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THIRD ANNUAL REPORT

of the

AID - ARS PROJECT

Major Cereals in Africa

1966

THIRD ANNUAL REPORT
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AID - ARS PROJECT

Major Cereals in Africa

G. F. Sprague

This report will include (1) current status of the project, (2) a brief summary of accomplishments, and (3) detailed reports of activities of the individual scientists.

CURRENT STATUS

This AID-ARS project was authorized in 1963 under PASA AID/Res.20. Delays were encountered in obtaining formal approval by the African countries involved and still further delays because of the unavailability of local housing. The first staff assignments were made in September 1964.

Two regional locations were established to serve the differing ecological conditions. One regional center is located in Nigeria and the second in Uganda and Kenya. In each region our staff is associated with existing research organizations. The plan of operation is to extend or supplement existing research programs through provision of additional staff, equipment, and financial support. The program is to be fully cooperative in all aspects.

The program, as planned, can be divided into three major phases: (1) to increase cereal production in Africa through cooperation with and support to research institutions in Nigeria, Uganda and Kenya, (2) to sponsor and stimulate cooperative research among all countries within each region, and (3) to provide in-service training, at the headquarter stations, to individuals sponsored by their respective governments.

The location of the current and proposed staff is as follows:

Location	Name	Discipline	When posted
Institute for Agric.Res. Zaria, Nigeria	O. J. Webster	Sorghum Geneticist	Sept. 1964
	_____ 1/	Pathologist	April 1967
	G. T. York	Entomologist	Febr. 1966
	K.R.Stockinger	Soil Scientist	June 1966
Kaduna, Nigeria	A. Kosage	Admin. Ass't.	July 1965
Federal Res. Station Ibadan, Nigeria	J. Craig	Maize Path.Breeder	Sept. 1965
Maize Research Centre Kitale, Kenya	S.A.Eberhart	Maize Geneticist	July 1964
Serere Expt. Station Serere, Uganda	G.A.Schumaker	Soil Scientist	May 1966
	Kenneth Starks	Entomologist	Jan. 1967
	_____ 1/	Millet Geneticist	March 1967

1/ Candidates for these positions have passed the physical examinations and security clearance is in progress.

The research activities of our staff is fully cooperative. Therefore no attempt will be made to allocate credit for each activity but rather to provide a measure of total progress.

Consideration is being given to the development of closer relations among research and educational institutions. If suitable arrangements can be developed up-grading the technical competence of the local staff would be simplified and the efficiency of in-service training would be greatly increased.

SUMMARY

Regional sorghum nurseries were initiated in 1966 with plantings made in Chad, Cameroon Republic, Dahomey, Ghana, Niger, Nigeria, Senegal, Uganda and Upper Volta. Twenty-four items were included. Tests of this sort should demonstrate both differences in yield potential and areas of differing growth requirements.

Experimental sorghum hybrids have been developed in Nigeria. Plant population and fertilizer response trials with the material are under way.

Sources of resistance to several important diseases have been identified within the World Sorghum Collection. Further trials of such material are underway. The incorporation of such resistance into standard types is being initiated.

Weed control is becoming a problem of increasing importance. Striga and other weeds of economic importance are not controlled with heavier than normal rates of the herbicides commonly used on maize and sorghum.

The main insect pests of sorghum are "shoot fly", "stem borers" and the sorghum midge. Chemical control measures are needed to protect experimental plantings. Chemical control for commercial planting is not feasible at present. Sources of resistance to these pests are being sought.

Sorghum midge or a closely related type has been found to attack millets in the Kano area.

Fertilizer use on cereals in northern Nigeria is low by U. S. standards; 100 pounds of ammonium sulphate and 100 pounds of superphosphate being the common recommendations. Greater applications give little increase in grain yield. It appears that the local varieties have a low yield potential.

Maize has exhibited a greater response to fertilizer than sorghum. A 4 X 2 NP factorial was grown in 1966. Results were not satisfactory due to insect attack and soil variation. Yield response was linear up to 90 pounds of nitrogen. Response to phosphorus was also observed with no significant interaction between nitrogen and phosphorus.

In northern Nigeria marked response is obtained from dung, while N in the form of ammonium sulphate gives a negative response. pH differences between these two treatments may be as great as 1.0 unit. All crop residues are normally removed and this practice may accentuate the pH differences. The extent to which yield differences are influenced by pH and by organic matter remains to be explored.

A study of the factors which govern the accumulation or depletion of organic matter in tropical soils is being initiated.

Additional information is needed on plant-soil-water relations. Information will be accumulated through use of run-off plots and a hydraulic weighing lysimeter. Studies now under way or in the developmental stage should provide relatively precise information on factors limiting crop production in the area.

Maize research in West Africa is being conducted at both Samaru and Ibadan. Maize has not been an important crop in northern Nigeria but preliminary trials suggest it may be well adapted to the higher elevations. Breeding studies have been initiated.

Uniform maize regional trials have been planned for 1967. Countries which have agreed to participate are Cameroon Republic, Dahomey, Liberia, Senegal, Sierra Leone and Upper Volta.

Maize trials were initiated in Liberia in 1966. Fertilizer rates, however, were so inadequate that the trial was discarded and fertilizer response trials established in the late season crop of 1966.

The main diseases of maize in West Africa are rust (*Puccinia polysora*) and leaf blight *Cochliobolus heterostrophus*.

Four races of rust have been identified under greenhouse and field conditions. Resistance to this disease is being sought in all of the local or exotic populations deemed to have potentialities for the area. This is being done by evaluation of S_1 lines and compositing those exhibiting a satisfactory level of resistance.

Thirty maize varieties, including introductions from Kenya, Dahomey, Ghana, Taiwan and Colombia, were evaluated for leaf blight resistance in the first crop of 1966. Eleven of these possessing the most resistance were regrown in the second crop and used for the production of S_1 lines. These are being evaluated for resistance and the more resistant types will be recombined as a part of the population improvement program.

The coordinated maize program in Kenya continues to demonstrate significant progress.

Comprehensive studies are underway comparing the relative efficiencies of breeding procedures suitable for use in the developing countries. These studies are concentrated in the Kitale program as this is potentially the maize surplus area of Kenya.

One hundred thousand acres were planted to hybrid maize in 1966. Seed produced in 1966 will permit planting of 450,000 acres in 1967.

Yields of varietal hybrids, now in commercial use, produce yields 35-40 percent greater than the conventional hybrid first released in 1963 and which has since been replaced. Yield potential of the newer hybrids is relatively greater at the higher elevations.

Breeding procedures involving the development of synthetics and the use of these in hybrid combinations are being utilized in the Embu and Katumani programs. Each of these areas has its own specific maturity requirements. The percentage increases achieved compare favorably with those from the Kitale program, although the yield level is materially lower.

Demonstration plots have been continued on an extensive scale. These have been used to emphasize the relative importance of the individual components of the "combined package" recommendations. Of these, timely planting was most important, accounting for yield differences of approximately 20 hundred weight (35 bushels per acre). The relative importance of the other variables studied was somewhat dependent upon maturity and the geographical area of the tests.

Cooperative trials have been grown at 14 locations in Kenya, Uganda and Tanzania. These trials will be extended to include Ethiopia, Malawi and Zambia in 1967.

Due to delays in the construction of housing and staff recruitment our participation in the sorghum and millet program in Uganda has been limited. The soil scientist arrived in May, an entomologist will be posted in January 1967 and the geneticist in early spring.

Experimental sorghum hybrids have been developed and the possibilities of commercial seed production are being explored. Extensive demonstration activities will be required if this new material is to become widely used.

Recurrent selection schemes have been initiated as a basis for further population improvement in sorghum. Comparable studies are underway with bullrush millet and superior hybrids should be available in the near future.

Fertility and population density studies are underway. Preliminary results indicate no response from nitrogen fertilizer unless phosphorous is also applied. Yield increases of 100 percent have been obtained but even at these maximum levels yields remain relatively low by U. S. standards.

Comprehensive studies of plant-soil-water relations are being initiated to establish factors limiting crop yield potential.

NIGERIA

Work in Nigeria is conducted at two main centers; Institute for Agricultural Research, Zaria and Federal Research Station, Moor Plantation, Ibadan. Dr. O. J. Webster serves as the local coordinator. In this capacity he has liason responsibilities for all consultation activities and in addition is responsible for maize breeding at Zaria and cooperates with the local staff on sorghum and millet breeding studies. Because of these diverse responsibilities his report has been divided into two separate sections. Reports of the other scientists are reproduced here essentially as received.

Staff Consulting Activities
O. J. Webster

Several members of the research staff, stationed at Zaria, have provided counseling services within Nigeria and to Senegal, Gambia and Niger. Only a brief resume of these activities will be presented.

Dr. Webster served from (November 22 to December 16, 1965) as a member of a team to survey the agriculture of Senegal and Gambia and recommend projects to A.I.D. for possible support. The leader of the team was John Beasley, IADS Regional Coordinator for Africa and included Cannon C. Hearne, Extension Specialist for IADS; Dr. Paul Putman, Livestock Specialist, ARS; French Hyre, Specialist in Cooperatives, FCS; and Donald Meeker, Information Specialist, Office of Information. The report and recommendations of the team were filed by Mr. Beasley.

Dr. Futrell accompanied Mr. Andrews to Hadejia on January 28 to observe the experimental work being conducted under irrigation. The main crops were wheat and barley.

Drs. York, Futrell, Webster and Mr. Andrews visited the Wurno irrigation scheme near Sokoto March 2. A part of the report is as follows:

Description of Scheme. A low dam was built across the Reima River valley about 6 years ago to impound water during the wet season. Below the dam a dike was built to encircle about 3000 acres. The purpose of the dike is to prevent flood waters from entering from the outside during the wet season. The main canal supplying the site circles the area on the south side. Each year during the wet season water from the adjacent barren hills either fills the canal with silt or washes out the banks. The repairs to this canal is a seasonal task and, in 1965, were not completed before the end of November. This is late for optimum time of planting of the wheat. Drainage canals of adequate size have not been provided to drain the area and reduce the accumulation of salts.

400 acres are under cultivation. 300 acres are divided into 4 acre plots and allocated to farmers. The remainder is used to test different field crops, vegetables and rotation systems.

Experimental crop testing observed. The barley sample plots for brewing were divided in order to compare the effect of nitrogen on grain yield and malt quality. The plant growth on these plots, as well as other plots and fields, was variable due to variations in soil fertility, drainage, and accumulation of salts. The barley grain was plump and bright.

The NPK trial on wheat using the variety, FA8193 was impressive. Nitrogen was applied as sulphate of ammonia at rates of 200, 400, 600 pounds per acre (22% N), and 100 and 200 pound of super-phosphate. The control plots were a near failure but yields of 30 to 50 bushels will be harvested from the plots receiving nitrogen. There was no visual response from phoshate.

The wheat variety plots included Florence Aurora (8193), Tuscon, Geza 147, Géza 148, Yagui, and Local.

The sorghum trial was planted to 7 early maturing varieties and hybrids. The plantings were made in 3-row plots, rows about 25 feet in length, and replicated twice. Seedlings were made on November 27 and in general stands were good. Plant growth had been delayed by cold nights. If sorghum is grown as a dry-season crop, such early maturing types must be planted not later than the end of October or delayed until the end of February.

Sugar cane plots are being established using local stocks for seed. The crop is being established for direct consumption rather than a sugar crop.

Drs. York, Futrell and Messrs. Heathcote and Andrews visited the Bronu Irrigation Schemes, March 17-20. The North Chad scheme encompasses over 2000 acres, mostly planted to wheat. Numerous miscellaneous crops are being tried in experimental plots. The South Chad scheme included 650 acres of which 28 are for experimental purposes. An additional 500 acres will be added in 1967. Plans are being developed for a larger scheme which will take water from Lake Chad. One problem with these irrigation schemes is their remoteness from population centers and the large investment required for roads.

Dr. York went to Katsina, June 14-16 at the request of Mr. Kazure, Provincial Agricultural Officer following reports of damage to crops by army worms in several areas of the province. He reported:

> "In the area 20 to 25 miles east of Katsina, the main problem was larvae going from "geza" a native shrub, to young millet and sorghum, and also to cow peas. Evidently two species were involved, the light colored larvae going to millet and sorghum and the dark colored ones to cow peas. A number of larvae of both species were brought back to Samaru for rearing and identification.

"Since this problem is apparently associated only with recently developed farm land that is extending into the bush, the following suggestions are made to alleviate the damage:

1. Prior to planting, cut off all geza sprouts in the fields to prevent egg deposition.

2. If sprouts of geza are not destroyed early in the season do not cut them when the agricultural crops are small. Delay the destruction of geza until the larvae have completed their development on this native host plant. The cutting of geza at the time of early weeding forces the larvae to the small and highly vulnerable agricultural crops.

"Although there was evidence of earlier damage to crops by army worms, the situation at the time of this trip was no longer critical. Most of the larvae had matured and entered the soil to pupate. At the Zambu Farm near Daura we did not find any army worms. However, at a small village about 25 miles southeast of Katsina a few larvae were still present. Damage here had been severe and replanting of some fields had been necessary. A small meadow had been practically cleaned of all grass. By digging in the sod and finding pupae and prepupae the farmers were made aware of where their previous heavy population of worms had gone."

Drs. York and Stockinger in mid-July traveled by plane to Yola and were taken by a Land Rover to the Mambillo Plateau to inspect the maize trial. Seed for this trial was supplied from Kenya by Dr. Eberhart. The "lowland" Nigerian maize varieties are not adapted to this area of 4-5000 feet elevation. A favorable report was made of the adaptation of the introduced varieties. Additional seed will be requested for 1967.

