VII	36.34			
101	44,17	1	31.29	VIII	33.71			
11	43.00	U	27.84	VI	31.67			
IV	40.13	1.0	27.04	×	23.96			
V	37.96	VI	25.16	EXC	16.25			
VI	35.50	V	25.13		0.001			
	0.01		0.1					
Chec	ks35.50_	_0.05_	_25.46	0.05_	31.67			
			NS-					

_		L	INDAMAGE	D	
1	30.38	V	47.62	1X	56.42
11	28.46	VI	46.13	X	52.09
VI	26.83	11	45.38	VIII	45.29
V	26.34	1	44.58	VI	44.33
111	25.12	111	43.71	VII	41.50
IV	24.71	IV	40.04		0.001
	N	IS	N	S	
Theck	s 26.83_	0.00	1_46.13	NS_	_44.33
			0.001_		

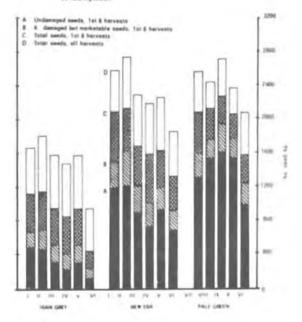
a/ See Table 5 for description of treatments.

Table 7. Effects of Laspeyresia attack on cowpea seed weight.

	GRAM			
	UNDAM	AGED	DAMAGED	% LOSS
RAN GREY	11.723	***	8.060	31.25
NEW ERA	11.500	***	8.360	27.30
PALE GREEN	9 190	***	7 148	22:22

<sup>\*\*\*</sup>F-test significant at 0.001

Figure 2. Effects of insecticidal sprays on insect damage to cowpeas.

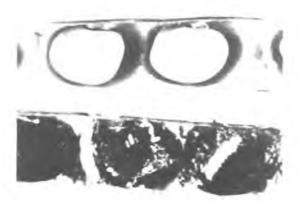


rudinal axis. Damage averaged 3% and treatments did not significantly reduce damage.

Laspeyresia ptychora severely damaged seeds of all cultivars tested but New Era suffered less damage than the others (Table 6). Spraying with DDT plus lindane tended to increase seed damage probably due to selective destruction of parasites and predators. Gardona, and lindane plus dimethoate significantly reduced the level of Laspeyresia damage to seeds, however, damage was still considerable. Seed

b/ Level of statistical significance (F-test).

damage increased significantly with the age of the crop in the field. Table 7 shows that weight losses are in the order of 20 to 30% when seeds are attacked by Laspeyresia.



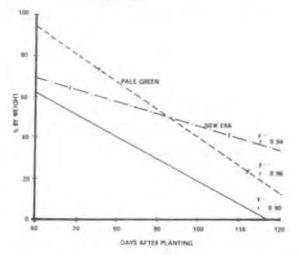
Comparison between undamaged cowpea seeds and seeds that suffer from typical Laspeyresia damage

Undamaged and Marketable Seeds. In the check plots, New Era and Pale Green produced a significantly greater percentage of undamaged seeds than Iran Grey (Table 6). DDT plus lindane, and endosulfan sprays gave no significant increase in percentage undamaged seeds. Gardona, and lindane plus dimethoate did significantly increase the proportion of undamaged seeds.

Figure 2 gives a view of the proportions (by weight) of seed yields divided into different categories. DDT plus lindane treatments did not change the weight percentage of marketable Iran Grey or Pale Green seeds, however, it did decrease the marketable fraction of New Era when applied under treatments I and IV. Gardona and lindane plus dimethoate significantly increased the marketable fraction of Pale Green seeds.

Figure 3 shows significant negative correlations between percentage undamaged seeds and age of the crop in the field. This emphasizes the importance of early-maturing varieties and prompt harvesting.

Figure 3. Weight of seeds (%) without insect damage in unsprayed cowpeas.



Yields and Economic Evaluation. An initial appraisal of the economic feasibility of each of the treatments was made. A more thorough analysis of the economic feasibility is not warranted until additional field experiments are completed. Figures 2 and 3 and Tables 8 and 9 contain the results and analyses of seed yields.

The variable costs associated with each treatment are the costs of insecticide and labor required to apply the insecticide. The prices of insecticides are shown in Table 5. The cost of labor was taken as U.S. \$0.75 per manday with an estimated requirement of two mandays to apply insecticide to one hectare. In our economic evaluations, costs of insecticide plus labor to apply the insecticide are expressed in terms of cowpeas at U.S. \$0.25 /kg.

The fixed costs associated with each treatment can be attributed to land, labor

Table 8. Cowpen seed yields; Effects of insecticidal sprays, 1971.

		TREATMENT	& KG/H	A	
CULTIVAR	FIRST (	HARVESTS	ALL HARVESTS		
IRAN GREY	11a	1170	H	1832	
	10	1142	1	1678	
	111	964	V	1608	
	V	963	10	1601	
	IV	879	IV	1505	
	VI	450	VI	957	
		0.01 <sup>b</sup>		0.01	
NEW ERA	11	2139	11	2764	
	1	2097	1	2597	
	111	1700	(11)	2311	
	V	1647	V	2283	
	IV	1595	IV	2202	
	VI	1345	VI	1873	
		0.1		NS	
PALE GREEN	1X.	2275	ix.	2727	
	VIII	2151	VIII	2581	
	VII	2099	VIII	2462	
	X	2076	X	2403	
	VI	1693	VI	2093	
		NSC/		NSC.	

a/ See Table 5 for description of treatments

b/ Level of statistical significance (F-test).

required for land preparation, planting, weeding, and harvesting. It is assumed that the yield of cowpeas obtained in the untreated plots represents the return to the fixed costs involved in the production of cowpeas.

An indication of the feasibility of each of the treatments was obtained by comparing the net cumulative yield of cowpeas for each treatment, after the deduction of costs of insecticide and labor for application of the insecticide, with the cumulative yields ob-

Table 9. Effects of inserticidal sprays on cowpea yields: grams seed per 100 pods.

	RAN GRE	C	NEW ERA	PAI	E GREEN
11.0	113.29	T	104.13	IX	100.50
1	106.04	10	102.50	X	97.54
111	98.13	V	97.88	VII	92.58
V	96.96	VI	92.88	VIII	89.92
(V	95.17	111	90.17	VI	89.38
VI	86.96	IV	89.17		0.1
	0.001	)	0.1		

a/ See Table 5 for description of treatmentsb/ Level of statistical significance (F-test).

tained in the untreated plots. The results are shown in Figures 4, 5 and 6 for cultivars Iran Grey, New Era and Pale Green respectively.

Simple regressions relating cumulative cowpea yield at each harvest to level of insecticide use were estimated. Highly significant levels of fit were obtained using a semi-log relationship:

$$y_i = a + \beta \log x_i + \epsilon_i$$
  
where  $y_i = \text{cowpea}$  yield in kg/ha  
 $x_i$  insecticide used in U.S. dollars/ha

The standard errors of forecast kg cowpeas/ha measured at the means of the observations were the same across treatments within each variety but differed substantially across varieties. The standard errors of forecast are:

Cultivar	Highest Estimate	Lowest Estimate
Iran Grey	92	64
New Era	343	299
Pale Green	176	142

The standard error of forecast obtained from the estimated regression provides some

c/ Treatment IX (Gardona) is significantly larger than VI (untreated check) at the 0.1 level in a one-way analysis of variance comparing pnly these two.

Figure 4. Iran Gray send yields less treatment costs

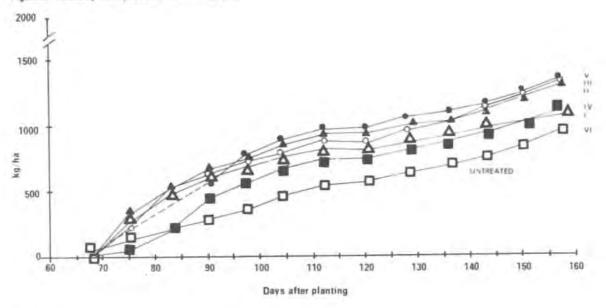


Figure 5. New Era send yields plus treatment costs.