The sorghum nurseries located at Kasarawa (Sokoto), Tungun Tudu, Daura, Gumel, and Hadejia were visited by the staff in September and October. A brief preliminary report of the adaptation of the entries included is given in the section on sorghum breeding.

Drs. Stockinger, York, Webster, Curtis, and Mr. Andrews went to Maradi, Niger, October 7, 1966. The morning of October 8 was spent touring the station with J. Nabos, Director and his staff. We were shown the millet trials which included hybrids from India. These were short and looked quite attractive. J. LeConte millet-maize-sorghum specialist for IRAT visiting from Paris discussed his breeding program on millets and gave us an outline of his breeding methods. Dr. Curtis in turn explained the method suggested by Eberhart. The early maturing sorghums in the west African yield trial looked promising. Sorghum midge was causing severe losses to the later maturing varieties.

A breeding program was being started to develop short statured sorghum varieties by crossing local varieties to short varieties from U.S.A. and back-crossing the short plants to the local parent.

A and B lines of Combine Kafir-60, Wheatland, and Redlan were being maintained and used in producing hybrids. We were shown a nursery with F_1 hybrids from crosses between these lines and local varieties.

Following a tour of the station we were taken to a small irrigation station under the direction of Charoy Jean. Studies are being conducted on the use of water on different crops. This pilot scheme is designed to provide information for use on larger irrigation projects. Considerable time was spent looking at the lysimeters in which several crops were growing.

Other technicians on the station included Jouan Bernard, plant pathologist (INRA) and Germenot Roger, Agronomist.

In the afternoon we visited the SIM Farm training Center supervised by John Okers. Mr. Okers organized this center 16 years ago. The school runs for a 3-year period during which time the boys are given an academic education as well as practical experience in crop production. Most boys enter Government Service upon completing the course. We were shown the orchard and horticulture crops which are watered during the dry season by 5 windmills. Two more were to be erected. Mr. Okers served as our interpreter during the day.

Just before dark we visited the (Center Formation Feunes Cultivateurs) CFSA 10 miles south of Maradi. This center was started by Mr. Okers at the request of AID. Mr. Koegel, (AID) is now in charge. The farm has 300 acres under cultivation and we were shown excellent crops of cotton, corn, sorghum, cow peas, peanuts and a 40 acre field of irrigated rice. The boys come to this farm for one season and then return to their village. Midge was causing considerable loss of seed set on the sorghums.

Sorghum, Maize and Millet Breeding

O. J. Webster

Sorghum Regional Trials. A regional nursery was established in 1966 and planted in Senegal, Upper Volta, Niger, Dahomey, Ghana, Nigeria, Cameroon Republic, Chad, and Uganda. All cooperating countries except the Cameroon Republic supplied seed of entries. The nursery included

	Entry	Source
1.	Ck-60 x IS 3691	India
2.	Ck-60 x IS 84	"
3.	Ck-60 x IS 3687	"
4.	MS 172 x IS 84	"
5.	MS 3675 x IS 84	"
6.	MS 3675 x IS 3798	"
7.	MS 3675 x IS 3691	"
8.	MS 3675 x IS 1122	"
9.	CK-60 x IS 3797	"
10.	NK-300	U.S.A.
11.	E 57	"
12.	F 61	"
13.	F 64	"
14.	63-18	Senegal
15.	Sorgo 59	Upper Volta
16.	A 313	Ghana
17.	708	Chad
18.	Short Kaura	Nigeria
19.	154-51 (Gourma)	Niger
20.	175-63 (Jan Jare)	"
21.	178-63 (Bagoba)	"
22.	179-63 (Babadia fara)	"
23.	H x 57 (Ck-60 x SB 65)	Uganda
24.	Serena	"

No reports have been submitted to date from any of the cooperators and no decision has been made regarding the continuation of the nursery. One serious problem arising with growing this type of a nursery was noted at Maradi, Niger and at three locations in Nigeria. Since there is a wide range of blooming dates between varieties, sorghum midge (*Contarinia sorghicola*) increased on the first varieties to head and infested the later varieties resulting in a very poor seed set. The midge not only reduced the yields of the later maturing varieties in the nursery but also other nursery material in adjacent fields. In areas where this insect is a problem, and this includes all of Africa, the only solution is to group early material and spray or dust with an insecticide during the flowering period.

Nigerian trials. The annual precipitation at Zaria-Samaru averages 44 inches, beginning in May and terminating in October. Along the northern boarder of Nigeria the precipitation is 20 to 25 inches falling between mid-June and mid-September. Since sorghum varieties and hybrids from the U.S.A. are too early maturing to fit the Samaru season it might be assumed that they would be better suited to a shorter season. Trials near Sokoto and Daura in 1965 were disappointing while the one at Hadejia was better. The short, early types have also performed reasonably well at Kano.

In 1966, five early maturing hybrids with a local variety of sorghum and a millet variety were planted in replicated plots near Sokoto, Tungun Tudu, Daura, Gurmel and Hadejia. The area was given a blanket of 100 to 150 pounds of super phosphate prior to planting. Two replications were given an application of 100 pounds of sulfate of ammonia at the time of thinning and the other two received 200 pounds.

The trial at Sokoto was on sand underlayed with laterite. Plant development was much better than was noted in the 1965 trial. The soils at Tungun Tudu are more fertile than those nearer Sokoto. Plant development in this trial was excellent and the yield potential higher. The crop at Daura was also good. The soils at Daura are sandy but the fertility of the test plot has been maintained by generous applications of barnyard manure in addition to commercial fertilizers. The rains in the north came late this year and planting was delayed until mid-July. If late planting could be followed each year, early varieties with short stalks may have a place. Normally however, sorghums are planted a month earlier. The variety required for the area along the Nigeria-Niger borders probably should be a compromise between the short, early U.S. types and the late, tall locals. The millet varieties in the tests performed poorly due to late planting.

Breeding and Trials at I.A.R. About 50 acres was required to plant the sorghum breeding nursery and yield trials at the Institute. Dr. David Curtis and Mr. David Andrews have been working diligently to develop sorghum varieties which are more productive than the local varieties and which will respond to increased applications of fertilizer. The breeding work started in the mid-1950s was concentrated upon the evaluation and selections with local populations. This work was very rewarding in as much as composites of selected lines have exceeded the yield of the parent population by as much as 20%. Fertilizer population trials have demonstrated that yields decrease when local varieties are planted at more than about 10,000 plants per acre. Increases in rates of fertilizer only produce taller plants which are more apt to lodge.

The breeding program at present is aimed at the development of short-statured varieties which will fit the season of the different ecological zones of northern Nigeria. These varieties in turn can eventually be used as parents for the production of sorghum hybrids. A promising new line is illustrated in Figure 1, a selection from the cross Combine Kafir-60 A x Short Kaura. It has been necessary to develop adapted A and B lines as well as R lines for the local production of hybrids. A few cytoplasmic

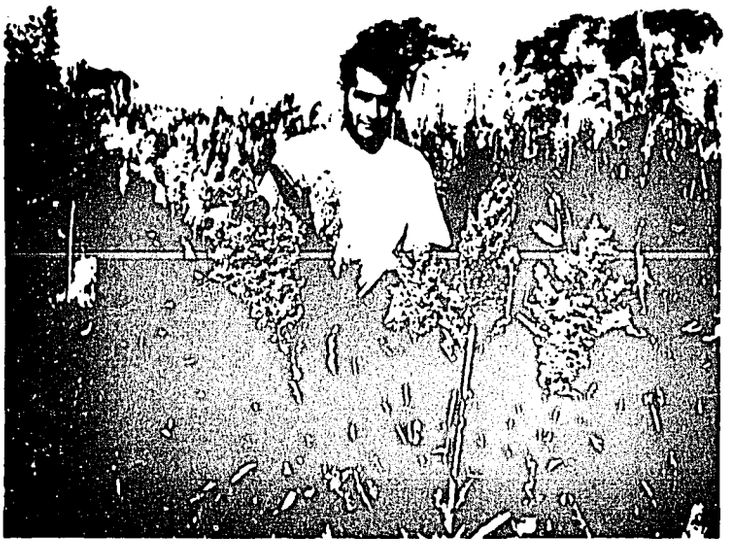

Figure 1. A promising new sorghum variety developed by the Institute for Agriculture Research, Samaru, Nigeria. Selection (5842/1) from the cross, Combine Kafir-60 x Short Kaura.

Figure 2. A promising sorghum hybrid developed by the Institute for Agriculture Research, Samaru, Nigeria. (Dr. D. Curtis, Head of Botany Section).

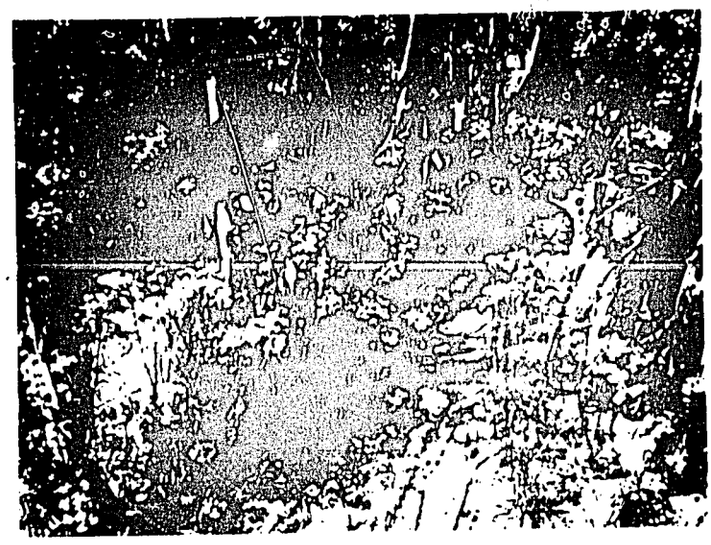

Figure 3. Witchweed (Striga hermonthica) in a sorghum field, northern Nigeria.

Figure 4. Mexico-5 maize, Samaru, Nigeria, showing high ear placement.

Figure 5. Late millet from Upper Volta grown at Samaru, Nigeria, possibly resistant to downy mildew.

sterile (A) lines have been developed and were crossed to newly selected R lines in 1965. An attractive F_1 hybrid is shown in Figure 2. This is a cross between a line derived from crossing Combine Kafir-60 B x Farafara-59 and one from the cross Combine Kafir-60 A x Short Kaura-60.

The sorghums at Samaru were attacked by stem borers late in June. Control measures were started too late to be effective. As a result, the main stem of most plants was killed. This is the most serious damage which borers have caused at Samaru. An infestation of army worms was quickly brought under control by chemical sprays. The final sorghum crop was mostly tillers which developed after the main stem had been killed. In spite of an attempt at chemical control sorghum midge was devastating. The only seed which developed on many lines was from under selfing bags.

Dr. Futrell planted the seed of the 1000 lines of the "World Collection" which was not received in time for planting with the rest of the collection grown in 1965. About 12 of these lines from India seemed to be resistant or tolerant to stem borers. Seed of these lines will be increased under irrigation during the dry season for more extensive tests next year. Only one line in the collection had a good seed set. Hopefully this line may have tolerance to midge.

James Ogborn joined the Institute staff in July as a weeds specialist. He will devote most of his time to studies on the control of witchweed (Striga hermonthica) and chemical weed control in sorghums. There are probably few cultivated fields in northern Nigeria, as well as much of west Africa, which are not infested with seed of witchweed (Fig. 3). Farmers have been forced to live with this pest and crop rotation has given only partial control. Some fields are so badly infested that sorghum and millet are no longer planted. Very little research has been conducted on the use of herbicides as a means of weed control at Samaru. A small test was made in 1965 using Atrazine on maize and sorghum. No reduction in weed growth was noted when as much as 4 pounds per acre were applied.

Maize (Samaru). The maize improvement work at Samaru is the sole responsibility of Dr. Webster. The breeding and testing of sorghums and millet is mainly an Institute activity with the cooperation of the project personnel.

The 1965 report outlined the Samaru program but yield results were not available at that time. The detailed report has been distributed to interested persons and a few copies are available. A summary of the 1965 results follow:

> The 1965 maize project was expanded to include not only the Uniform Federal Trial but additional yield trials of varieties and hybrids, seed of which was provided from the Federal Department of Agriculture, University of Ibadan and the Experiment Station of the Western Region. This increase in the testing program made it possible to evaluate a greater range of materials to the environment of Samaru.

Mexico-5, the most productive variety tested in the North, gave a yield of 5300 pounds in the Federal Trial and was only exceeded in yield by H503. The most productive entries tested were variety-hybrids from the Western Region. Four of the entries in this test exceeded 6000 pounds per acre. The highest yield of all entries tested was 6700 pounds recorded for a variety-hybrid, V-67 (Br-155xH507).

Root-lodging caused by winds during the tropical storms occurring in August and September is a major problem in maize production in west Africa. Many of the maize varieties produce stalks 12 to 14 feet in height with ear placement from 6 to 8 feet above the soil (Fig. 4). Large ears produced when the crop is grown on fertile soil increases the vulnerability of the plant to wind. Several new introductions from Colombia, South America have ears no more than 4 to 5 feet from the ground and in observation plantings were the most resistant to root lodging of all entries tested. The 4 most promising lines out of 26 tested were (USA 342 x Diacol V206)- 4 x Diacol V 254, (Cub. 325 x USA 342) - 4 x Diacol V 254, Composite III Amarillo Centro America (Cuba 40-Hawaii 5-San Luis Potosi 104) - 2, and Nar. 330 a-7#a.

The maize project was planted on a field considered to be relatively fertile. A blanket application of 200 pounds of superphosphate was applied preplant. A yield of 2700 pounds per acre was harvested from plots receiving no nitrogen fertilization and there was considerable variation in the yields between replication and even between rows in a single plot. Plots with 30 pounds of nitrogen applied at thinning averaged 3200 pounds while those receiving an extra 30 pounds a month later averaged 4000 pounds. An additional 30 pounds of nitrogen, making a total of 90, applied a week after tasseling gave only a small increase over the 2 applications. Uniform applications of fertilizer at moderately high rates are necessary to decrease variability in plant development and to more accurately measure the yield potential of the most productive varieties or hybrids.

A plant population trial revealed that similar yields can be expected if single plants are spaced at 1 foot intervals in the row, 2 plants in hills at 2 foot intervals or 3 plants in hills spaced at 3 foot intervals.

Yields of component parts of plants were taken for 2 varieties harvested at four 2-week intervals beginning at time of tassel. The data suggest that for silage production the optimum time of harvest would have been about 35 days following tasseling. 22 percent of the nitrogen in the plants harvested 42 days after tassel was in the grain. One hundred twenty-five pounds of nitrogen on an acre basis were calculated to be in the crop at final harvest. Nitrogen had been applied at a rate of 90 pounds per acre.

The yield trials conducted in 1966 were similar to those conducted in 1965. The complete report will be available at a later date. The nursery was planted in early June. Seedling emergence was good on the field planted May 26 while emergence was poorer on two other fields planted the next day. This variation in stands illustrates a problem in the management of the soils at Samaru. A light shower after planting sealed the soil surface and the coleoptiles of the germinating seed were not able to penetrate the crust. Good emergence requires either that no rain should fall after planting in moist soil or frequent showers to keep the surface wet.

Yields in 1966 ranged between 3 to 4,000 pounds or about 1000 pounds less than recorded for 1965. This reduction may be accounted for by borer damage and poorer soil fertility. Although there were numerous borers in the maize the damage was slight compared to that in the sorghum fields. The highest yield recorded in the Federal Trial was 4300 pounds per acre for Mexico-5.

The breeding nursery included over 1000 S_2 or S_3 lines derived from numerous sources. The lines harvested will be top crossed to a local variety during the dry season and yield tested in 1967 to determine their potential combining ability.

The present breeding objectives call for plants which will tassel in 70 to 80 days, with an ear height no greater than 5 feet, tight husks, pendant ears, and plants with a good root development to prevent root lodging. The ears on such a plant would be mature towards the end of the rains, and the grain would dry on the plant with a minimum of damage from weather or insects. Since there is no local food preference in the North flint-dent should be better than floury type. It is possible that a good yellow-dent will be acceptable.

Since no introduced varieties have all of the characteristics desired, four composites have been made up which were grown in isolation. From such composites and others to be made up we expect to approach the above objectives. The basic source of varieties in the composites includes introductions from Colombia and a selection from an advanced generation composite of USA cornbelt yellow dent hybrids. Mexico-5 is included in one composite. One composite was made up of a group of introductions from Kenya. Since these "high altitude" varieties are not well adapted to Samaru there is less potential in this composite than the others. Next season opaque-2 and floury-2 genes conditioning high lysine will be included in the isolation blocks of composites and detasseled. Lines of "tall" brachytics will be managed in the same way.

We are requested to conduct a maize trial on the Mambillo Plateau, elevation 4 to 5000 feet. Dr. Eberhart provided seed of several varieties from Kitale, Kenya for the test. Drs. York and Stockinger visited the Plateau in July and reported that the crop looked promising. No yield results or scores for adaptation have been received.

Millet (Pennisetum). In northern Nigeria, millet is second only to sorghum as a food crop and in the dryer area it supercedes sorghum in importance. It is difficult to evaluate the potential of millet vs. sorghum. Millet is generally planted with the first rain which wets the top 3 or 4 inches of soil. The first planting often fails because of a lack of subsequent rains. It some season this crop may be replanted 3 or 4 times before the crop is established. The seed of millet is small and cost of replanting with this crop is less than if sorghum seed was used. In areas when both crops are grown there seems to be a preference for millet as food.

Millet might be classed as a neglected crop from the standpoint of the plant breeders in Africa. Populations collected from various parts of northern Nigeria have been compared in numerous yield trials and one from Bornu Province appears to be superior to the others. This population is a heterogeneous mixture and a 'crash' program is under way to select out high yielding genotypes. This is being done using a mass selecting program suggested by Dr. Eberhart and also by inbreeding and bulking seed of lines with the highest combining ability.

The World Pennisetum Collection was grown at Kano in 1965. Stands of the exotic lines were poor and the value of the nursery was further reduced by a heavy infestation of stem borers. A nursery of 2300 items was regrown in 1966. Dr. Futrell was able to take notes on reaction to downy mildew.

Downy mildew is a major disease on millets in west Africa and a source of resistance is needed for breeding purposes. In 1965 several lines were supplied us from Calude Dumont, sorghum-millet breeder in Upper Volta, which under epidemic conditions were free of the disease. These are day-length sensitive lines which, at Kano, are late in maturing and very tall (Fig. 5). By growing these lines in pots during the dry season it has been possible to make crosses with selected plants in Bornu local. The F_1 seed was planted in the field in 1966 and F_2 seed will be planted during the dry season or in 1967. The lines from Upper Volta are very susceptible to smut and ergot.

In 1964 seed of several lines of millet was supplied by Dr. Glenn Burton from Tifton, Georgia. The seed was planted at Kano by Dave Guymer. The seedlings emerged and died and it was suggested that they were supersensitive to the downy mildew organism. Additional seed including the A and B lines of Tift-23 was supplied by Dr. Burton in 1966 and planted at Samaru and Kano. The results were the same as in 1964. Dr. Futrell studied the diseased plants and sent the following report to Dr. Burton October 12, 1966. "Only a few plants emerged, and when they reached the 4 to 6 leaf stage they showed symptoms like those observed on sorghum caused by downy mildew. Upon examination this was found to be the sorghum downy mildew, Sclerospora sorghi. I cannot find any record of S. sorghi being reported on on millet. The downy mildew that has been reported on millet is Sclerospora graminicola. The difference in the two species is that the conidia of

S. sorghi germinate by germ tube and those of S. graminicola germinate by zoospores. The downy mildew on Tift-23 at Samaru and Kano produced conidia that germinated by germ tube. The infection was so severe that little or no seed was set on the A line when it was pollinated."

To this letter Dr. Burton made the following reply. "Am I to conclude from your letter that Tift-23 pearl millet is the only millet genotype susceptible to Sclerospora sorghi? It would be interesting to know if all Nigerian millets are resistant to this form.

'You will recall that all of the hybrids having Tift-23A as one parent when planted in India showed a very high resistance to Sclerospora graminicola. Likewise they apparently have had no problem with getting stands with Tift-23A in India where Sclerospora graminicola is prevalent. I am wondering if they have Sclerospora sorghi in India or if perhaps they might have different races than you have in Africa.

Certainly, the results reported in your letter of October 12 are interesting and indicate the need for more study."

When the next plant pathologist arrives he will need to give special attention to the downy mildew species of millet as well as to smut and ergot. In addition, he will have the 'complex' of the sorghum smuts to study.

Crosses have been made between the yellow endosperm millet and other local types in an effort to improve the grain quality of the crop. The discovery of this source of carotene in millet was reported by Curtis, Burton, and Webster, 'Carotenoids in Pearl Millet'. Crop Science 6:300-301, 1966.

ENTOMOLOGY

G. T. York

Office and laboratory space is provided by the Entomology Section. The present permanent quarters are quite convenient and satisfactory. Working conditions and cooperation with the entire entomological staff are exceptionally good.

Considerable work has already been done on the major pests of sorghum and millet in Northern Nigeria. Most of this was by K. M. Harris who presented his results in a number of publications. These as well as other reports on cereals of Africa were reviewed to obtain a general background of work already completed.

Insects of sorghum

The three major pests of sorghum are:

1. the shoot fly *Atherigona varia* ssp. *soccata* Roud.
2. the stem borers (several species) and
3. the sorghum midge *Contarinia sorghicola* (Coquillett).

In addition, army worms, grasshoppers and aphids can cause varying degrees of damage.

It should be pointed out that two separate and quite distinct types of control are involved. One type of control is required for the experimental plantings of various research groups at the Institute for Agricultural Research, as well as research groups in other countries. Any appreciable damage by insects could disrupt these experiments so that an entire year's work could be lost. Plant breeders could, in the case of severe damage, lose the results of several years work. Consequently, chemical controls must be developed for adequate suppression of pests on these experimental plantings.

On the other hand the yield produced by farmers is so low that they cannot afford much expense for control work. If a crop is severely damaged it will be replanted if time permits or other crops will be planted as substitutes. Control must be largely through farm practices such as time of planting, destruction of crop residues to prevent a carry-over of the pests, and the use of varieties adapted to local conditions. This does not mean that with improved varieties and increased production, chemical control will not be necessary for the future. It undoubtedly will be but how fast these changes will occur is an open question.

The Shoot Fly Atherogona varia ssp. soccata Roud.

This insect, also called the Sorghum Shoot Fly and Sorghum Maggot was previously classified as Atherigona indica infuscata v. Emd. A recent review of the group now changes this to the above mentioned nomenclature. It is in the family Muscidae of the Order Diptera.

Damage is caused by the maggot feeding on the young tip or terminal growth. Since plants are very small when attacked, usually two to six inches in height, the growing tip is usually killed. Tillers will develop on some plants, but even with this secondary growth the plant has suffered a severe set-back.

At Samaru, on experimental plantings, the insect was noted soon after young plants appeared above ground. Spraying with carbaryl was started shortly thereafter and the infestation kept at a low level. However, to do this the spraying had to be done every two to three days. This was done only on those fields where a uniform stand was needed for the special experiment. In most cases seeding was sufficiently heavy to allow for some loss by this pest. Obviously an extensive spray program is out of the question for the farmer and he simply follows the procedure of planting a bit heavy with the expectation that some plants will be killed.

Some plant resistance to shoot fly has been noted by workers in India. This probable resistance will be studied more carefully during the coming season. A graduate student in Botany expects to use this as a thesis problem and I will work closely with him.

Systemic chemicals are reported as being effective in controlling shoot fly. Some work will be done with these as a substitute for the time consuming and expensive spray schedule now used on experimental plots.

Stem Borers.

The infestation of stem borers, as noted by Dr. Webster, was very severe this year. Several people here at the Institute have stated it was the most severe they have ever known. Unfortunately, the severity of the infestation was not noted until many of the larvae were already established in the leaf. Those which had crawled into the tightly bound developing leaves, or bored into the center of the growing tip were thus well protected from the action of insecticidal dust.

Five percent DDT dust was applied by placing it in cheesecloth bags and shaking it over the plants. A fairly large portion of the experimental plantings were treated in this manner. Several applications were made but control was not effective. As indicated above, many of the larvae had penetrated to parts of the plant where the insecticide could not reach them.

Due to the heavy damage suffered this year from stem borers and the possibility of a similar situation developing next year, it has been decided to buy a tractor-mounted sprayer. Since the local allotment was not quite sufficient for the spray equipment which was considered essential for this type of work, the Cereals Project has agreed to furnish the additional funds. A high clearance tractor is already present at the Institute, so this should serve for first and second brood control work. With careful observations on the developmemt of the borers by light trap collections and field observations it is believed that proper timing of the sprays will adequately control the stem borer.

A few small scale tests were made with insecticides other than DDT. Five percent dieldrin granules applied at 20 and 40 lbs. per acre caused moderate burning of tender leaves in the funnel. Although this looked rather bad a few days after application, plants recovered and continued a normal growth. Control of borers was satisfactory. However, due to the high toxicity of this insecticide, and the lack of concern by local workers to appreciate this hazard, it is felt that dieldrin can only be used for limited experimental work handled under very close supervision.

Carbaryl, an insecticide of low mammalian toxicity, gave satisfactory control when applied as a spray.

Sumithion, a relatively new insecticide of low mammalian toxicity, gave good control at a slightly higher than recommended dosage.

Additional work with insecticides with special reference to amounts and time of application are scheduled for next season.

It should be pointed out that the stem borer responsible for the damage this year was Busseola fusca (Fuller). Although the eggs are laid in clusters, usually under the leaf sheath of the stem, the young larvae migrate to the leaf whorls where they feed for some time. During this migration and the early feeding stage they are quite susceptible to insecticides. On the other hand several species of Sesamia are also present in this area. The eggs of Sesamia are deposited in the same site as Busseola but in this case the young larvae bore directly into the stem. Accordingly, it is virtually impossible to concentrate enough insecticide around the egg mass to cause any mortality. Our optimism for control of borers for the coming season is based on the supposition that Sesamia will not build up to out-break proportions, and that Busseola will again be the major species with which we have to contend.

With the serious situation of stem borers that developed in the Samaru area, there was considerable concern regarding the general situation in Northern Nigeria. A questionnaire was prepared in cooperation with the Research Liaison Section of the Extension Service and sent out to all of the Provinces. Although the replies are not all in and results have not been tabulated, a cursory examination of material submitted to date shows that the heavy outbreak experienced here was not general over the country.

A number of stations reported average infestations, some less than average and some more than average. In areas of heavy infestation other food crops were interplanted to compensate for the loss. Local varieties of sorghum can, in general, tolerate a moderate infestation of stem borers without seriously affecting the yield. However, farmers are aware of the stem borer and often inquire about the possibility of control practices.

The Sorghum Midge *Contarinia sorghicola* (Coquillett).