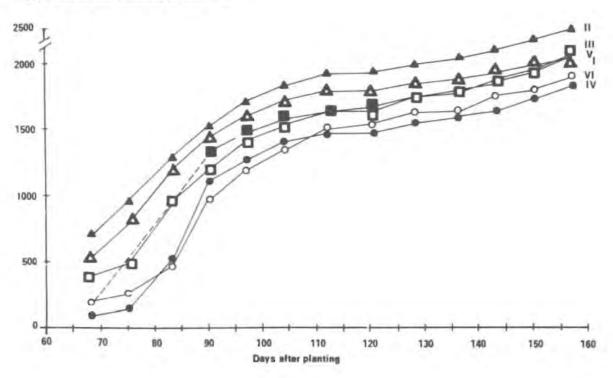
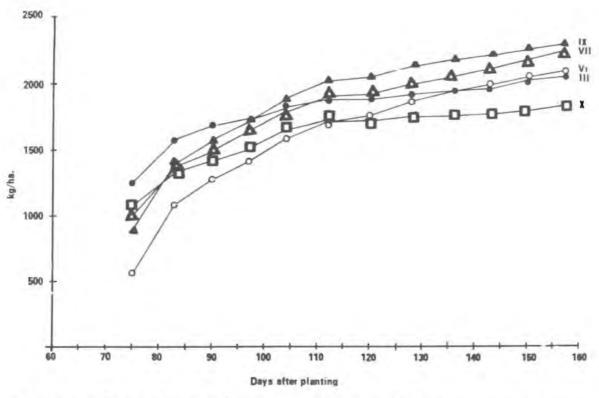


Figure 6.



information on the risk inherent in the cowpea production process.

The proportion of the seeds undamaged by insects declined significantly with successive harvests (Fig. 3). Only treatments nine and ten in Pale Green increased the proportion of undamaged seeds and the marketable seeds over the untreated plots (Table 6). For these treatments, the higher seed quality which was not accounted for in this analysis, adds significantly to the profitability of these treatments.

Although most of the treatments gave increased total yields, the marketable proportions of seed obtained under some treatments were lower than from the untreated plots.

In summary, all treatments except six

were profitable it treatments and harvests were terminated after six pickings. The levels of profit obtained in each of the treatments differ to some extent but individually remain approximately constant following 95-105 days after planting. The risk involved in the yields obtained versus treatment costs differs substantially across cowpea cultivars. While the levels of profit obtained from the highest yielding treatments for each cultivar appear similar, the risk involved in achieving this level of profit can differ significantly. The improvement in seed quality under treatments nine and ten adds to their levels of profitability

#### CULTURAL PRACTICES

Insect Damage - Weed Relationship in Conpeas. Samples of Westbred cowpea seeds from two weed control experiments examined for

Table 1. Relative abundance of insects and damage associated with various untreated grain legume plants.

	INSECTS								LEAVES DAMAGED BY	
PLANTS	Leaf hoppers	Hemip- tera	Aphids	Thrips	Leaf beetles	Leaf worms	Grass- hoppers	Sucking Insects	Chewing Insects	GENERAI
IVu-30	Ha	M	0	н	M	M	0	н	M	V-H
IVu-37	H	M	0	н	M	M	0	M-H	M	H
Vu-76	H	L	0	H	M	M	.0	H	M	V-H.
Vu 335	H	M	0	Н	M	M	0	ЭН	M	H
Vu-1283	H	M	0	н	L-M	L-M	0	M-H	L-M	H
Vum-1	M	F	0	L	L	L	D	L	L	L
Vau 21	M	H	0	M	Ŀ	L	0	H	M	9
IVau-31	M	H	0	M	L	L	0	H	M	H
IVm-1	M	Н	0	M	L	L	0	н	L-M	Н
P1-1	1.	0	0	L	V-L	0	0	0	V-L	V-L*
ICc	L	M	L	M	0	0.	M	L	L	L
IGm-1	L	L	0	L	L	L-M	0	V-L	L	L
IGm-2	L	L	0	L	L	L-M	0	V-L	L	L
(Gm-80	L	L-M	VL	V-L	1	L-M	L-M	L	L	La

a/ H = heavy: M = moderate. L = light; O = none; V = very.

Red spider mites present on leaves, but not abundant.

IVu = Vigna unguiculata (cowpea) IVum = Vigna umbellata (rice bean) IVau = Vigna aureus (green gram)

IVm Vigna mungo (black gram)
IPI – Phaseolus (unatus (lima bi

P) = Phaseolus lunatus (lima bean) ICc = Cajanus cajan (pigeon pea)

ICc - Cajanus cajan (p IGm - Glycine

insect damage showed that cowpea seeds from weed-free plots had significantly less damage from Hemiptera, Laspeviesia and Melanagromyza.

Intereropped Compeas and Maize. It is believed by some that insect and disease problems are less severe under the traditional mixed cropping of cowpeas with other crops such as cassava, sorghum, maize or miller than in monocultures. A 1971 experiment compared cowpea insect situations in cowpea monocultures and in intercropping of cowpeas with maize. The intercropping of cowpeas with maize appears to have increased the overall insect problems on cowpeas but further work is required, before definite conclusions can be drawn.

Table 11. Relative susceptibility of various unprotected grain legume flowers (15per plot) to insect attack

	LEPIDOPTER	ROUS LARVAE	THRIPS				
No./100 flowers		% flowers	% flowers damaged		Nymphs/flower		s/flower
IVu-30 IVu-37	36.69 36.69	IVu-37 IVu-30	35.00 33.34	IVu-335 IVum-1	18.81 3.67	IVu-335 IVum-1	16.04
IVu-1283 IVu-335	36.68 31.68	IVu-1283 IVu-335	33.34 23.34	IVu-76 IVu-30	2.57	ICc IVu-1283	6.02 4.17
ICc IVu-76	21.68 8.34	ICc IVu-76	21.67	(Vau-31 (Vau-21	1.39	IVu-30 IVau-31	3.84
IVm-1 IVum-1	8.34 5.00	IVm-1 IVum-1	8.33 5.00	IVu-1283 IVm-1	1.17	IVau-21 IVu-37	3.30 2.80
IVau-31 IVau-21	1.67	IVau-31 IVau-21	5.00 1.67	IVu-37 ICc	0.45	IVu-76 IVum-1	2.08
IGm-1 IGm-2	0.00	IGm-1 IGm-2	0.00	IP1-1 IGm-2	0.17	IP1-1 IGm-80	0.35
IGm-80 IP1-1	0.00	IGm-80 IP1-1	0.00	IGm-1	0.04	IGm-2	0.07
	0.001 a	11.151	0.001 a	IGm-80	0.00 l	IGm-1	0.05 I

IVu = Vigna unguiculata

ICc = Cajanus cajan

IVm = Vigna mungo

IVau = Vigna aureus

IVum = Vigna umbellata IGm = Glycine max

IPI = Phaseolus lunatus

# RELATIVE SUSCEPTIBILITY OF VARIOUS LEGUMES

Assessments started in September as a series of field plots, with fourteen entries — 5 cowpeas, 3 soybeans, 2 green grams, 1 black gram, 1 lima bean, 1 rice bean and 1 pigeon pea. No insecticides were applied.

Observations and insect counts were made in the field (Table 10). Flower samples were examined for lepidopterous larvae, larval damage, and thrips (Table 11). Pods and seeds will be examined and results will be reported in 1972.

# GRAIN LEGUME PATHOLOGY

#### COWPEA

Seedling diseases Cowpea stands with as low as 25% establishment are encountered, with both pre- and post-emergence death of seedlings. Several potential pathogens were isolated and experiments conducted to determine:

- Which of the isolated organisms are pathogenic to cowpea seedlings.
- The reactions of seedlings of several legume species to the pathogenic organisms.
- 3. The effect of age of cowpea seedlings on

a/ Level of statistical significance (F-test). Number connected by the same line do not differ significantly according to Duncan's Multiple Range Test.

their reaction to the pathogenic organisms.

 The effectiveness of various seed dressing compounds for the protection of cowpea seedlings against the pathogenic organisms.

Of seven fungi inoculated to sterilized soil, only two — Rhizoctonia solani and Pythium aphanidermatum — adversely affected emergence and establishment of cowpea seedlings (Table 12). The symptoms observed on seedlings growing in soil inoculated with these two organisms are similar to those observed on diseased seedlings in the field — brick red, dry, sunken lesions in the R. solani treatments and water-soaked collapse of seedlings in the P. aphanidermatum treatment. It was concluded that R. solani and P. aphanidermatum are responsible for seedling deaths in the field, and they were the organisms used in subsequent investigations.

Seeds of the five legume species Vigna unguiculata (var. Prima), Glycine max (var. Hsi-Hsi), Phaseolus vulgaris (var. IPVI) Phaseolus lunatus (var. IPI 32) and Cajanus cajan (var. 1758 Mak. 1) were planted in soil inoculated with pure cultures of R. solani and P. apbanidermatum. P. lunatus was the species least affected by the two pathogens (Table 13).

Seedlings of cowpea at five ages (33, 26, 19, 7 and 0 days after planting) were subjected to an inoculation of R. solani and P. aphanidermatum grown in sterile sand-cornmeal mixture and placed around the stem bases of seedlings. Seedlings 19 days old or more seem little affected by the pathogens by this method of inoculation, (Table 14) although one 26-dayold Westbred plant and one 33-day-old Westbred plant developed typical wet-stem rot symptoms in the P. aphanidermatum inoculated pots.