This tiny insect is found in sorghum growing areas throughout the world. Although undoubtedly present in this area for centuries, it was not until 1953 that it was recorded at Ibadan. Once its presence was noted it was found throughout Nigeria in the same year.

Development is quite rapid. It goes through a complete life cycle in two to three weeks. Thus when there is a continuation of development of sorghum varieties throughout the growing season, as is the case with experimental varieties, populations can build up rapidly and cause extensive damage.

Control is costly and time-consuming. To be effective, sprays or dusts must be applied every two or three days. It is only on valuable experimental plantings that such a control procedure can be utilized. Farmers must rely on varieties that all mature at about the same time to prevent the build-up of high populations.

At Samaru the sorghum midge was first noted in late September. In early October three fields were selected for making counts of midges to determine population trends. Two of these fields were being treated for midge control. The early counts showed an average of nearly three midges per sorghum head on the untreated field and less than one on the treated fields. By mid-October the count on the untreated field had increased to between four and five per head, and treated fields between one and two per head. The untreated field was plowed soon after mid-October for other experimental work. On October 22 one of the treated fields reached a maximum population of 16 midges per head and the other was only two per head. Both fields levelled off at five to six midges per head, and by late November the count had dropped to one midge or less per head. At this late period most of the larvae are going into diapause, or resting stage, to carry over in the dormant state until next season. Control was far from satisfactory but was made extremely difficult due to the great range in plant heights, being from three to four feet high in the low types to 15 to 18 feet in the tall varieties.

No parasites were observed in the Samaru area. However, from two heads sent in from Sokoto there was a heavy emergence of a hymenopterous parasite as yet unidentified. Several parasites have been recorded from the sorghum midge but have not been considered effective in controlling the population. Careful studies of these parasites, with proper handling of the populations, might offer some degree of control.

As mentioned in Dr. Webster's report, the sorghum midge is a serious problem especially on nurseries where there is a wide range of blooming dates. He has also mentioned the finding of one line that hopefully may have tolerance to the midge. If this does prove to be true it will be a major step in breeding for resistance and may reveal factors responsible for this resistance.

Insects of Millet

The principle insect pest of millet is the stem borer Coniesta ignefusalis. This borer is difficult to control as the young larvae on hatching bore directly into the stem. In general plants can tolerate a moderate infestation of borers without seriously reducing the yield.

The work this season has been confined to general observations. At Samaru a fairly heavy infestation developed on early millet. Fifteen to 20 larvae per stalk was not uncommon. Emergence of moths from this first generation reached a peak on September 5 to 7 as recorded from light trap collections. Over 200 moths per night were taken. Since the light trap was at least one fourth mile from the nearest millet it is quite clear that these moths can travel some distance. Although Coniesta is primarily a pest of millet it has been recorded as infesting sorghum late in the season. Fortunately this transfer to sorghum was not noted this year.

A midge, or more correctly pupal cases of a midge, on millet was noted by Dr. Curtis this season. Specimens have been reared from millet heads and they are quite distinct from the sorghum midge. Material has been submitted for identification of the species, but a determination has not yet been received. A cursory examination of the literature on millet insects has failed to give any information on such a pest. It therefore seems likely that this is a new problem of millet, or perhaps more correctly stated, the finding of a previously undetected pest of millet. Since it was not detected until late in the season it will be studied more carefully next year.

Insects of Maize

Maize is subject to the same stem borer problem as sorghum, namely Busseola and Sesamia. Thus far Coniesta has not been found in maize. Busseola, in addition to boring in the stem, will also injure the ear. Although very little of this was noted in field corn, possibly due to the time of ear development in relation to second brood development, it was a real pest to garden sweet corn.

At least one species of Heliothis is found in this part of the country. Although it is presently considered mainly a pest of cotton, it may become important to maize as production increases. Some injury to kernels of mature ears has been noted. This was from infestations in the field. Identifications of these pests have not yet been made. Plans are being made for a more extensive study of these pests for next year.

Miscellaneous Insects

Termites. The work on termites is a cooperative undertaking with Dr. Stockinger, Soil Scientist. Details of the proposed work will be submitted by Dr. Stockinger.

From the entomological standpoint we are interested to know what effect termites have on stem borers and, when termites are controlled, the effect of direct sunlight and temperature on the borers when the stalks are laid on the soil surface. Under present farm practices the stalks are placed in large piles in an upright position. They are used in various ways, depending on the locality, for such purposes as fence and house building, stock feed, and fuel. Entomologists have in general recommended the burning of excess stalks prior to the emergence of moths at the beginning of the rainy season to reduce the level of infestation for the ensuing crop. Crop residues returned to the soil are accordingly virtually nil. If crop residues are to be used it is essential that we have information on the fate of borers, parasites and disease as they might effect the following season's population.

Armyworms

Several species of armyworms are present in Nigeria but the most common one is *Laphygma exigua*. This species was reported from a number of areas in Northern Nigeria this season. It was believed to be more severe than usual.

Control when warranted can be accomplished with several readily available insecticides. The biggest problem is immediate action when destructive populations are first noted. By the time reports are sent in and recommendations for control are returned the damage has been done. It has been suggested that Agricultural officers in the field be informed of armyworm problems and recommended procedures for control, and that they be instructed to initiate control immediately when destructive populations are noted. This suggestion has not been put into effect but may be worked out before the next season.

On the trip to the Bornu Irrigation Schemes of March 17-20, armyworm damage was noted on the wheat being grown there. Fortunately most of the wheat was nearly mature and the stripping of leaves had caused little or no reduction in yield. Recommendations were made for protecting a small amount of late planted grain. The species was similar to the armyworm *Pseudaletia unipuncta*. Due to extreme weather conditions only three of the larvae collected and brought back pupated. Two of these were parasitized and the third failed to emerge as an adult so positive identification was not possible.

Grasshoppers

No injury from grasshoppers was noted this season.

Aphids

At least two species of aphids are common and sometimes very abundant on sorghum and maize. They are controlled in due time by predators, mainly syrphid fly larvae and coccinellids. No parasites have been observed but are undoubtedly present. Chemical control has not been considered necessary due to theeffective biological control. However, aphids are a nuisance to the plant breeders when selfing bags are placed over individual heads of sorghum. Large amounts of honeydew are produced which makes the heads quite messy and in some cases necessitates washing prior to threshing. No effective control has been developed.

SOILS

Karl R. Stockinger

In looking over the soils problems of Northern Nigeria and similar Savannah areas of West Africa, the most obvious needs are nitrogen and phosphorus. Nearly all soils respond to the application of these two elements, but the recommended rates are very low by American standards. A hundred pounds of ammonium sulphate and a hundred pounds of superphosphate are common recommendations. Larger applications give little increase in grain yield, although stover yield of sorghum is increased by more nitrogen. This is due to the local varieties having a low yield potential and not responding to fertilizers. Also, the long growing season of the local sorghum variety allows it to explore the entire soil and use native soil fertility quite completely.

A 4 X 2 NP factorial experiment on a local commercial farm with maize was tried this year. Information from last year's trials indicated that maize was more responsive to fertilizers. The site used was quite heterogeneous and had one low spot where water stood after rains. Yields were very low, ranging from less than a bushel to 20 bushels to the acre. Linear responses up to 90 lbs. of nitrogen in the form of ammonium nitrate were obtained. Good phosphorus responses were also obtained and there was no significant interation between the two fertilizers. Low yields were due to corn borers, poor rooting and lodging due to planting on high ridges which would not be maintained properly, and poor soil. It showed other factors limit yield but without fertilizer yields were nil. Further work is needed when varieties more responsive to fertilizers and with a higher yield potential are developed.

At Kano and Samaru long term DNPK (D is for dung) show a pronounced yield response to dung while N in the form of ammonium sulfate gives a negative response. The effects are much more pronounced on grain yield than on stover yield, and also on sorghum and cotton than on ground-nuts. The dung treatment raises the pH while the ammonium sulfate lowers the pH, producing a difference of 0.8 pH unit at Kano and 1.0 pH unit at Samaru between the extreme treatments. The organic carbon levels were nearly doubled by the addition of two tons dung every year for 16 years at Samaru. Differences between treatments are accentuated by the removal of all crop residues from all treatments. At Samaru the experimental site is subject to a high water table which rises to the surface in wet years. Termites are not present on the Samaru site but may be at Kano. The evidence indicates that supplying N by means of dung produces better yields than by means of ammonium sulfate, probably because of the effect on pH and related factors. However, other effects of organic matter might show up if the pH effects were counteracted by means of lime. These experiments show that the organic matter level of tropical soils can be affected by soil management. The agronomists of the Institute are going to apply lime to the plots at Samaru to study the pH effect and its influence on yield. They are also going to drain the plot area to make the results applicable to well drained soils. These experiments point out the need for more research on the effects of organic matter on soil properties which effect yield.

The factors which govern the accumulation or depletion of organic matter in tropical soils needs to be investigated. Would the return of crop residues, especially at high fertility level, result in increased organic matter levels in the soil? Do termites destroy crop residue and prevent organic matter levels from building up? Very little organic matter is returned to the soil in the savannahs. On range lands the natural vegetation is burned every year to provide earlier grazing for cattle. On crop land the residues are removed or burned. As a result, soil organic matter levels are naturally low. The above experiments showed that relatively small amounts of dung resulted in large differences in sixteen years. An experiment to study the effect of termites on crop residues has been started with Dr. York. Termites will be controlled on some plots with insecticide and the difference in decomposition rate of crop residues will be observed. Also, the survival of stem-boring larvae in crop residues left in the field will be observed. Existing experiments will be evaluated as to the physical effects of the additional soil organic matter as well as the chemical effects.

More information is needed on plant-soil-water relations. Runoff plots are in operation at Samaru and good information is being collected on the effects of various cultural practices on runoff. A hydraulic weighing lysimeter is being constructed using butyl rubber irrigation tubing as the support for the lysimeter. This is being constructed similarly to the ones at Brawley, California. This should enable us to get good estimates of evapo-transpiration. The watershed on which the Institute farm is located drains into a lake from which outflow is being measured. This gives a good estimate of runoff, underground seepage and evapo-transpiration for the basin for the season. A neutron soil moisture probe and scalar will be ordered as soon as local clearance is obtained for the source. This will be used to measure soil moisture changes during the season in the watershed to help in this study as well as other soil moisture studies.

Drainage is a problem in some areas, especially at the end of the rainy season. Its effect on crop growth is different from temperate zone effects because the highest water tables occur at the peak of the rainy season when most crops are just starting into the reproductive phases of their life cycl In the temperate zones the water table is highest usually in the spring and results in cold soils and delayed planting. A graduate student, Mr. Palmer, is going to work on the problem of the effect of high water table on a developed root system and how the root system regenerates in the mature plants when the water table recedes at the end of the rains. I am helping him organize his program and set up his research. I am also helping in getting the DNPK experiment drained, using underground tile lines. Both experiments will be watched to see what problems will be encountered in drainage as well as the effect on crops. This will be the first subsurface drainage in Northern Nigeria.

The effect of cool soil temperatures at time of germination on the subsequent development of the plant may be important in sorghum and maize in Nigeria. In the Mambillas highlands (elevation 5,000 feet) it has been observed that maize planted just as the rains start does much better than delaying planting several weeks. Since the season is long enough for the

maize to mature in both cases, it appears that the effect is due to the rapid cooling of the soil with the start of the rainy season. Webster has also noted that sorghum is difficult to germinate and grow with irrigation at Samaru during the dry season because of the cold soils and cool weather. Perrier observed at Illinois that corn germinated at low temperatures grew much slower than corn germinated at high temperatures, even though both treatments were subsequently maintained at the same temperature. A small exploratory experiment will be tried to test this and see if low temperatures at germination cause low growth. Soil temperatures will also be measured to see how the temperatures vary during the year, especially when the rains start and stop.

In summary, yields with present varieties are extremely low and even with optimum cultural practices maximum yields of sorghum are only about 2,000 pounds per acre. Varieties with higher yield ceilings are urgently needed to reap the benefits of fertilizers and other management inputs. The present varieties can support only a small increase in costs because of their small potential. However, research on cultural practice must continue so that when new varieties are developed their maximum potential can be quickly realized. Indicators other than grain yield (for example, total dry matter production) may be used to assess plant response. Areas of research which need further work are soil organic matter, soil moisture, and soil temperature and their interaction with plant growth. These areas will be explored more thoroughly in the coming year.

PLANT PATHOLOGY

(Prepared for M. C. Futrell)

Dr. Futrell devoted a considerable portion of his time during his 2-year tour studying the diseases prevalent in the World Sorghum Collection at Samaru. He was able to isolate sources of resistance to downy mildew (Sclerospora sorghi, Weston and Uppal) and lines tolerant to sooty stripe (Ramulispora sorghi, Olive, Lefebvre and Sherwin). Resistant lines to downy mildew were intercrossed to study the reaction of their progeny to this disease.

Dr. Futrell made a significant contribution to the etiology of ergot (Sphacelia sorghi, McRae) and emphasized the problem of seed production of sorghum in the tropics due to Fusarium scab.

Summaries of the papers published by or submitted to the Plant Disease Reporter by Futrell and Webster follow:

Ergot infection and sterility in grain sorghum

Plant Disease Reporter 49: 680-683, 1965.

"The sterility often associated with the ergot disease is apparently not caused by the pathogen. Unfertilized cytoplasmic male sterile florets were susceptible to ergot infection. The disease did not develop on the B line of Combine Kafir-60, but the cytoplasmic male sterile A line was the most susceptible line in the test. Two lines from India with "twin" seeds became infected. Experimental lines with female sterility caused by chromosomal aberrations showed a low degree of susceptibility to the fungus. Cytoplasmic male sterile plants of the A line of Combine Kafir-60 had 50 percent of the florets infected with ergot when they were not pollinated. Pollination of the florets at the time they became receptive reduced ergot infection to 8 percent. The data indicated that the ergot fungus infected flowers only when they were not pollinated. Ergot could become a serious problem in hybrid seed production with male-sterile lines in Nigeria. These experiments indicate that this disease can be controlled or markedly reduced in a cytoplasmic male sterile line by having an abundance of pollen available from the pollen parent when the sterile florets become receptive."

Sources of resistance to the downy mildew disease of sorghum. Plant Disease Reporter (in Press) 1966.

"Part of the world collection and the Nigerian collection of grain sorghums was screened for resistance to downy mildew in 1964 and 1965 in a natural epiphytotic at Samaru, Nigeria. Twenty-two lines in the Nigerian collection were free of mildew in both years. Fourteen percent of the

entries in the world collection were resistant in 1965. The highest percentage (47%) of resistant entries was found in the Caffrorum race. Most of the resistant entries were collected in southern Africa, which is probably the geographic point of origin for sorghums resistant to downy mildew. Most of the resistant lines in the Nigerian collection were collected in the Adamawa Province, which is located in the eastern part of Northern Nigeria. Sorghums collected in the southern and western part of Northern Nigeria were susceptible. Twenty-eight resistant lines, mostly from races other than Caffrorum were crossed with the sterile A line of Combine-Kafir 60 to combine genes for resistance to downy mildew from two sources into progeny plants variable in plant height and maturity. Selections from these crosses will be made to produce a wide range of adaptation."

Races of sorghums resistant to sooty stripe disease
Plant Disease Reporter. (in Press) 1966.

"We evaluated 2,693 lines or varieties of sorghum at Samaru, Nigeria for resistance to the sooty stripe disease in a natural epiphytotic. Only 5 percent of the entries in the test were resistant to the disease. Forty-seven percent of the lines collected in Volta, 10 percent of the lines collected in Nigeria and 6 percent of the lines collected in Mali were resistant. We found 17 percent of the resistant entries in the Conspicuum race and 10 percent in the Caffrorum race. Data show that west Africa is the geographic point of origin of sorghum resistant to the sooty stripe disease. Data also show that the greatest number of lines or varieties resistant to this disease were in the Conspicuum race which is endemic to west Africa."

Host range and epidemiology of the sorghum ergot organism
Plant Disease Reporter (in Press) 1966

"The source of primary inoculum of ergot, Sphacelia sorghi McRea on sorghum, Sorghum vulgare Pers. is probably guinea grass, Panicum maximum Jacq. growing wild in Nigeria. Ergot conidia collected from guinea grass and used to inoculate sorghum and millet, Pennisetum typhoides, Stapf. and Hubbard, produced the disease on both crops. The sorghum ergot was cross-inoculated on and infected maize, Zea mays L. Near 100 percent relative humidity was necessary during the first 12 to 36 hours (24 hours was optimum) of the incubation period for infection. The incubation period ranged from 7 to 9 days. The secondary spread of the disease was by flies, bees and other insects. Secondary spread was rapid during the wet season and non-existent during the dry season. Sorghum plants were easily infected during the dry season if high humidity was maintained under plastic bags for the first 24 hours of the incubation period. Sclerotia produced during the wet season were poor due to fungal parasites. Excellent sclerotia were produced during the dry season. Sorghum was inoculated and infected during 9 months of the year from January to October. Maize was inoculated and infected with ergot

conidia from sorghum in August. Ergot conidia collected on guinea grass infected sorghum and millet when inoculated in May but not in February and March. The Indian Sorghum Selection 1112 produced 9.1 grams of ergot sclerotia per head and combine Kafir-60 produced 2.8 grams per head."

Fusarium Scab of Sorghum in Nigeria

"Fusarium moniliforme was found associated with seedling blight, stalk rot, 'Pokkah boeng', head blight and scabbed seed of sorghum grown in experimental plots during the wet season at Samaru, Nigeria. Grain of 2,266 lines was examined for the presence of Fusarium spp. Ninety percent of the Fusarium isolates were F. moniloforme and ten percent were F. roseum f. cerealis. Forty of the lines had a 100 percent Fusarium infection and zero germination, and seed of all of these showed typical scabbed symptoms. Individual scabbed kernels were found in nearly all lines studied. Only 60 of the 2,266 lines were free of Fusarium. There was increased incidence of Fusarium on seed when the heads were covered at flowering with kraft paper bags. Seed grown under irrigation and harvested during the dry season had a much lower incidence of scab than seed grown and harvested in the wet season. Seed produced during the dry season and treated with a seed dressing containing thiram had a low incidence of Fusarium when germinated."

Our next pathologist will devote his efforts to a study of the smuts of sorghum, and the smuts and downy mildew of pearl millet. Crop losses from these diseases range between 5 and 10 percent and the development of resistant varieties and suitable control measures are needed. All known smuts of sorghum are found in Nigeria and possibly numerous hybrid derivities between them.

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MAIZE IMPROVEMENT IN KENYA

S. Eberhart, M. N. Harrison, A. Y. Allan,
F. Ogada and C. Kagira

A coordinated program of maize improvement is being conducted by the Maize Research Section with funds from the following sources: the Kenya Ministry of Agriculture; the Maize and Produce Marketing Board (Kenya); the Ministry of Overseas Development (Great Britain); the Rockefeller Foundation (U.S.); and the United States Agency for International Development with the Agricultural Research Service of the U. S. Department of Agriculture in cooperation with the East African Agricultural and Forestry Research Organization.

Ecological conditions in Kenya require maize breeding programs for three distinct regions. One long rainy season occurs west of the Rift Valley where most of the maize is grown between 4000 and 7500 feet. The senior staff at Kitale includes the Senior Maize Research Officer, M. N. Harrison; Maize Geneticist, S. A. Eberhart; Maize Breeder, F. Ogada; Maize Agronomist, A. Y. Allan; Assistant Maize Breeders, B. Gichui and E. Okul; and Assistant Agronomist, J. Wakhungu. The assistant maize breeder at the Kakamega substation is B. Wamalwa. Breeding trials are also conducted on the Plant Breeding Station, Njoro, and on private farms near Endebess and Kitale.

East of the Rift Valley altitudes are similar but there are two rainy seasons. Hence, medium maturing varieties are required to permit two crops a year. The Maize Breeder at Embu is C. Kagira. A Maize Agronomist, T. Gatheca, has recently joined the staff and additional expansion of the facilities and personnel is planned. The drier areas of this region require a much earlier maturing maize to escape the drought. The development of early maturing varieties is done at the Katumani Research Station near Machakos. The assistant maize breeder, E. Omolo, has gone to Iowa State University for further training and has been replaced by H. Mauuye.

Maize Genetics

The primary contribution of the U.S.A.I.D./E.A.A.F.R.O. maize genetics research is adapting breeding methods to conditions present in developing countries and in evaluating the relative efficiencies of these methods so that future breeding programs can make maximum progress for the minimum expenditure of funds. A Comprehensive Breeding System has been developed by Eberhart and Harrison to serve as a general guide for establishing or modifying breeding programs. A manuscript is being submitted to Der Züchter for publication and this system will be presented to all breeders in Western and Eastern Africa for their consideration. This is the system being used at Kitale, Embu, and Katumani with great success.

The comparisons of breeding methods is well under way using the long season varieties. Some preliminary data are available to predict increases

that may be expected for yield. These are presented in Table 1. The predictions for the plant-row method are based only on selection among plant-rows as the exact formula for including the effect of mass-selection within plant-rows and the selection of male plants prior to pollination has not been derived. However, this latter selection should greatly increase the progress. The method labeled "half-sib" is selection for general combining ability using the variety as tester and recombining remnant selfed seed. Predicted progress from S_1 testing per se should be even more effective but data to give this estimate will not be available until next year. Full-sib or testing plant-to-plant crosses has an advantage at locations where two crops a year are possible since only two seasons are required per cycle.

These estimates of progress are extremely high compared to results obtained in the U. S., but they are comparable to gains obtained in Mexico and Colombia. Table 2 indicates that these predictions may be realistic estimates. Data from only four of 11 locations has been analyzed thus far. The yield of Ec. 573 was low because two locations were at 4,000 and 5,000 feet where Ec. 573 yields less relative to Kitale II. The expected and observed progress in Ec. 573 is most encouraging and emphasizes the importance of the introduction of improved breeding material from the center of origin of maize (Central and South America). Seed of improved Ec. 573 has been increased by the Kenya Seed Company and will be used in all seed production requiring Ec. 573 in 1967.

Table 1. Expected progress for yield from different breeding methods expressed as per cent each year.

Variety	Breeding Method			
	Mass Selection	Plant-row	Half-sib	RRD
Kitale II	--	6	12	--
Ec. 573	--	11	22	--
Kitale II x Ec.573	--	--	--	7
Kitale Composite A	6	8	16	--

Table 2. Progress from selection in three varieties by the plant-row selection method for yield (Cwt./acre).

Variety	Expected	Observed
Kitale II	50.8	50.8
Kitale II (1) C_1	53.4	53.5
Kitale II (1) C_2	56.1	52.8
Ec. 573	29.7	29.7
Ec. 573 (2) C_1	34.0	36.6
Ec. 573 (2) C_2	38.2	40.4
Kitale Composite A	47.9	47.9
Kitale Composite A (3) C_1	50.4	48.4
Kitale Composite A (3) C_2	53.0	48.8

Maize Breeding--Kitale

Hybrids were first available in 1964 in Kenya. The superiority of the hybrids over the improved synthetic variety Kitale II was about 20%. New hybrids have been released each year with even greater superiority especially at higher altitudes (Table 3 and Figure 1). The improvement in H611, H612 and H613B was due to the improvement of Kitale III and the elite inbred lines used to form Kitale II. The inbred lines A, F, and G required seven to ten years from initial inbreeding to utilization. If recurrent selection had been started at the same time (1955) with the two year cycle now being used, a fifth cycle improved version of Kitale II should now be available showing 25 - 40 percent increased yield over Kitale II. At least half of this improvement should be reflected in the variety cross. Hence, the variety cross (Kitale II C5 x Ec. 573 C1) should be superior to H613B in yield. Consequently, inbreeding and evaluation of inbred lines is being phased out and all resources are being devoted to developing improved populations and variety cross hybrids. Kitale Composite B was developed from several sources of elite Kenya varieties to increase the genetic variability; and hence, the expected gain from selection. A small amount of Ec. 573 (25%) will also be added to this variety to increase the genetic variance even further. Kitale Composite C was developed from selected material derived from Ec. 573 and two additional Central American varieties (Cometico and Costa Rica 76). The results in table 4 suggest that the mild mass selection practiced during the four cycles of recombination of this material has produced considerable improvement, since Kitale Composite C was originally greatly inferior to Kitale II and even inferior to Ec. 573. Selection has now been intensified

Table 3. Varieties and hybrids available in Kenya and their relative performance from 16 locations in 1965 and 14 locations in 1966.

Variety	Pedigree	Year of Release	Relative Yield (%)
Local farmers			93
Kitale II		1960	100
Kitale III		1965	108
H611	Kitale II x Ec. 573	1964	118
H611B	Kitale III x Ec. 573	1966	126
H632	(A x G) F	1965	134
H612	(A x G) x Ec. 573	1966	130
H613B	(F x G) x Ec. 573	1967	134
H613C	(F x G) x Ec. 573 C1	1968	(140+) predicted