Thirteen fungicide seed dressing compounds were evaluated for control of seedling disease in cowpeas planted in soil inoculated with R. solani and P. aphanidermatum. A standard volume of inoculum was poured evenly over the surface of pasteurized soil in clay pots and a 2-cm layer of commeal-soilsand mixture (1:1:2) added to each pot. Seed was planted one week after inoculation. Beno-

Table 12. The number of cowpea seedlings emerged from soil inoculated with various fungi, seven days after planting.

		Replicate			
Treatment	1	2	3	4	Mean
Control	10	1.1	12	12	11.25
Rhizoctonia bataticola	1.1	12	12	11	11.50
Rhizoctonia solani	0	0	0	0	0.00
Pythium aphanidermatum	2	3	3	2	2.50
Colletotrichum capsici	11	12	12	12	11.75
Colletotrichum lindemuthianum	31	12	12	11	11.50
Fusarium oxysporum	12	12	11	12	11.75
Botryodiplodia theobromae	12	12	12	12	12.00
			LSD 5%		1.04

Table 13 Total number of seedlings (Max 40) of 5 legume species emerged at 7 days after planting and established at 10 days after planting in sterile soil and soil inoculated with Rhizoctonia solani and Pythium aphanidermatum.

Species	Cor	Control		R. solani		P. aphanidematum	
	7 DAP	10 DAP	7 DAP	10 DAP	7 DAP	10 DAF	
Vigna unguiculata	39	39	0	0	o		
Glycine max	39	39	8	1	0	(	
Phaseolus lunatus	39	39	33	29	27	23	
Phaseolus vulgaris	39	39	9	5	11		
Cajanus cajan	39	40	3	0.	10	10	

myl (Methyl 1-(butyl carbamoyl)-2-benzimidazole carbamate), Oxycarboxin (5, 6-Dihydro-2methyl-1, 4-oxathiin-3-carboxanilide-4, 4 dioxide), Carboxin (5, 6-Dihydro-2-methyl-1, 4oxathiin-3 carboxanilide) and Chloroneb (1, 4-Dichloro-2, 5-dimethoxy benzene) applied as a dry dust (2g/kg seed) showed promise against R. solani, with Benomyl the most effective at a high dosage of R. solani inoculum, The results with P. aphanidermatum are not so clear. In one test almost no plants established in any treatment, while in the second test there was good seedling establishment in all treatments including the non-treated control. Attention will be given to standardisation of inoculum dosage with P. aphanidermatum.

Slight phytotoxicity was noted on cowpea seedlings growing from seed treated with Vitavax (Carboxin) and Plantvax (Oxy-carboxin). A test was made with these compounds at four rates of application (2,6,18 and 36g/kg seed) on seed of Prima cowpea. No treatment adversely affected germination or emergence but in all treatments the primary leaves developed yellow margins and at 36 g/kg seedlings were stunted. In similar test with Benomyl, Prima cowpea showed no phytotoxicity symptoms.

Anthracnose. The fungus Colletotrichum lindemuthianum causes a severe anthracnose on cowpea stems, petioles, pods and leaf veins. The splash-dispersed pathogen spreads rapidly in monoculture cowpeas during the cool rainy season, and if the disease builds up in the early stages of crop development, considerable yield loss can be expected. The pathogen is seed-borne and in tests at IITA diseased seedlings are consistently obtained from surface-sterilized, blemish-free seed harvested from plots with high incidence of anthracnose. Seed-borne infection has been reduced with dusts (2 g/kg seed) and soaks (12 hr at 30 C in 0.2% aqueous suspension) of the fungicide Arasan 75 (Tetramethylthiuram disulfide) and Benomyl, but control is not complete.

The cowpea germplasm collection, grown three times in 1971, was scored for anthracnose incidence using the scale:

Category S	core	Description
Immune	0	No disease
Immune	1	Small black blotches or flecks on stems.
Highly Resistant	2	Few scattered small eliptical tan lesions
Moderately Resistant	3	Few scattered large eliptical lesions.
Moderately Sus- ceptible	4	Many small lesions.
Highly Susceptible	5	Many large lesions.

Highly Susceptible 6

Lesions coalescing to cover large areas of stem.

Highly Susceptible 7

Coalesced lesions over most of stems and branches, plants, dying.

A total of 269 lines (19.1%) showed no anthracnose in any planting, 281 lines (19.3%) had 'highly resistant' as their most susceptible score in any planting, 170 lines (12.1%) had 'moderately-resistant' as their most susceptible score in any planting, 174 lines (12.34%) were moderately susceptible in at least one planting and 516 lines (36.6%) were highly susceptible in at least one planting. Only four lines gave highly susceptible reactions in all three plantings.

Certain lines were highly susceptible in the first planting and highly resistant or free of anthracnose in later plantings, while many lines were free of anthracnose in the first two plantings and severely attacked in the third planting. Escape, out-crossing and race changes in the pathogen are all possible explanations for these observations.

To further test lines identified as having little or no disease in field plantings a technique was developed whereby all lines were given a standard inoculum dose and maintained at optimum conditions for infection and disease development.

Petiole segments about 4.5 cm long were cut from 4-week-old Prima cowpea plants and placed with their cut ends immersed in 0.7 percent water-agar in clear polystyrene boxes. Three petiole segments were placed in each box, and by means of an Aglamicro-pipette three 0.005 ml drops of a C. lindemutbianum spore suspension were spaced along the length of each petiole segment. Eleven spore concentrations (9.77 x 10<sup>6</sup> - 9.5 x 10<sup>3</sup>) were used, with each concentration used at nine inocula-

tion sites. The inoculated petiole segments were incubated at 22 C, and about 3,000 lux for 12 hr/day. Small water-soaked lesions were noted on the segments four days after inoculation and by six days after inoculation many segments had developed large, spreading, water-soaked lesions. The most severe and consistent teactions were on segments that were inoculated with spore suspensions of concentrations 3.1 x 10<sup>5</sup> and 1.5 x 10<sup>5</sup> spores/ml. Control (uninoculated) petiole segments remained green and blemish-free throughout the test, and no visible contamination occurred in the water-agar in any box.

A second experiment was made with petiole segments and seedlings of known susceptible and known immune varieties with two isolates of C. lindemuthianum. Petiole segments were taken from 9-week-old, field-grown plants of one immune, one low-susceptible and four high-susceptible lines. Inoculation of procedure was the same as that used in the previous experiment. Concentration of spore suspension was 5 x 105 spores/ml. Nine-dayold seedlings of one immune, one low-susceptible and two highly susceptible lines were atomized to run-off with part of the same spore suspension used to inoculate petiole segments. After inoculation the boxes of petiole segment were incubated as in the previous experiment. The seedlings were maintained in a mist chamber that provided mist for 5 sec/10 min. period.

Reactions on detached petioles were classified:

- 0 No blemish
- Small dark flecks at inoculation site (IS)
- 2a Small dark flecks and dark red streaks at IS
- 2b Dark red, shiny appearance throughout IS
- 3a Small water-soaked streaks at IS

- 3b Water-soaked appearance throughout IS
- 4a Water-soaked streaks extending beyond the confines of IS
- 4b Large water-soaked lesions extending beyond the confines of IS to coalesce with lesions from other IS on the petiole-

Examination of the segments with a stereoscopic microscope six days after inoculation revealed that reaction categories 1, 2a and 2b represented necrosis of the surface cells of the petioles, with no sporulation of the pathogen at the inoculation sites. These reaction categories can be regarded as expressions of immunity. Reaction types 3a, 4a and 4b, various types of water-soaked lesions, all developed fertile acervuli by six days after inoculation (the setae and clumps of conidia were clearly visible on the lesion surfaces at x 30 magnification) and can be regarded as expressions of susceptibility.

Susceptible seedlings developed as many as 25 discrete lesions per plant and as lesions spread and coalesced the seedling stems collapsed. There was good agreement between detached petiole and seedling classification of varietal reactions.

The results indicate that detached petiole segments can be used to give a qualitative (immune vs susceptible) and probably a quantitative (size of lesion, time from inoculation to sporulation) measure of varietal reaction to C. lindemuthianum. The technique was used to test 300 lines and 70 were immune, 18 were slightly susceptible, 34 were moderately susceptible and 171 were highly susceptible. Time to sporulation varied from three to eight days. The petiole segments of five lines developed highly susceptible lesion types but the position of the lesions on the segments indicated that disease developed from natural inoculation of the petioles in the field prior

to detachment. The lines identified as lowsusceptible - development of small lesions or slow to sporulate - will be tested for consistency of reaction on detached perioles.

Wet Stem Rot. Wet stem rot, caused by Pythium aphanidermatum is characterized by a complete water-soaked girdle of the cowpea stem beginning at ground level and rapidly spreading up through the stem to the lowest branches. Infected plants die quickly and more than 25% stand reduction has been observed at IITA. Field observations indicate that cowpea plants are most vulnerable to this disease four to five weeks after planting. In a pot experiment Westbred cowpea plants from one to seven weeks old were inoculated with a P. aphanidermatum oospore suspension by three inoculation methods:

- (a) oospores injected into the base of the stem at soil level and injection sites wrapped with wet tissue paper,
- (b) stems wounded with a needle at soil level and tissue paper dipped in oospore suspension wrapped around the stem bases, and
- (c) stems not wounded and tissue paper dipped in oospore suspension wrapped around the base of stems.

After inoculation the plants were placed in a mist chamber that provided mist for five seconds per 10-minute period. Typical wet stem tot symptoms developed within a week of inoculation. The results indicate, that susceptibility to wer stem tot varies with age and that the wounding of stem bases has no synergistic effect on infection (Table 15). Injection of oospores into the stem bases greatly increases infection.

During the late season 1971 a field experiment was conducted with simulated wet

Table 14. The mortality of Westbred and Prima cowpea plants when exposed to inoculum of Rhizortonia solani and Pythium aphanidermatum at five different ages.

Inoculum	Age in days at inoculation	Variety	No. of plants at inoculation	No. of plants 18 days after	No. of plants Dead
R solani	0	Prima Westbred	48 48	2 0	46 48
	7	Prima	45	31	14
		Westbred	47	37	10
	19	Westbred	46	45	1
	26	Prima	48	47	1
		Westbred	48	48	0
	33	Prima	47	46	1
		Westbred	48	45	3
P. aphanidermatum	0	Prima	48	11	37
		Westbred	48	13	35
	7	Prima	48	47	1
		Westbred	48	41	7
	19	Westbred	48	48	0
	26	Prima	44	44	0
		Westbred	48	47	11
	33	Prima	47	47	0
		Westbred	46	45	1*

<sup>\*</sup> Typical wet-stem rot symptoms

stem rot to obtain information on the relationship between wet stem rot incidence and yield loss. Plots of Prima cowpea were subjected to four stand reduction treatments, (64, 32, 16 and 8% of stand thinned) at three stages in the growth of the crop (25 days after planting (D.A.P.), 42 D.A.P. and 49 D.A.P.).

Plants to be thinned were selected randomly in each row and cut off at ground level. Harvest was taken from the center 15m of the center three rows, a harvest area of 34.2 m<sup>2</sup>, at 62, 69 and 76 D.A.P. Yield data included grain weight per plot, grain weight per plant, 100 grain weight, number of pods per plant and number of seeds per pod.

The data of those parameters with significant treatment differences are summarized in Figures 7, 8 and 9. The regression of percent

Figure 7. The relationship between yield (kg/ha) and stand reduction at three stages of crop growth in Prima cowpex.

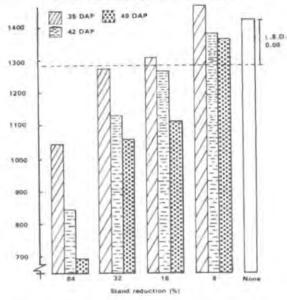
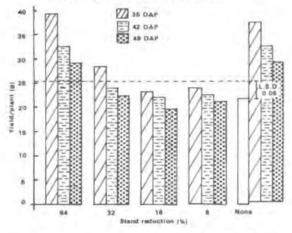


Figure 8. The relationship between yield/plant (g) and stand reduction at three stages of crop growth in Prima cowpea.



stand reduction on percent yield loss for each thinning date is given in Figure 10.

A positive relationship between the incidence of wer stem rot and the use of the fungicide Benlate as a foliar spray was noted in two field experiments. In the second experiment incidence was assessed 47 D.A.P. when the crop had received three applications of 0.2% a.i. Benlate or Kocide 101 at the rate of 1500 l/ha. The results confirmed the observations made in the first experiment that the use of Benlate as a foliar spray in cowpeas promotes increased incidence of wet stem rot (Table 16). One possible explanation for this

Figure 9. The relationship between the number of pods produced/plant and stand reduction at three stages in crop growth in Prime cowoes.

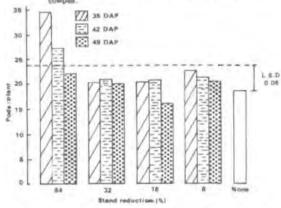
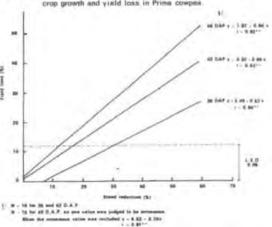


Figure 10. The relationship between stand reduction at three stages in crop growth and yield loss in Prime cowpee.



phenomenon is that as Benlate is not effective against Phycomyceteous fungi but has a broad spectrum of activity against other fungi it may eliminate competition for Pythium and thusgive it a greater opportunity to infect.

Table 15. The number of cowpea plants with wet stem rot one week after inoculation of plants of different ages with an oospore suspension of Pythium aphanidermatum

Age at inocu-	Inoc	Total			
lation (weeks)	Injected	Wounded	No Damage	1000	
1	1	1	0	2	
2	0	0	2	2	
3	2	0	0	2	
4	4	2	2	8	
5	0	0	0	0	
6	3	0	0	1	
7	0	O	1	1	
INOCULATION	8	3	5		

 INJECTED: Oospore suspension injected into cortex at base of stem and inoculation area wrapped with moist tissue paper.

WOUNDED Base of stem wounded with needle and tissue paper dipped in oospore suspension wrapped round stem.

NO DAMAGE Tissue paper dipped in oospore suspension wrapped round stem

Table 16 The number of plants with wet stem rot in plots of Westbred, Prima and Adzuki Cowpea treated with two foliar applied fungicides.

FUNGICIDE*	WESTBRED	PRIMA	ADZUKI	FUNGICIDE
Benlate	15.25	5.0	14.5	11,6
Kocide 101	4.25	0.0	2.5	2.2
None	1.75	0.5	0.5	0.9
			L.8	S.D.0.05=4.1

Three applications of 0.2% a.i. a 1400 L/ha.

Cercospora Lea/Spot. Two species of Cercospora, C. canescens and C. cruenta can cause
severe leaf spotting and defoliation in cowpea.
The incidence of leaf spot caused by each
species was assessed in two plantings of the
cowpea germplasm collection in 1971. Only a
small proportion of lines were moderately or
severely infected with C. canescens and few
lines were infected at all with C. cruenta. One
line, IVu 57 (New Era), had severe C. cruenta
infection in the variety trial.

A detailed assessment of the incidence of C. canescens leaf spot was made in a field a experiment set up for entomological studies in which Westbred cowpea grown as a sole crop in dense (75 x 25 cm) and sparse (150 x 75 cm) stands was compared with a sparse stand in a mixed planting with maize. Although there appeared to be more leaf spot in the densely planted plots, a count of the numbers of leaves with and without leaf spots on five plants in the center row of each plot revealed a greater proportion of spotted leaves in the plants interplanted with maize.

Observations of cowpeas during five seasons indicate that the Cercospora leaf spots do not always reach epidemic proportions, even in highly susceptible varieties. Information is required on the epidemiology of the Cercospora leaf spots and the degree of yield reductions that they may cause.

Virus Diseases. The amount of virus in cowpea plantings at IITA is still much less than that observed at other local agricultural stations but appears to be increasing. In the germplasm collection planted in the late season 1970, 49 lines developed virus symptoms, whereas a total of 142 lines were recorded as having virus symptoms in the second planting of the cowpea germplasm collection 1971, and 350 lines developed virus symptoms in the third planting. The third planting received only one application of insecticide at an early stage of growth whereas the second planting received regular insecticide application throughout the crop growth.

Diseased leaves were collected from most of the plants with virus symptoms in the second 1971 planting of the cowpea collection, a description recorded of each leaf and color transparencies obtained for most of the leaves. The symptoms were divisible into four groups:

- (a) cowpea yellow mosaic type (CYMV) with severe yellow mottle and severe distortion of leaves.
- (b) green mottle type (CGMV) with a faint to pronounced green mosaic or mottle and no leaf distortion,
- (c) bright yellow spot/moutle of leaves (CB YMV) varying in intensity from a few small spots to almost the entire leafler laminae colored yellow, and
- (d) symptoms not classifiable as CYMV, CGMV nor CBYMV.

# OTHER COWPEA DISEASES

Bacterial pustule, Xanthomona vignicola, was observed in eight lines in the second planting of the germplasm collection and in 15 lines in the third planting, 1971.

Powdery mildew (Erysiphe polygoni) and rust (Uromyces vignae) occurred in several varieties in 1971, but as they occurred at a late stage in the growth of the crop they are not regarded as important diseases.