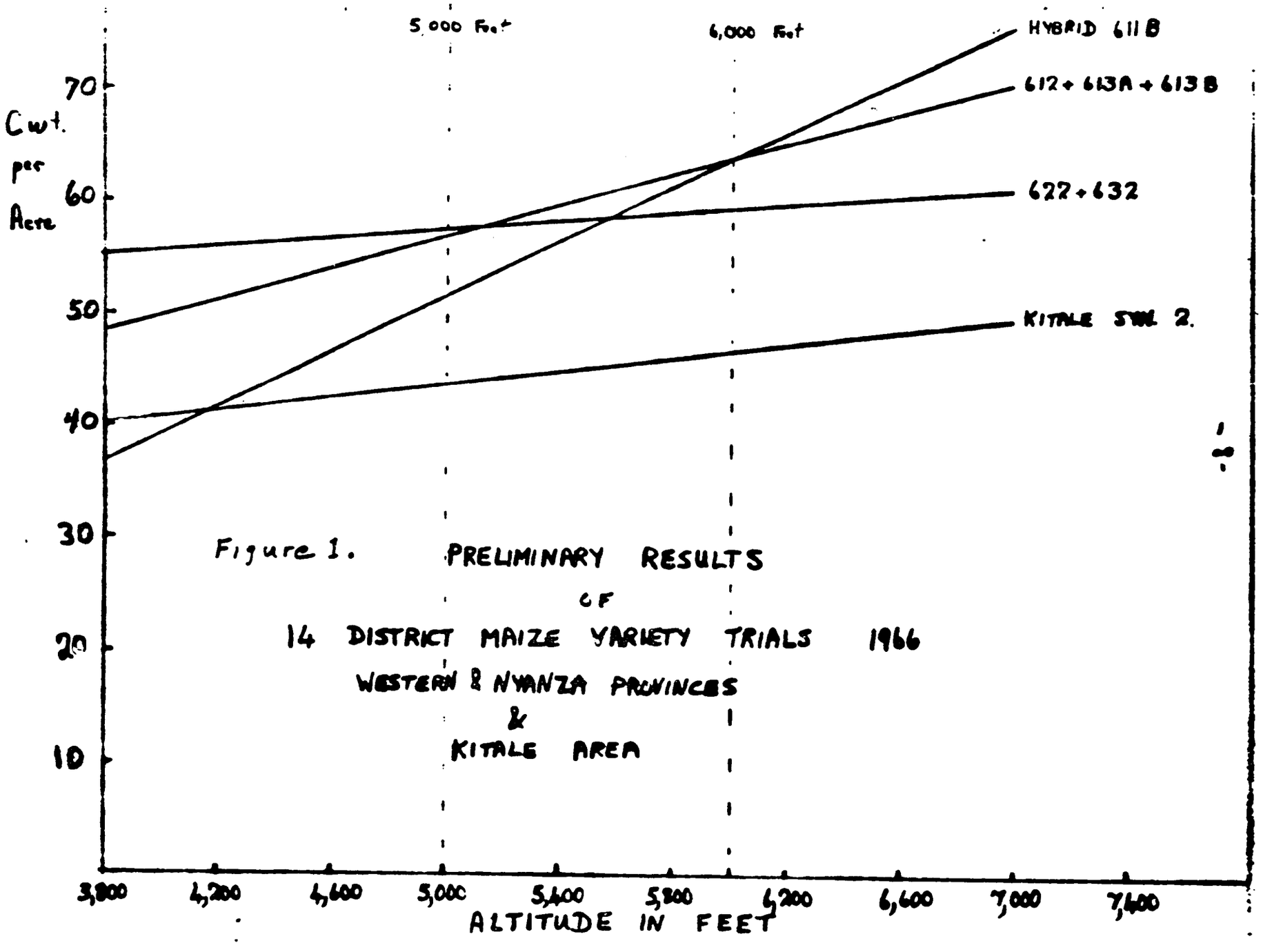

Figure 1. PRELIMINARY RESULTS OF 14 DISTRICT MAIZE VARIETY TRIALS 1966 WESTERN & NYANZA PROVINCES & KITALE AREA

Table 4. Yields (cwt/acre) of composite varieties grown at four locations in 1966.

Variety	Observed	Expressed as % Kitale II
Kitale II	50.8	100
Kitale II C2	52.8	104
Kitale III	54.7	108
Ec. 573	29.7	58
Ec. 573 C2	40.4	80
Kitale Composite A	47.9	94
Kitale Composite A C2	48.8	96
Kitale Composite B	52.3	103
Kitale Composite C	49.6	98

Trials were at 4000, 5000, 5900, and 6200 feet.

in these varieties. S_1 testing per se was begun in Kitale Composite C this year and plant-row selection is being used for Kitale Composite B until the introgression of the selected Ec. 573 lines is completed. At that time S_1 testing will also be used. The future commercial hybrid will be the variety cross, Kitale Composite B x Kitale Composite C, whenever it has been improved sufficiently to outyield H613.

Since maize is the staple food of Kenya, the improvement in the quality of protein in the maize is extremely important. Genetic stocks carrying opaque-2 and floury-2 have been obtained and will be incorporated into the commercial hybrids. Varieties homozygous for opaque-2 and floury-2 have a higher percentage of the essential amino acids, lysine and trytophane. Gains of rats and older pigs has been as good from high protein opaque-2 varieties as from a balanced ration including soybeans.

Maize Breeding--Embu

Although a maize breeding program was not initiated at Embu until 1965, rapid progress is being made using the Comprehensive Breeding System. An initial collection of Central American accessions has been screened. Eleven of these have been selected as well as four local varieties including the best Kitale and Katumani material for evaluation in a 15 variety diallel. Two new breeding populations, Embu Composites A and B, will be composited from the best of these 15 varieties next year and recurrent selection will

be used to produce continued improvement. The variety cross (Embu Composite A x Embu Composite B) will be produced and evaluated. Considerable improvement over the local variety (Muratha) is expected since the topcrosses of the selected varieties to Muratha outyielded Muratha by 35%.

An experimental hybrid (H511) involving the best Kitale and Katumani varieties was produced and tested for immediate use while the composites are being formed (Table 5). The variety cross of Muratha and Eto (a variety from Colombia) also outyielded Muratha. Kitale hybrid H632 was the highest yielding variety, but it is not possible to get two crops a year with such a late-maturity variety; and, if the rains end early, a crop failure can occur.

Maize Breeding--Katumani

The Comprehensive Breeding System has been equally successful at Katumani for the short season maize synthetics, developed from local and introduced germ plasm as shown below.

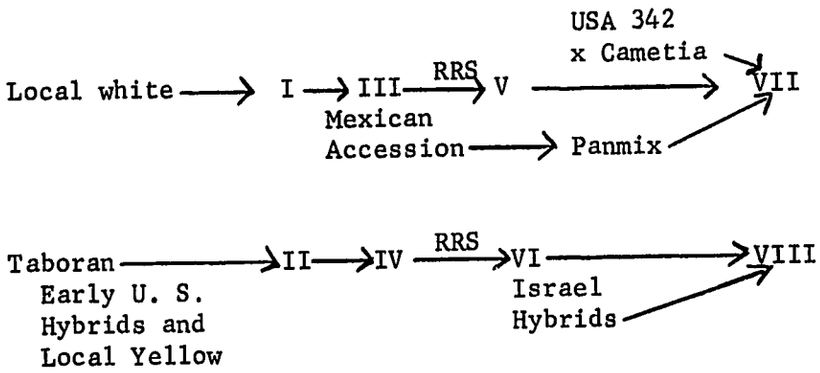

Table 5. Performance of medium season varieties at five locations near Embu in 1966.

Variety	Days to Tassel	Yield	Expressed as % Of Muratha
Katumani Composite A	66	25.8	71
Muratha	74	36.4	100
Eto x Muratha	77	43.0	118
H 511 (experimental)	76	44.8	123
H 632	90	55.6	153

The Local White variety was too late for the average season at Katumani. Selection in this material for earliness was effective with little change in yield in a normal season (Table 6). Taboran is from the Mexican Salvadureño race obtained through Tanzania. Reciprocal Recurrent Selection (RRS) at Katumani was extremely effective in increasing yields from Katumani III to Katumani V and from Katumani II to Katumani IV. Katumani VI has only recently been synthesized and no yield results are available. Since original introductions were limited, additional accessions have been obtained. The Katumani Panmix was composited from Mexican accessions, Katumani III and Katumani II. Although the original accessions were greatly inferior in yield to the Katumani synthetics, later maturing and susceptible to disease; four cycles of mass selection in this extremely variable population has produced a variety equal in performance to the improved Katumani IV and Katumani V (Table 7). Results of the five-variety diallel indicate that Katumani VII and VIII will give as high yields as Katumani V and VI; but genetic variation should be increased because of the genetic divergence of the new material. The variety crosses showed 25% heterosis over the parental varieties. As soon as Katumani VII and VIII have been composited full-sib selection and/or S_1 testing will be initiated to produce additional improvement.

Since it is not feasible to produce the Katumani variety cross hybrid at this time, the commercial product is the advanced generation of the variety cross. Katumani Composite A was obtained from Katumani III x Katumani IV with mass selection each cycle of seed increase. Seed sufficient to plant 35,000 acres was produced in 1965 by the Kenya Seed Company and two-thirds of this was purchased by farmers in the Katumani area in the second rains of 1966. Additional extension work is needed to convince the farmers that the short season maize must be dry-planted to obtain the full benefits and that it is not to be merely a variety to be used if they don't get their longer-season, local varieties planted on time. Seed of Katumani Composite B (V x VI) syn 2 also has been mass selected during the bulking and will be released next year by the Kenya Seed Company. Once the initial stocks have been released, it is hoped the better farmers will supply their neighbors with the improved short-season varieties. If the extension service can use the improved varieties to get the improved cultural practices adopted as well, the chronic famine condition of this area can be changed to one of self sufficiency.

Table 6. Yields of short season varieties at five locations near Katumani in 1966.

Variety	Days to Tassel	Yield cwt/acre	% Local white
Local white	78	17.4	100
Katumani III	68	18.6	107
Katumani V	62	26.4	151
Katumani II	62	23.4	134
Katumani IV	60	27.4	157
Katumani Composite A	63	24.9	142

TABLE 7. Results from a five variety diallel at three locations near Katumani in 1966.

Variety	Days to Tassel	Yield (cwt/acre) Variety	Yield (cwt/acre) Average in Crosses
Katumani IV	60	26.8	31.1
Katumani V	61	29.4	31.3
Katumani Panmix	66	29.8	31.2
(USA 342 x Cametia)syn 2	72	18.8	29.7
(Israel hybrids) syn 1	67	19.4	31.8
Average	65	24.8	31.0

Maize Agronomy

Although the increased yields from hybrids over local varieties has been impressive when compared under the same growing conditions, the comparison of hybrids grown with good cultural practices to local varieties as normally grown has been spectacular. Trials were grown to obtain data on the relative importances of six of the main agronomic factors effecting yields. Preliminary data are available from two locations (Table 8) for long season varieties and three locations of medium season varieties. The yield at these locations of long-season local maize variety, late planted with poor land preparation, late weeded, and no fertilizer was 8.7 cwt. per acre compared to 59.7 cwt. when the best hybrid was grown as recommended. Time of planting is the most important factor and the variety used is next. But unless these basic husbandry factors are at a high level, then high yields cannot be obtained. Conversely, it was found that fertilizers are a waste of money where the husbandry levels are very low. Similar results are available from the Embu area using medium season varieties; an improved medium season hybrid will not be available until next year for the Embu area.

Whereas the extension service had not been able to get these improved agronomic practices widely adopted previously, the new hybrid varieties have been used as the "lever" to get them adopted. This "package deal" in which the better farmers are sold hybrid seed and are strongly encouraged to use improved cultural practices has been very successful. The local extension instructors supervised the farmers closely when the hybrids were first introduced to an area but now new hybrid growers also learn from their neighbors. Table 9 gives the expansion in acreages of hybrid maize. Almost without exception the hybrid maize is grown using improved cultural practices to the best of the farmers ability.

Table 8. Factors affecting the yield of long-season varieties of maize at two locations and medium-season varieties at three locations in 1966.

Factor	Long-season Maize Yield (cwt)	Long-season Maize Difference	Medium-season Maize Yield (cwt)	Medium-season Maize Difference	Approximate cost/acre
Late planting Early planting	44.2 24.2	20.0	47.1 25.9	21.2	nil
14,000 plants/acre 7,000 plants/acre	36.8 31.6	5.2	41.3 31.7	9.6	$1.40
H 613 A Local variety	42.6 26.0	16.6	---- ----	---	$1.30
Clean weeded 1 late weeding	37.0 31.8	5.2	38.1 34.9	3.2	$3.00
50 lbs. P_2O_5 0 Phosphate	36.0 32.6	3.4	39.4 33.5	5.9	$4.71
70 lbs. Nitrogen 0 Nitrogen	34.6 34.0	0.6	36.9 36.1	0.8	$10.40

Table 9. Acreages of long-season hybrid maize varieties grown in Kenya.

Year	Large Scale farms	Small Scale farms	Total
1963	390	10	400
1964	33,500	1,500	35,000
1965	52,000	18,000	70,000
1966	50,000	50,000	100,000
1967	(100,000)	(350,000)	(450,000)

* 1967 acreages are predicted from seed supplies available in 1966.

Regional Cooperation

The effectiveness of the Comprehensive Breeding System has been proven by all three Kenya breeding programs with three distinct types of breeding material. One of the main problems in Kenya will now be storage facilities, markets for surpluses that are expected and alternative cash crops with a higher industrial or export value.

The next logical step is to extend the success of the Comprehensive Breeding System in Kenya for maize to other African countries and other crops.

The main points of this system are: (1) introduction and evaluation of adapted accessions as well as the evaluation and selection of local varieties, (2) the formation of at least two breeding populations from the best material, (3) systematic recurrent selection within each population, and (4) the production and distribution of the variety cross or composite produced from the variety cross by a commercial seed company in cooperation with an effective extension service.

This system was presented to Eastern Africa maize, sorghum and millet breeders at a workshop conference in 1965. In 1966 follow-up visits were made to most of these countries to help work out the details of implementing such a breeding program. Previous breeding work for Zambia had been done by Southern Rhodesia using the traditional inbreeding and hybridization methods with good success. One breeding population (Variety A) is being formed from this material by the Zambian maize breeder and recurrent selection will be initiated. New accessions are being obtained and evaluated to form the second population so that a variety cross hybrid can be produced. Meanwhile, Rhodesian hybrids are being used commercially.

The accessions obtained for the Ukuriguru, (Tanzania) and Embu (Kenya) breeding programs were evaluated in an East-African Cooperative trial at 14 locations in Kenya, Tanzania and Uganda. The results of this trial will provide information on genotype by environmental interactions as well as selection of material to be used in the new breeding populations in each country. The first breeding population has already been formed from Kenya varieties and Central American accessions obtained from Kenya at Ukuriguru (Ukuriguru Composite A). Two seasons of mass selection have been completed and plant-row selection will be initiated in 1967.

Exchanges of breeding material have been made among all the eastern Africa countries and also with Nigeria. The interchange of material and methods and the coordination of maize breeding in Eastern Africa should greatly increase the effectiveness of this research.

MAIZE PROJECT

Moor Plantation, Ibadan, Nigeria

J. Craig

The activities of the maize improvement project consist of regional programs involving participating countries in West Africa and research programs, concerned with maize improvement, conducted in Nigeria.

The objectives of the regional programs are to provide assistance in initiating or conducting maize improvement programs, to provide in-service training facilities for trainees from participating countries, to encourage cooperative programs and improve liaison among maize workers in the countries of West Africa.