Rhizoctonia leaf blight or web blight occurred in nearly all plantings during 1971. It was not as destructive in the germplasm collection when entries were planted in single hills as it was when entries were planted in 5m rows. In the planting of entries in single hills, plants were staked and thus had fewer leaves near the ground, and also had less trampling of virus and leaves during day-to-day activities in the plots. The incidence of web-blight will be closely watched in yield trial plots in which plants will be subjected to little disturbance.

Stem rot caused by Sclerolium rolfsti has been observed at IITA but incidence is scattered and the disease is not regarded as important.

#### SOYBEAN DISEASES

Bacterial Pustule. Bacterial pustule, caused by Xanthomonas phaseoli var. sojense was the most important soybean disease in IITA in 1971. It was first noted in the soybean collection grown during the first rains, and occurred with great severity on many lines in both first and second season plantings. Of 381 lines examined for bacterial pustule incidence in the late season planting, 144 lines were severely infected, 82 lines were moderately infected, 65 lines were lightly infected and 90 lines showed no sign of the disease. The apparent sources of immunity and resistance will be further tested in 1972 in disease nurseries and controlled inoculations.

Purple Seed. Soybeans harvested during the latter part of the first rains 1971 showed a great deal of Cercospora purple stain. A detailed count was made of the proportion of purpled seed of 33 lines and incidence ranged from 5.5% purple seed (IGM 1) to 91% purple seed (IGM 384). Twenty-three lines had more than 20% purple seed and 12 lines had more than 40% purple seed. The lines with a high proportion of purple seed harvested during the

later part of the first rains showed little or no purple seed in the harvest maturing at the end of October when the weather was dry.

Virus Disease. During October and November 1971 plants of Improved Pelican in the plant physiology field plots developed severely distorted leaves. By the beginning of December adjacent plots of Hsi-Hsi and IGM 126 also showed the same symptoms. By late December much of the new growth in Improved Pelican had normal leaflets. The symptoms matched closely those described for soybean mosaic, a disease of minor importance in the soybean producing areas of the United States. The disease, reported to be seed-borne, can be transmitted in as much as 100% of the seeds of susceptible varieties but the percentage is much lower in most improved varieties. Tests at IITA with 80 seeds from each of two varieties with severe symptoms in the field produced no diseased plants. Attempts to mechanically transmit the disease also produced no diseased plants. The disease is unlikely to become important but all reports of incidence will be closely monitored.

#### PREMATURE SENESCENCE

Certain lines of both soybean and cowpea maturing at the end of the second rains displayed uneven maturation, and those plants that senesced before their sister plants, were seen to have a heavy incidence of Rhizoctonia bataticola (the sclerotial stage of Macrophomina phaseoli, the charcoal rot organism) in the senescing tissue at the base of the stem and in the roots. A similar occurrence was noted at the end of the second rains in 1970. The relationship between the premature senescence and loss of yield needs to be established.

# Root, Tuber and Vegetable Improvement Program

The IITA root and tuber crop improvement program emphasizes the minimization of limiting factors of production, the fitting of the plant to advanced techniques of cultivation, and the improvement of quality for human consumption. Our research goals are to improve varieties for maximum production per unit of area and time; to develop widely adapted plant types responsive to intensive management and more efficient carbohydrate assimilation; to breed genotypes better suited for mechanization; to incorporate resistance to major diseases and insect pests; to improve quality, nutritional values and keeping qualities-particularly in yams and sweet potatoes to introduce desirable propagation characteristics and to breed for wide adaptation.

IITA is ideally located to test for resistance to cassava mosaic virus under field conditions and major emphasis is on identitying and incorporating resistance to the disease.

Specific methods include recurrent selection through population improvement, interspecific crossing, selection and testing over a broad range of environments, and "chromosomal engineering."

The vegetable program is identifying and developing vegetable varieties and systems of production suited for the humid tropics. The inclusion of tropical vegetables in the program helps focus attention on the need for "balance" or "protein" foods in tropical diets. Since taste and specific preferences of various peoples must be considered, the approach is

a program in which investigations of temperate and tropical vegetables are integrated.

### CASSAVA IMPROVEMENT

About 150 Nigerian cassava cultivars, including four recommended in Nigeria, were collected in 1971. These included 10 lines that appeared resistant to cassava mosaic virus and several tree cassavas collected mainly in Western State. The variety Llanera, reported to have high protein content, was introduced from Colombia through CIAT. The introduction of cassava as vegetative cuttings proved difficult and required considerable time to clear phytosanitary procedures. Therefore, major emphasis was on seed introduction.

Local cultivars were evaluated for earliness of root production and one cultivar identified for fast development of edible roots. Heavy lodging was also observed in certain cultivars. However, there were varietal differences and lodging will be considered during screening for higher fertilizer response.

Cassava Flowering- Under field conditions most local cultivars flowered, with a difference among genotypes ranging from continual flowering to flowering for only a few weeks. Varieties were grouped into five categories based on flowering characteristics and flowering characteristics considered in formulating breeding schemes.

Diseases, Insects and Weeds. Cassava mosaic virus (CMV) is the most serious cassava production problem in West Africa. Expression of CMV varies with the season, being less severe in the dry season than during the wer seasons. A cassava clone reported to be resistant to CMV exhibited mosaic symptoms in the early stages of growth and immediately after sprouting but the symptoms disappeared as the plants developed. In screening for resistance to CMV, observations were made in the wet season. Functional field resistance is considered as one possible solution to the disease problem.

Cassava damage caused by Tetranychid mites during the dry season is a serious problem in Nigeria, particularly in eastern Nigeria where cassava is grown extensively. Grasshoppers (Zonocerus variegatus) are also a serious pest during the dry season.

Plant establishment during the dry season was poor in non-weeded plots as compared with weeded plots. The poor establishment is apparently caused by moisture stress caused by competition of weeds for moisture.

This, in turn, resulted in attack by termites as planting stock became dry.

Cassava Breeding. Crosses for 24 combinations were made, including lines resistant to CMV intercrossed among themselves, local cultivars x CMV-resistant lines, local x local, and local x tree cassavas. The objective of crossing was to develop improved populations with resistance to cassava mosaic virus, high quality, early maturity, resistance to lodging, and high yield potential. A cassava breeding scheme is proposed as shown in Figure 1, which consists of genetic manipulation, recombining populations, preliminary evaluation, and screening and yield trials.

An attempt was made to improve cassava

seed germination. Scarifying with abrasives combined with wet-heat treatment in soil increased germination by about 30% compared to wet-heat treatment alone. The treatment consisted of:

- 1. rubbing the seed coat with sand paper,
- placing the seeds in wet soil or sand in petri dishes,
- incubating the dishes for three days at 30C and
- planting the treated seeds in peat pots filled with ordinary soil. This investigation will continue.

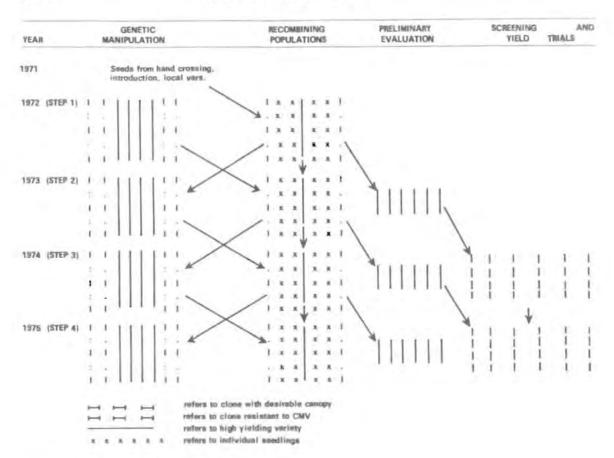
In an attempt to maximize production from limited planting stocks we found individual cuttings 2 to 5 cm long, including a node, were the minimum feasible size.

#### SWEET POTATO IMPROVEMENT

About 10,000 clones of sweet potatoes were produced from seedlings during 1971, including varieties collected in Nigeria. It is believed that sweet potatoes are not extensively grown and utilized for food in tropical Africa because they are sweet and moist when cooked. However, some clones are less sweet and dry, and taste almost like yam when cooked.

Most of the sweet potatoes flowered under field conditions during the dry season from October to January. Combinations of shorter day length and cooler temperatures during this period may have stimulated flowering. Most cultivars did not flower in the wet season.

Two virus-like symptoms, including a ring spot and vein clearing were frequently observed in our sweet potato plots. These are probably viruses previously reported in Nigeria. Rapid spreading of virus-like symptoms was associated with large populations of aphids during



the wet season. However, when a healthy sweet potato was grafted on a plant which showed vein clearing, the symptoms were transmitted to the healthy plants.

Observations during the dry season suggest that the sweet potato weevil (Cylas puncticollis Boh.) may be the most important problem in the field and in storage when sweet potatoes are grown as a dry season crop. Black rot caused by Macrophomina phaseoli, is also a storage problem. However, there appear to be clonal differences in susceptibility to both sweet potato weevil and black rot damage.

Breeding. Hybrid sweet potato seeds were obtained from 13 combinations and open-pollinated seeds from nine different sources were obtained. The objective of this crossing was to improve populations for yield ability, eating quality, resistance to drought, and good canopy structure.

Dry Season Evaluation. About 500 clones were grown in the dry season without irrigation or fertilizer. From the preliminary clonal evaluations in the dry season it is noted that promising sweet potato varieties might be selected for relatively high yield and early maturity, low

Table 1. Sweet potato yield trial in dry season, 1971.

Var. Name	Weevil damage	Vine wt.	Root wt.	Rt. /Vine Ratio	Marketable tuber (kg)
	107	17.01	1.87		
ITS 1	9.9	11.3	16.7	1.48	14.5
ITS 2	42.6	8.9	19.2	2.15	17.2
ITS 3	12.4	9.9	20.7	2.25	18,4
ITS 4	28.7	3.5	12.9	3.70	10.6
Local var	11.8	17.9	16.4	0.92	12.2

sugar content, better palatability, resistance to sweet potato weevil and resistance to drought.

Some clones showed a yield potential of 20-30 tons/ha in four months during the dry season and had better consumer acceptance locally as defined by dryness and sweetness.

An advanced yield trial including several varieties was conducted in both the wet and dry seasons. No fertilizers were applied in either season and the trial was not irrigated during the dry season. For the dry season trial, slips were planted during September. The crop received moisture from rain only twice but with the slips established at the end of the rainy season, the crop grew vigorously throughout the dry season (Table 1).

Some varieties yielded 30 to 40 tons/ha in five months when grown in wet season and 10 to 20 tons/ha in four months during the dry season. The root to top ratio of fresh materials in most varieties was higher in the dry season than in the wet season. It was also observed that there might be a high genotype-season interaction in sweet potatoes, suggesting that evaluation is needed in both seasons in order to screen for wider adaptation.

# YAM IMPROVEMENT

A total of 117 local cultivars of yams were collected in Nigeria, of which 101 cultivars were Dioscorea rotundata, 7 were D. alata, 3 were D. cayenensis, 5 were dumetorum, and one was D. esculenta. Several wild, related species of yam were also collected. Future collection of yams in West Africa, will emphasize D. rotundata, D. dumetorum and D. cayenensis.

Within each of the Dioscorea species a wide range of variation was observed in root shape, root size, texture and aerial vegetative characters. In white yam (D. rotundata), yellow yam (D. cayenensis) and D. dumetorum, all indigenous in West Africa, tremendous variations in root characteristics were observed. Less variation was noted in D. alata, which is not indigenous to West Africa. Therefore, there appears to be good possibility of developing yams with desired agronomic traits in West Africa.

Aerial Tuber Production. Four plants D. rotundata consistently produced aerial tubers on the stems at the blooming stage. These aerial tubers appeared to result from stem

damage caused by laborers during weeding, ridging and re-staking. Those stems that received mechanical damage also showed symptoms similar to die-back and their leaves dried up. The aerial tubers ranged in size from about a few millimeters in diameter at the top of branch to two to three centimeters in diameter near the damaged portion of the stem. The damaged stems formed aerial tubers at almost all nodes and on the axis between the axillary branches and leaves of each node. In an attempt to induce such awial tubers in white yams, four treatments were carried out including severing the stem to one-half its diameter, severing one-third of the stem diameter, ringing twistingand breaking the stem at its base The treatments one-half severing, one-third severing and ringing did not induce aerial tuber formation within three weeks after treatment but the twisting and breaking caused the vam to initiate aerial tuber formation within two weeks after treatment and produce aerial tubers of considerable size about three weeks after treatment. These artificially induced aerial tubers appeared exactly the same as those caused by inadvertent damage.

The mechanical inducement of aerial tubers has several implications for commercial production of white yams including possible substitution of aerial tubers for seed yams, separation of seed yam production from commercial production for food, mechanization of planting, and elimination of dormancy.

Yam Yield and Yield Components. Yield per hill of yam consists of two components, number of tubers per hill (u) and average tuber size (v). Assuming the plants are equally spaced this relationship would also apply to area yields (kg/ha). Hence yield can be expressed as the product of these two components as w = uv. This relationship can be considered geometrically as rectangular with its edges, u and v, as shown in Figure 2.

From the data on a local cultivar, Atoja, the relationship between number of tubers per hill, average tuber size together with yield per hill was investigated. The relationship is written as:

$$\begin{array}{c} w=uv\\ v=c10\,^{ku}\\ \text{Hence }w=cu10^{ku}\\ \text{where }c\text{ and }k\text{ are constants.} \end{array}$$

This relationship is illustrated in Figure 3. It is seen that the average tuber size decreases as the number of tubers per hill increases with the relationship:

$$v = 1.234 \ 10^{-0.1019u}$$

Yield per hill shows somewhat constant change as number of tubers per hill increases. This indicates there is a compensation between the yield components of yam, such as number of tubers per hill and average tuber size. Such compensation will result in substantial experimental error in the component data and more so in the yield data since yield per se is a complex trait. These studies on the optima of yield components of yams will continue.

Yam Crossing. Considerable efforts were made to cross yams. A variety of white yam, Ihobia, was used for the trial because of its profuse flowering of both sexes. A total of 33 female inflorescences of this cultivar were bagged to pratect against outcrossing, and four of these inflorescences were crossed with pollen using a specially made fine brush set in a pin holder. Twenty of the 33 inflorescences, including one pollinated inflorescence, dried up almost immediately after bagging. Of the remaining 13 female inflore-

Figure 2. Diagram of yield of yam tuber per hill (w) in terms of product of number of tubers per hill (u) and average weight per tuber (v).

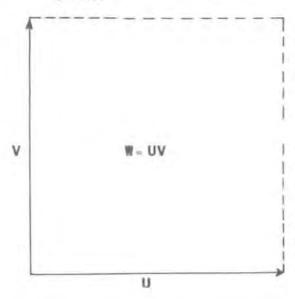
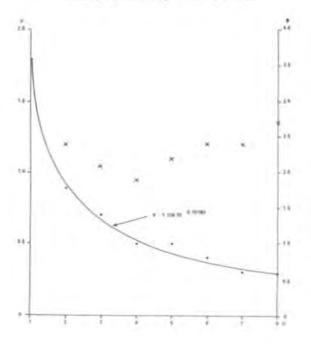


Figure 3. Relation between number of tubors per hill (u), average weight per tuber (v), and yield of tuber per hill (w) in yam-Yield (w) is plotted as I against tubers per hill (u)



scences, the 10 which were bagged without crossing did not set any fruit, but fruits were produced on three following cross pollination. This suggests that controlled crossing in yams is possible.

## MORPHOLOGY OF THE YAM PLANT

Reports on the morphology of the edible yam plant (Dioscored sp.) are scarce and incomplete. Preliminary studies on the inflorescence morphology of edible yam species were conducted since a proper understanding of the inflorescence morphology is essential for the conduct of viable physiological and breeding studies.

Plant materials used in this study were vars. Aimo and Atoja (Dioscorea rotundata). These plants were started from "tuber cutrings" in April 1971. Flowering began in early August Collected flowers were either dissected and studied fresh or killed and fixed in formalde-hydeacetic acid-ethanol. Killed flowers were dehydrated in a graded alcohol series and embedded in paraffin wax. Sections were cut 10µ thick. Serial sections were stained with thionin-orange G or safranin-fast green.

Flowering Habit. Flowering of most D. rotundata plants starts in early August underIbadan conditions and continues until late September. Flowers are reported in the literature as unisexual and the plants as dioecious since the staminate and pistillate flowers are produced on separate plants. We observed hermaphroditic flowers on some plants, an indication that dioeciousness does not always exist. Staminate and pistillate flowers are borne on inflorescences that arise at leaf axils either single or in groups.

The flowering capacity of yam plants is low. Some plants produce stuminate and some pistillate flowers while others do not flower. Among those plants that flower a high percentage produce staminate flowers (Table 2).

Staminate Flowers. These flowers are 2-3 mm in diameter, sessile and borne on spikes subtended by small bracts. The perianth is basally connate and consists of a calyx of three sepals and a corolla of three petals.