Regional Programs

Uniform Maize Trial Program (see Appendix I, page).

This program was designed to provide information on the performance of maize varieties at a number of different locations in West Africa. The following countries - Cameroon Republic, Dahomey, Liberia, Nigeria, Senegal, Sierra Leone, and Upper Volta have agreed to participate in this program. The first trials will be conducted in 1967. Entries in the trial will consist of maize selections supplied by the participating countries. The STRC maize project will be responsible for preparing trial reports for distribution to all interested parties.

Liberian Maize Improvement Program (see Appendix II, page).

In response to a request by the Government of Liberia for assistance in planning a maize improvement program the OAU/STRC maize Pathologist visited Liberia in November 1965. A program of maize yield trials involving personnel of the University of Liberia and the Liberian Department of Agriculture was proposed and accepted. These trials were started in the early season of 1966.

A tour of maize trial sites in Liberia was made in July 1966. As a result of observations made during this tour it was decided that trials to determine optimum rates of fertilizer application for maize were necessary before undertaking maize variety trials. These fertilizer response trials were started in the late season of 1966. It is expected that the results of these trials will provide sufficient information for the resumptionof maize variety yield trials in 1967.

Trainee Program.

None of the West African countries have made use of the in-service training facilities offered by the maize project at Moor Plantation. Two countries, West Cameroon and Liberia, have expressed interest in this program and may send trainees in 1967.

Seed Distribution Program.

Seed stocks of several maize varieties which yield well in Nigeria are maintained by the maize project. In response to requests in 1966, seeds were sent to Dahomy, Senegal, Republic of Malagasay, Gambia and the Republic of Central Africa.

RESEARCH PROGRAMS

Puccinia polysora Program (see Appendix III, page).

The objectives of this program are identification of the races of P. polysora present in Nigeria, identification of maize selections resistant to these races and the transfer of this resistance to maize composites for use in breeding programs.

Initial studies indicate the existence of 4 races in the collection of P. polysora isolates made to date. S_1 lines of maize varieties and composites that appeared to be probable source of rust resistance were produced in the early season of 1966. These lines are being tested for reaction to the P. polysora isolates under green-house conditions. In tests conducted to date a synthetic composed of maize selections resistant to rust in Kenya appears to be a good source of resistance to the Nigerian strains of P. polysora. Four of the 30 S_1 lines from this composite have shown a hypersensitive type resistance to all P. polysora isolates in the present collection.

Cochliobolus heterostrophus program.

The objectives of the C.heterostrophus program are the identification of maize selections resistant to this pathogen and the use of these selections to improve the leaf blight resistance of maize varieties and composites used in breeding programs.

Thirty maize varieties including introductions from Kenya, Dahomey, Ghana, Taiwan and Colombia were evaluated for leaf blight resistance in a disease nursery during the early season of 1966. Eleven maize selections which appeared highly resistant to leaf blight were used for the production of S_1 lines. These inbreds are being tested to determine their reaction to inoculation with C. heterostrophus at various stages of growth. Certain of these lines have given highly resistant reactions to inoculation at relatively early stages of growth; investigations of this characteristic are continuing.

Lodging Resistance Program.

The objective of this program is to determine the effect of mass selection for root strength in a pan-mictic maize population on root strength, ear height and yield. This program was started in the early season of 1966. Approximately 1000 plants were planted in an isolation plot; at maturity observations were made on the ear height and the lbs. of pull required to uproot each plant in the plot. From these observations the ratio of lbs. pull per ft. of ear height was calculated for each plant.

The plants forming the upper 10% of the population in terms of lbs. pull per ft. of ear height were selected as ear parents to furnish seed for the second cycle of selection. The mean ratio of lbs. pull per ft. of ear height for all plants was 10 lbs. per ft. of ear height and the mean ratio for the selected plants was 21 lbs. per ft. of ear height. After 3 cycles of selection comparisons will be made among the original, first, second and third cycle populations for root strength, ear height and yield.

Drought Tolerance Program

Juvenile drought tolerance in maize would be of value during the late season, September thru November, in areas of West Africa where 2 crops of maize can be grown per year. Usually a period of low rainfall, late August to mid-September, separates the early and late growing seasons. In consequence maize plantings are usually delayed until regular rainfall commences in late September. As a result the effective growing period for maize in the second season is often less than 90 days.

Drought tolerant maize would allow plantings to be made in August with less danger of stand losses due to short droughts. Planting in August would increase the length of the growing season and should result in higher yields.

Attempts will be made to evaluate the drought tolerance of maize selections by growing them in hydroponic sand-gravel beds during the dry season (early December to late February). The plants will be deprived of water at 3 weeks of age and observed for differences among selections in rate of wilting and death. Other studies will be carried out to determine if sufficient positive correlation exists between reactions of maize to moisture stress in hydroponic beds and reactions to moisture stress in soil to make this method of screening practical.

Maize selections that appear to be drought tolerant will be used to form a composite which will be subjected to a recurrent selection program for drought tolerance.

Maize Disease Survey Program (Appendix IV, page ___).

The objective of this program is to gather information on the annual incidences of maize diseases in the 4 regions of Nigeria. This program was started by conducting a training course in maize disease survey techniques. This course was given in June of 1966 and was attended by agricultural officers from each of the 4 regions in Nigeria. The training course lasted for 1 week and the trainees were taught to score maize plots for severity of attacks of maize rust and maize leaf blight.

These officers will conduct annual surveys of the incidences of maize rust and maize leaf blight in their respective regions. The information provided by these surveys will be of value in assessing the relative importance of these diseases in Nigeria.

Disease Loss Evaluation Program (Appendix V).

The objective of this program is to determine the reductions in yield attributable to maize diseases that appear to be of economic importance in West Africa.

A study to determine the reductions in yield caused by maize rust (*Puccinia polysora*) was carried out in the early season of 1966. In this experiment the yield of Lagos White, a rust susceptible variety, subjected to conditions conducive to a rust epiphytotic was 43.8% less than the yield given by this variety when protected from rust by applications of Dithane S-31 fungicide.

A similar study to assess the reduction in yield caused by maize leaf blight (*Cochliobolus heterostrophus*) is planned for the early season of 1967. Information gained from this program coupled with results of the annual maize disease survey can be used to estimate annual losses in maize yields in Nigeria caused by these diseases.

Maize Collection Screening Program.

This is a cooperative program with the maize breeding section of the Nigerian Federal Department of Agricultural Research. The maize collection and the maize selections presently in the maize breeding program are being screened for resistance to *Cochliobolus heterostrophus* and *Puccinia polysora*. Sixteen hundred and eight maize entries were screened in the early season of 1966. The information obtained in this and future trials will be used in making selections among lines in the breeding program and in identifying sources of resistance for future use.

SUMMARY

The OAU/STRC maize project at Moor Plantation is engaged in regional programs promoting maize improvement in West Africa and in research programs dealing with disease problems and other factors which reduce maize yields in West Africa.

The current regional programs are uniform maize yield trials among West African countries and assistance with a maize improvement program in Liberia.

Research programs are identification of races of *Puccinia polysora*, development of maize composites resistant to *P. polysora* development of maize composites resistant to *Cochliobolus heterostrophus*, use of mass selection to improve root lodging resistance in a pan-mictic maize population, devising of a technique to identify juvenile drought tolerance in maize, development of a drought tolerant maize composite, assessment of losses in maize yields caused by diseases, annual maize disease surveys of Nigeria and a disease resistance screening program of the Nigerian maize collection.

APPENDIX I

Proposal for Uniform Maize Trials for West Africa

The following proposal for conducting uniform maize trials in countries of West Africa should be regarded as a tentative plan put forward for criticisms and suggestions for improvement. It is hoped that, with the assistance of all concerned, a plan satisfactory to all participants can be drawn up and that uniform maize trials can be started in 1967.

The countries presently being considered as possible participants are:- Cameroon, Chad, Senegal, Upper Volta, Niger, Ghana, Liberia, Sierra Leone and Nigeria. Each country would be allowed a maximum of 2 entries in the trials. The entries submitted should be varieties recommended or likely to be recommended for use. If a participating country had additional entries on which it wanted information, these could be planted in small observation plots by the other participants if they wished to do so.

The STRC major cereals project maize specialist would act as liaison between participating countries, receiving seed of the various maize entries submitted, forwarding this seed to trial sites and collecting and distributing the results of the trials in each country to all participants.

The experimental design will be a complete randomized block with 4 replications. Plots will consist of two 25 plant rows of each maize entry. Rows will be spaced 3 feet apart with 1 foot between plant stands within the row or rows spaced 1 meter apart with 30 cm. between plant stands within the row. Maize will be planted at the rate of 3 grains per stand and thinned to 1 plant per stand 2 weeks after emergence. The date of planting and amount and kind of fertilizers applied will be determined by the officer in charge of the trial in each country.

The following observations should be made during the course of the trial.

1. Previous crop on trial site.
2. Previous fertilizer application on trial site.
3. Planting date.
4. Number of plants per plot 4 weeks after emergence.
5. Amount and kind of fertilizers applied.
6. Dates of fertilizer application.
7. Date of 50% anthesis of each entry.
8. Monthly rainfall from planting to harvest.
9. Incidence of maize rust and Cochliobolus leaf blight for each entry (see enclosed maize disease rating scales).
10. Number of lodged plants (root lodging) per plot one month after anthesis.
11. Number of lodged plants (stalk breakages) per plot one month after anthesis.

APPENDIX I (cont'd.)

12. Number of plants per plot at harvest.
13. Number of lodged plants (root lodging) per plot ar harvest.
14. Number of lodged plants (stalk breakage) per plot at harvest.
15. Date of harvest.
16. Grain moisture content of each entry at harvest.
17. Shelling percentage of each entry at harvest.
18. Yield (wt. of husked ears) per plot at harvest.
19. Comments on matters of interest not noted above e.g. wind storms, insect attacks.

After completion of the trial the record of the observations will be sent to S.T.R.C. major cereals project maize specialist for analysis. After analysis the results of the trials will be distributed to all participants and to any other interested party.

APPENDIX II

Tour of Maize Trials in Liberia

A tour of maize trial sites in Liberia was carried out in July to observe disease incidence and appearance of plants at 3 months after planting. These trials were designed to evaluate the effects of 3 levels of fertilizer application on yields of 2 maize varieties, NS 1 and Cuba 374. Fertilizer treatments were (1) no fertilizer, (2) 400 lbs. of 15-15-15 and (3) 400 lbs. of 15-15-15 and 54 lbs. of urea per acre. The trial sites were Monrovia, Suakoko and Gbadine.

Monrovia Site:

Plant growth was poor in all treatments. Plots receiving 15-15-15 and urea were slightly more vigorous than plots receiving 15-15-15 alone. Plants in plots receiving no fertilizer were poorest in growth and showed severe stunting. Several plants when split open showed a brown to purplish discoloration of the basal nodes characteristic of iron or aluminum toxicity.

The incidence of maize leaf blight, *Cochliobolus heterostrophus*, was low and no southern maize rust, *Puccinia polysora*, was observed at this site. Moderate incidence of another maize rust, *Physopella zeae* was noted on both NS 1 and Cuba 374.

Suakoko Site:

Plant growth at Suakoko was poor but superior to that at Monrovia. The plots receiving no fertilizer showed severe stunting and phosphorous deficiency symptoms. Plots receiving 15-15-15 showed phosphorous and nitrogen deficiency symptoms. Plots receiving 15-15-15 and urea exhibited phosphorous deficiency symptoms.

APPENDIX II (cont'd.)

Incidences of maize leaf blight and maize rusts (P. polysora and P. zeae) were low. Low rainfall, 2 inches in April and 2 inches in May, was partially responsible for poor plant growth at this site.

Gbadine site:

Plant growth was moderately good in plots receiving fertilizer and poor in plots receiving no fertilizer. Plants in plots receiving 15-15-15 alone showed nitrogen deficiency symptoms. Incidences of cochliobolus maize leaf blight and rust (P. polysora) were low. High incidence of rust (P. zeae) and helminthosporium leaf spot, Helminthosporium carbonum were observed. Plants growing in poorly drained areas of the field exhibited symptoms of iron or aluminum toxicity.

Local supervision of these trials has been excellent at all sites. Instructions have been followed exactly and all data properly recorded.

In view of the symptoms of nutrient deficiencies and iron or aluminum toxicity observed the next series of trials will involve applications of limestone and higher levels of phosphorous and nitrogen. Unfortunately single element fertilizers have not yet been secured by the Department of Agriculture of Liberia; this should be done as soon as possible. In addition a supply of dolomitic limestone is needed to reduce the possibility of magnesium deficiency following application of limestone.

The incidences of helminthosporium leaf spot and physopella maize rust observed indicate that these diseases are a matter of importance in Liberia. A screening program to evaluate resistance of maize selections to these diseases will be started this year.

Maize Fertilizer Trials

Purpose:

To compare effects of applications of limestone, fertilizer and limestone + fertilizer on yield of the maize variety Cuba 374 at 3 sites, Monrovia, Suakoko and Gbadine, in Liberia.

Materials and Methods:

The experimental design is a split plot with 3 main plot treatments, 2 sub-plot treatments and 6 replications. The main plot treatments are (I) no lime, (II) 1000 lbs. of lime per acre and (III) 2000 lbs. of lime per acre. Sub-plot treatments are (A) 400 lbs. of 15-15-15-5 (15% N, 15% P_2O_5, 15 K_2O and 5% Mg) per acre applied 7 days after planting and 200 lbs., of 15-15-15-5 and 100 lbs. of urea (45% N) per acre applied 6

APPENDIX II (cont'd.)

weeks after planting and (B) no fertilizer. Main plots measure 24 ft. by 25 ft. and consist of 8 rows of maize 25 ft. long. Sub-plots consist of four 25 ft. rows of maize.