Sepals and petals are usually similar in size and color and therefore can be referred to as tepals. In young, closed flowers only the green sepals are seen but with time they separate exposing green petals. Separation of the petals occurs later, leaving a small opening through which the androecium is observed. The androecium contains two whorls of three stamens each. Anthers are basifixed on short slightly connate filaments and composed of two thecae dehiscing in extrose and introse fashion. Pollen grains are small and sticky, which makes pollination by wind impossible. Staminate flowers open in the afternoon during which time pollination takes place. Open flowers were not observed during early parts of the day or late afternoon and night, making pollination by visiting night insects unlikely. Large numbers of thrips some of which had pollen grains on their bodies, were observed in opened flowers. Considering the size of opening between the petals it is speculated that thrips are possible agents for pollination.

Pistillate Flowers. The pistillate inflorescence is an axillary spike. The perianth consists of a calyx of three green sepals and a corolla of three yellow-green perals. The sepals and perals are lobed above the ovary and look like those staminate flowers. Pistillate flowers are about 1 cm long. A singlepistil with trifurcated stigma occupies the center of the flower.

Table 2. Percentage of flowering in a population of 391 plants of D. rotundata var. Ihobia.

Plant type	Number of plants	Percent of Population
Non-flowering	216	55.2
Flowering	175	44.8
Plants producing staminate flowers	139	35.5
Plants producing pistillate flowers	36	9.3
TOTAL	391	

Two to three staminodes are located peripheral to the style. The ovary is inferior and
trilocular, each locule containing two ovules.
Placentation of the ovary is axile. Following
fertilization floral parts dry out while the
ovary continues its development into a winged
capsule, which opens vertically releasing
seeds with a thin leathery coat that helps in
seed dispersal.

Hermaphroditic Flowers. Botanists have always referred to yam as dioecious in that pistillate and staminate flowers are carried on separate plants. The occurence of hermaphroditic flowers on some plants of D. rotundata has not been reported before. It is believed that some of the plants with hermaphroditic flowers originated from tubers obtained from plants sprayed with maleic hydrazide in the previous season.

The structure and shape of the hermaphroditic flowers is similar to the pistillate flowers except for the presence of two whorls of stamens as in staminate flowers.

Stylar Transmitting Tissue. Pistillate and hermaphroditic flowers have styles composed of three tube-like chambers, each connecting from one lobe of the stigmatic surface to the ovary. The transmitting tissue contains a mucilagenous secretion through which the pollen tube grows to the ovary.

The presence of the transmitting tissue in yam flowers has not been reported in the literature although it has been reported to occur in Aloe of Liliaceae and Amaryllis of Amaryllidaceae. The chemical nature of the mucilagenous secretion in the transmitting tissue deserves further studies since it may have a bearing on possible incompatibilities within the genus.

# YAM SEED GERMINATION

Seeds of wild yams, possibly Dioscorea preussi, were collected from the Ibadan area. Attempts to germinate them in water without any other treatment failed. Fungus growth on the seed coat was severe and resulted in seed decay. The same experiment was repeated with seeds disinfected by a one-minute dip in 70% ethanol followed by 30 minutes in 25% Chlorox. The seeds were rinsed repeatedly in water to remove traces of chlorine and subjected to treatment either before or after planting in Petri dishes. The effect of the treatments on seed germination is summarized in Table 3.

Table 3. Effect of treatment on yam seed germination

TREATMENT	GERMINATION AFT	ER 3 WEEKS
Wet seeds for 1	veek at 5 C	
Wet seeds for 3 v	veeks at 5 C	2
Two days in water		
Two days in runn	-	
500 ppm Gibberel	lic Acid (GA <sub>2</sub> )	16
0.01 M KNO <sub>2</sub>	3	++
Distilled water	~	

#### YAM STORAGE

Yams are sold either as fresh tubers or dried product. In either form, heavy losses occur during storage. As fresh tubers, losses occur as a result of rotting, sprouting and weight reduction. Estimates of weight losses during storage vary but 10-15% occur during the first three months. Later the losses may be from 30-50%.

Yam tubers appear to have a rest period and until its end, tubers will not sprout even when provided with conditions favorable for the establishment of new growth. The length of the rest period varies among the species and cultivars. Most of the known cultivars within the rotundata and cayenensis species seldom keep for more than three months without sprouting.

Plants of (D. rotundata) var. Ihobia grown in the field were sprayed bi-weekly with a 5000 ppm solution of maleic hydrazide (MH-30) until run-off from 3 September until harvest 16-17 November. Solutions of 1% isopropyl-N (3-chlorophenyl carbamate), (CIPC), 5000 ppm Ethrel and 5000 ppm MH-30 were used as dips to preventsprouting during storage. All treated tubers were placed in wooden boxes and stored on well ventilated shelves at temperatures ranging from 25-30 C. Tubers were inspected weekly and scored for rotting and sprouting.

Tuber Structure and Sprouting. The yam tuber is composed of the fleshy storage tissue above which are a few small woody complets containing a large number of shoot apices. The complets are collectively referred to in the literature as "head." The shoot apices are well protected from the outside by many layers of leaves and leaf primordia. Some of these leaves are dry and form a scale-like sheath that is impervious to liquids.

During the tuber's rest period shoot apices in the comlet are dormant and subsequent growth is generally resumed by only one bud because of apical dominance. The fleshy storage tissue of the tuber lacks buds and therefore sprouting of the yam tuber can only take place by buds of the cormlets. Sprouting occurs on the fleshy storage tissue only in situations where the cormlets have been removed or if the cormlet buds have been damaged.

Maleic Hydrazide. The repeated sprays of maleic hydrazide on yam plants before harvest did not prevent sprouting of yam tubers during storage. The failure of MH-30 to prevent sprouting was probably due to poor absorption and translocation rather than low concentration for sprout inhibition of onions and white potatoes. The yam leaf is waxy and has a streamlined shape for maximum run-off, which probably reduces the amount of acid absorbed and translocated by the plant.

Tubers dipped momentarily in a 500 ppm solution of MH-30 sprouted. Dipping newly sprouted tubers in the same solution inhibited further sprouting. This inhibitory effect of the MH-30 on the newly sprouted tubers was a result of its absorption by the young shoots. In unsprouted tubers the protected apical buds are impervious to aqueous solutions, an indication that MH-30 is effective as a sprout and growth inhibitor provided absorption and translocation occur.

CIPC. Dipping yam tubers in 0.1% or 1% solutions of CIPC did not prevent yams from sprouting during storage. The failure of CIPC to prevent sprouting is probably due to the inaccessibility of the buds present in the cormlets to the solution. Rotting apparently increased as a result of the CIPC dip. This may have resulted from poor periderm forma-

tion on the cut or bruised surfaces of the tuber during harvesting and transport.

Cormlets Removal. The cormlets situated apically to the fleshy storage tuber are the only structure that contains buds with sprouting potential. The excision of the cormlets to remove all apical buds was found to delay sprouting significantly. The delay in sprouting is probably due to the lack of buds on the fleshy storage tissue of the tuber and the fact that new buds have to be initiated during a long period of time. Cormlet removal is effective in delaying sprouting. The loss of the cormlets has no importance since they are woody and inedible.

Removal of the cormlets releases apical dominance and results in the initiation of adventitious buds on the surface of the tuber. If the tubers are dipped in CIPC or MH-30 as the buds begin to break through the skin, it was found that initiated buds can be inhibited and later sprouting is prevented.

Ethrel. Dipping yam tubers in "Ethrel" solution resulted in injury to comlet buds as a result of the ethylene penetration through the bud scales. The treatment is equivalent in its effect to the removal of the comlets.

Tuber Bisection. Tubers that were divided transversely about the middle were the most promising for keeping purposes. There was a marked difference between the top and bottom sections. The tops showed some sprouting following 50 days of storage because of the presence of the cormlet buds. The bottom sections did not show any signs of sprouting after three months of storage.

Tubers cut in two, formed periderm over the cut surfaces and successfully sealed off the cut surface. There was no rotting as a result of cutting the tubers with or without sterilizing the cut surface. Periderm formation began three hours after cutting and was complete in 72 hours.

### VEGETABLE IMPROVEMENT

Emphasis is on collection of vegetable varieties developed for tropical or semi-tropical regions. Indigenous varieties popular in West Africa are also sought.

Tomatoes. Variety testing for high yield capability under humid tropical condition started during the 1971-72 dry season with 44 varieties grown under irrigation. The plants were staked but not pruned. Ibadan Local, a variety popular among farmers in western Nigeria, appears tolerant to many diseases prevalent at IITA.

The major tomato disease problem was leaf mold (Cladosporium). Except Manapal and Manalucie, which were not affected, and Pusa Early Dwarf, Ailsa Craig and Sutton Early Market, which were slightly affected, all varieties were moderately or seriously affected by leaf mold. Leaf roll was observed in many varieties with Floradel and Fireball most seriously affected.

Pepper. Thirty-five lines of pepper collected within Nigeria were planted for seed multiplication, classification and selection with special attention to disease resistance or tolerance. A yield trial with nine entries is in progress.

Okra. Three varieties of okra were evaluated for performance during the dry season. The varieties were a variety popular in western Nigeria, called Nigerian Local, a veriety from East Africa listed as East African, and Louisiana Green Velvet.

Total yields to date show no significant differences. Figure 4 illustrates the changes in yield with time. Louisiana Green Velver matured earliest but yield trends indicate that this variety reaches a lower peak and falls off earlier than the other varieties.

A disease that caused stunting affected the three varieties. Leaf yellowing was prevented in Louisiana Green Velvet and East African but was not observed in Nigerian Local. A Cercospora leaf spot that affected the older leaves caused progressive defoliation on all three varieties.

Thirteen varieties and lines collected in Nigeria are being multiplied.

Chinese Cabbage. The cultivars Wong Bok, F-1 Tropicana UPCA and Hybrid Chinese Cabbage were grown in small observation plots. All types produce good heads and appear well suited to our climatic conditions.

Tropical Leaf Vegetables. A collection of tropical leaf vegetables and pot herbs started in 1971. Most of the collection is from Nigeria but efforts are being made to obtain seeds from other sources. Species being grown for multiplication and selection are Amaranthus spp., Corchorus olitorius, Celosia spp. Basella ulba, B. rubra, Solanum nigrum, S. macrocarpon, Crassocephalum spp., Talinum triangulare and Ipomea reptans.

Amaranthus. The effect of broadcast seeding vs. drilling, and five fertility levels on the yield of Amaranthus grown under irrigation were tested. Broadcasting was superior to drilling. The plants responded well to fertilizer

Table 4. Fresh and dry weight of Amaranthus as affected by method of planting and fertilizer (15-15-15) rates.

ertilizer (15-15-15) rate kg/ha	Fresh Wt. Row	(kg./ha) Broadcast	Dry Wt. Row	(kg./ha) Broadcast
0	8570	12770	720	1070
100	15520	16830	1280	1530
200	22190	23640	1610	1920
400	21860	26000	1700	2200
800	22960	30050	1930	2510

Table 5. The effects of fertilizer (15-15-15) rate on chemical composition of Amaranthus leaves.

Fertilizer (15-15-15)				Percent	Dry wt.			
rate kg/ha	N	Ca	Mg	Р	Fe	Na	Mn	Si
0	3.14	2.20	0,51	0.74	0.06	0.09	0.02	1.02
100	2.84	1.90	0.42	0.60	0.05	0.08	0.02	1.10
200	3.23	2.20	0.56	0.62	0.04	0.08	0.02	1.28
400	3.14	1.90	0.58	0.61	0.04	0.07	0.02	1.69
800	3.42	2.10	0.64	0.70	0.05	0.08	0.03	1.46

and tertility levels of more than 200 kg/ha of 15-15-15 were significantly superior to 0 and 100 kg/ha (Table 4). Fertility level had no effect on the chemical composition of the leaves (Table 5).

Crassocephalum crepidioides. Although a favorite vegetable in Nigeria, C. crepidioides is seldom cultivated. Volunteer plants in cultivated fields are themain source of this vege-

table. Poor germination appears to be the major factor limiting cultivation.

Preliminary experiments indicate that light is required for germination. Seeds kept under continuous light started germinating after 6 days and by 15 days had 75-% germination (Table 6). Seeds kept in the dark did not germinate at 13 days but when removed from the dark and placed in continuous light 81% germinated within 24 hours. Seeds sown on

Table 6. The effect of light on germination of Crassocephalum crepidioides.

DAYS		MINATION N DARK BROWN
6	13	
9	15	
13	52	0
	Tr	ransferred to Light
14	66	-81
15	75	83

top of sterilized soil and left exposed to sunlight germinated well.

Cucurbits. A collection of Cucurbitaceae has been started with emphasis on those cucurbits important in West Africa. Special attention is being paid to those that produce edible seeds. Five muskmelon cultivars: Harper's Hybrid, Saticoy Hybrid, Hales Best, The Cape and Pure Gold were tested during the dry season. Harper's Hybrid, Saticoy Hybrid and Hales Best produced fruits of good quality and reasonable sizes. Yield data, however, were not meaningful as most of the fruit that reached maturity were protected from the fruit fly (Dacus spp) by paper or plastic bags. The fruit fly appears a serious limitation to commercial production of muskmelon.

Four watermelon varieties were used to test Malathion and Staley's Protein Bait No. 7 plus Malathion as possible control for fruit fly. The varieties are Charleston Gray, White Hope, Black Diamond and Early Midget.

In another trial the varieties Congo Jubilee, Dixie Queen, Early Midget and Charleston Gray were observed for yield, quality and tolerance to fruit fly.

# Other Activities

### LIBRARY AND DOCUMENTATION CENTER

The functions of the Library and Documentation Center include:

- Acquisition organization, maintenance of literature pertinent to the research and training program of the Institute.
- b. Dissemination of technical information to Institute staff and trainees through bibliographical, reference and current awareness services and provision of literature to cooperating research workers and institutions on request.
- c. Development and publication of retrospective and current bibliographies on subjects important to the Institute's research programs.
- Development of other reference tools such as union lists of scientific periodicals and directories of research workers.

The Library and Documentation Center has been in temporary quarters at Bodija since 1969. A permanent location at IITA with a main floor library and basement area for a bindery and additional stacks and storage will be ready in 1972.

As of December 1971, the library collection consisted of about 5,000 volumes of books and periodicals, more than 1,000 reprints and some microfilms. We receive 500 titles of current journals and annual reports, During 1971, the library became a depository for the reports and documents of the World Bank Group.

Because of our inadequate stock, we make extensive use of the resources of other libraries in Nigeria, particularly those in Ibadan. We also use the photocopy services of the British National Lending Library for science and technology, the U.S. National Agricultural Library, and the State Agricultural University, Wageningen, Netherland's.

In November 1971, the FAO and the International Association of Agricultural Librarians and Documentalists sponsored a symposium to launch an Agricultural Libraries Network (AGLINET). IITA participated, and was nominated as the network's regional representative for West Africa. AGLINET will promote rational exploitation of agricultural research information through close cooperation among the world's leading agricultural libraries. Members of the network will provide, on request, publications to other libraries in their regions as well as to other network members.

The 1970 Research Committee of the IITA Board of Trustees urged the library to play a leading role in promoting cooperation among agricultural and other scientific and technical libraries in Nigeria. In January 1971, the library published a list of holdings of scientific and technical periodicals at six agricultural libraries, four university libraries, and the National Library of Nigeria. Copies of the list were sent free to libraries, university faculties of agriculture, basic sciences and technology in Nigeria and to other West African countries.

Requests from other parts of the world were received and filled. This holdings list enables one to find any periodicals available in the country.

# Library Gifts

IITA has received gifts of publications from many institutions and individuals. The Rockefeller Foundation, Ford Foundation, USAID, Institut National pour l'Etude Agronomique du Congo Belge (INEAC), Institut de Recherches Agronomiques Tropicale et des Cultures Vivrieres (IRAT), and the Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) are major donors.

The collection of Dr. Will M. Myers, first chairman of IITA's Board of Trustees, was donated to the library by his family. The collection includes 160 book titles, 171 volumes of 11 periodical titles, and 153 reprints of journal articles. Dr. Myers had, before his death, also given many other publications to the library.

Several IITA staff members have also made donations to the library. Director H.R. Albrecht, Dr. J.C. Moomaw, Dr. S. Sadik, and Dr. R.A. Briggs donated many back numbers of various journals as well as books. The Director also maintains current subscriptions to a number of journals for the library.

# COMMUNICATIONS AND INFORMATION

The Communications and Information Office opened in September with the immediate task of planning for equipment and staff to properly serve the Institute. A priority assignment for the office was development of information materials and a system to handle visitors. A general visitors brochure, a more comprehensive brochure for scientists and technical visitors, and a series of five program area brochures were produced in November. We had more than 1,500 visitors during the last four months of 1971, primarily primary and secondary school students on excursion.

Equipment and supplies were ordered to set up a photographic laboratory, a graphics art section, an audiovisual loan pool, a print shop, and an editorial and information services unit.

# INTERNATIONAL SEMINARS

Six international seminars, part of a continuing series organized jointly by IITA, Ford Foundation and l'Institute de Recherches Agronomiques Tropicales et des Cultures Vivrieres (IRAT), were held during the year. Topics were mechanization of African agriculture, root and tuber crops research in West Africa, plant protection of tropical food crops, vegetable research in West Africa, and storage of tropical food crops.

During August IITA cooperated with the Ford Foundation and FAO to hold the Guinean Zone Conference at Ibadan on the establishment of cooperative agricultural research programs between countries with similar ecological conditions. The intent of the 1971 seminars was to identify the status of agricultural research under way in West Africa, determine gaps in the research and to establish working relationships among agricultural scientists in the region.