Limestone will be applied prior to planting. The main plots should be marked out and labeled and the required amount of lime applied as shown in the field plan, the limestone should be spread evenly over the main plots and worked into the soil. Apply 13 lbs. of limestone per plot (25 ft. x 24 ft.) for an application rate of 1000 lbs. per acre and 26 lbs. of limestone per plot for an application rate of 2000 lbs. per acre. Border rows at each end of the main plots should receive lime at the same rate.

Maize should be planted in rows spaced 3 ft. apart. with 1 ft. spacing between plant stands in the row. Plant at rate of 2 seeds per stand (if germination is poor use 3 seeds per stand) and thin to one plant per stand 3 weeks after planting. During thinning operation compensate for missing stands by leaving 2 plants in adjacent stand.

Border rows should be planted around the experimental block as shown on the field plan. No border rows are necessary between maize plots or sub-plots because only the 2 inner rows of each sub-plot will be harvested for yield data.

For fertilizer applications make a small hole with a hoe approximately 2 inches deep and 6 inches to one side of each plant stand. Place required amount of fertilizer in this hole and cover with soil. To apply 15-15-15-5 at the rate of 400 lbs. per acre apply 1 tablespoon of fertilizer to each plant stand. For the second application of fertilizer urea should be mixed with 15-15-15-5 at the rate of 50 lbs. urea to 100 lbs. of 15-15-15-5 and this mixture should be applied at the rate of 2 teaspoonfulls per plant stand.

All instructions given in previous trials for weed control and prevention of bird and rodent damage to plantings should be followed.

A duplicate set of records should be kept for each trial site. The following items should be recorded.

1. Field plan for site
2. Date of limestone application
3. Date of planting
4. Date of first fertilizer application
5. Date of thinning
6. Number of plants in 2 inner rows of each subplot after thinning

APPENDIX II (cont'd.)

7. Dates of weedings
8. Date of second fertilizer application
9. Number of plants in 2 inner rows of each subplot at harvest
10. Number of ears stolen from 2 inner rows of each subplot before harvest.
11. Date of harvest
12. Weight of husked ears from 2 inner rows of each subplot.
13. Moisture percentage and shelling percentage of a 10 ear sample from each subplot in first replication.
14. Weekly rainfall in inches from planting to harvest

APPENDIX III (cont'd.)

Puccinia polysora race identification

A study to determine if different races of Puccinia polysora were present in Nigeria was started in November 1965. Uredospores were collected from maize plants, infected with P. polysora, growing in an irrigated nursery at Moor Plantation during the dry season of 1965. Fourteen rust cultures originating from single uredospore isolates from this collection were produced for testing.

As no homozygous inbred maize lines were available for use as differentials it was decided to use 4 maize varieties, E.A.F.R.O. 231, NS 1, Lagos White and A.F.R.O. 49/53194, which had been maintained by line pollination for several years. Assuming that each variety would probably exhibit more than one class of reaction to a given P. polysora culture the ratios of the reaction classes within each differential could be used to identify differences among the P. polysora isolates.

Tests of maize differential reactions to inoculations with the P. polysora cultures were carried out under greenhouse conditions. In each test 48 seed of each maize differential were planted in plastic pots 4 inches in diameter filled with sterilized soil. Seeds were planted at the rate of 6 per pot. Ten days after planting, when plants had reached the 4 leaf stage, the pots were placed in a moist chamber where relative humidity was 100%. The plants were dusted with a mixture of uredospores and talc, left in the moist chamber for 20 to 24 hours and then removed to greenhouse benches.

The plants were observed for reactions to inoculation 12 days after removal from moist chamber. Inoculation reactions were classed as:

0; = Chlorotic or necrotic fleck
4 = sporulating sori rupturing epidermis
X = mixed reaction showing type 0; and type 4.

None of the differential exhibited any other reaction types.

APPENDIX III (cont'd.)

Ratios of the reaction types exhibited by the maize differentials were analyzed statistically to determine if the deviations among *P. polysora* cultures were significant at the 5% level. On a basis of these comparisons 4 races of *P. polysora* were found in the collection of 14 rust cultures (Table 1). These races will be referred to as A, B, C, and D until further investigation establishes their relationships to races of *P. polysora* reported by other investigators (Robert, 1962: Storey 1957; Ullstrup, 1965).

Table 1. Ratios of reaction classes of 4 maize varieties inoculated with 4 races of *P. polysora*.

Race	Reaction type* ratios** in indicated maize variety											
	EAFRO 231			NS 1			Lagos white			AFRO 49/53194		
	0;	X	4	0;	X	4	0;	X	4	0;	X	4
A	-	44	56	-	16	84	-	9	91	-	27	73
B	-	90	10	-	53	47	-	3	97	-	45	55
C	-	12	88	-	7	93	-	1	99	-	10	90
D	-	61	39	8	3	89	-	11	89	-	22	78

* 0; = chlorotic or necrotic fleck
4 = sporulating sori rupturing epidermis
X = mixed reaction, both type 0; and type 4 present

** Ratios for race A represent means of observations from tests of 7 *P. polysora* cultures which were not significantly different in reaction type ratios. Ratios for race C represent means of 5 *P. polysora* cultures which were not significantly different in reaction type ratios.
Ratios for races B and D represent reaction types to one *P. polysora* culture.

Seven of the isolates belonged to race A, 5 to race C and one each to race B and D. The small sample size prevents any conclusion being made concerning this disproportionate frequency of occurrence but it is possible that certain races of *P. polysora* occur much less frequently than others.

The following varieties have been selected as sources of inbred lines for use in investigations of the genetic factors governing reactions to the races of *P. polysora* noted above.

APPENDIX III (cont'd.)

Maize Varieties

(H 501) F_3	A F R O. P 63.51
(H 503) F_5	A F R O. P. 53.200
Metro	A F R O. P.59.289

P. polysora

Coastal synthetic Gui Hong

A F R O 49/53194

S^I lines of these varieties have been produced. These are being tested for rust reaction and will be subjected to further selfing and selection.

Literature Cited

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APPENDIX IV

Maize Disease Survey

A survey of maize diseases on farms in the Ibadan area was carried out in June, 1966. The purposes of this survey were training of Agricultural Assistants from the various Regions in maize disease surveying, testing the practicality of sampling methods and scoring techniques and assessment of incidence of maize rust (*Puccinia polysora*) and maize leaf blight (*Cochliobolus heterostrophus*) in the area surveyed.

The following method used for selecting observation sites, was devised by the Federal Department of Agricultural Research statistician.

APPENDIX IV (cont'd.)

1. Five sampling sites were selected along the first 25 miles of each major road leaving Ibadan.
2. Sampling sites were spaced 4 to 5 miles apart.
3. Maize fields used as sampling sites were at least 1/2 acre in size.
4. At each sampling site two 20 plant samples, each representing a different part of the field were scored for severity of maize rust and maize leaf blight.

The scales used for scoring severity of maize leaf blight and maize rust on sampled plants is given below. I. Scoring method for cochliobolus maize leaf blight.

Numerical
Grade

1. Slight infection, no lesions or very few lesions on leaves.
2. Light infection, small number of lesions on leaves below top ear, no lesions on leaves above top ear.
3. Moderate infection, small to moderate number of rust pustules on leaves below top ear, a few scattered rust pustules on leaves above top ear.
4. Severe infection, moderate to large number of rust pustules on all leaves.

The survey began on June 20 and was completed on June 25 the incidences of maize rust and maize leaf blight are shown in Table I.

Table I. Incidences of maize rust and maize leaf blight in 5 areas around Ibadan.

Area	Disease Incidence Score * Rust **	Disease Incidence Score * Blight ***
Ibadan - Oyo Road	2.3	2.07
Ibadan - Ife Road	3.2	2.6
Ibadan - Iwo Road	2.7	2.5
Ibadan - Ijebu Road	2.6	1.7
Ibadan - Abeokuta Road	3.0	2.7

* Each score represents mean of 5 sampling sites

** 2 = low incidence
3 = moderage incidence
4 = high incidence

*** 1 = trace
2 = low incidence
3 = moderage incidence
4 = high incidence

APPENDIX IV (cont'd.)

As shown in Table I, the incidence of maize rust ranged from light to moderate. It is probable that areas showing an incidence score of 3 or more would suffer an appreciable reduction in yield from this disease. The incidence of maize leaf blight was low in each area observed; reductions in yield due to this disease should be correspondingly light.

The data gathered during the survey were analysed by the Federal Department of Agricultural Research statistician. In the case of maize rust there was no significant differences in incidence among the areas. Significant differences existed among sites within areas. Leaf blight scores showed significant differences among areas, sites within areas, and samples within sites.

The reasons for the greater variability exhibited by maize leaf blight observations is not known. It is possible that differences in rainfall and temperature among the areas had more effect upon the relative incidence of blight than on incidence of rust. The variability among sites and among sampled plants within sites indicate the accuracy of survey would be improved by increasing the number of sampling sites per area and the number of plants sampled per site.

The statistical analysis also showed that the scoring system could be reduced to 3 classes, (1) little or no infection (2) moderate infection, and (3) severe infection, with no loss in accuracy of disease incidence estimates.

Agricultural assistants from the Niger Delta Development Board, the Northern, Western and Mid-Western Regions participated in the maize disease survey course. These trainees were taught to score maize plants for incidences of maize rust and maize leaf blight. In addition they were taught to recognize symptoms of Storey's streak, physoderma brown spot and helminthosporium leaf spot; these disease are of little importance to maize production at present but may be of economic significance in the future.

The Agricultural assistants attained a high degree of proficiency in assessing incidences of maize rust and leaf blight.

It is planned to have these officers conduct annual maize disease surveys in their respective regions. These surveys will provide information on the relative importance of the various maize diseases in Nigeria. Such knowledge will be of value in planning the allocation of funds and personnel for work on diseases of maize.

APPENDIX V

Effects of Maize Rust on Yields of Two Maize Varieties

This study was undertaken to determine the reductions in yield caused by maize rust (causal agent Puccinia polysora) of 2 maize varieties which differ in susceptibility to this disease. The maize varieties selected for this investigation were Lagos White, highly susceptible to maize rust and NS I which appeared to be moderately resistant to rust in field trials conducted at Moor Plantation in 1961 (Craig, 1961).

Materials and Methods:

This experiment was conducted at Moor Plantation, in the early season of 1966, the experimental design was a split plot, with 2 main plot treatments, 2 subplot treatments and 3 replications. Main plot treatments were (A) application of Dithane S-31, a mixture of nickel sulfate and maneb, to control rust and (B) no fungicide. Subplot treatments were (I) NS I maize variety and (2) Lagos white maize variety. Subplots consisted of one 50 ft. row of maize. Main plots were separated from each other by 4 border rows of Lagos white.

Plots were planted on April 12, maize seeds were planted in rows spaced 3 ft. apart with plant stands in the row spaced one ft. apart. Seeds were planted at the rate of 2 per stand and stands were thinned to one plant per stand 3 weeks after emergence. Fertilizer was applied at one week and 6 weeks after planting. The first and second applications consisted of 400 lbs. of 5-10-10 per acre and 400 lbs. of 16-4-0 per acre respectively.

The middle rows in each group of the 4 border rows between main plots were inoculated with uredospores of P. polysora 4 weeks after planting. Plants were inoculated by injecting an aqueous suspension of uredospores into the leaf whorls with a hypodermic syringe.

Dithane S-31 applications were started 4 weeks after planting. The Dithane S-31 was applied as an 0.3% aqueous suspension with a flox - 10 knapsack sprayer. Sufficient spray being used at each application to cover the leaves and stems of the plants. Applications were made at weekly intervals until 12 weeks after planting. The plots were scored for incidence of rust at 12 weeks after planting and harvested at 15 weeks after planting. The yields were analysed statistically to determine significant differences among treatments.

Results:

Growth of maize plants in all treatments was good. At 9 weeks after planting the unsprayed plots of Lagos white showed a moderate to heavey incidence of maize rust. The unsprayed plots of NS I showed a low incidence of rust. Rust incidence in the plots sprayed with Dithane S-31 was extremely low consisting of a few sori on an occasional plant.

APPENDIX V (cont'd.)

At 12 weeks after planting unsprayed plots of Lagos white and NS I showed high incidence of maize rust. Incidence of rust remained at a low level in the plots treated with Dithane S-31. Incidences of diseases other than rust were very low in all treatments. The results of evaluations for yields and rust incidence are shown in Table I.

Table I. Effects of Dithane S-31 on rust incidence scores and yields of 2 maize varieties.

Variety	Fungicide	Rust x Incidence	Yield x x
NS I	Dithane S-31	2	5043 a
NS I	None	3.5	3603 a
Lagos white	Dithane S-31	2	3230 a
Lagos white	None	3.8	1816 b

x 2 = low incidence, few scattered pustules on plant.
3 = moderate incidence, heavy infection on lower half of plant, light to moderate infection on upper half of plant.
4 = high incidence, heavy infection on both upper and lower halves of the plant.

x x Yields are given in lbs. of shelled grain per acre at 12% moisture; yields which do not have a letter in common are significantly different at the 5% level and yields with a letter in common are not significantly different at the 5% level.

As shown in Table I. Dithane S-31 gave very good control of rust in the treated plots. The high incidence of rust exhibited by the NS I control plots is quite different from the moderate resistance shown by this variety in previous years. It appears probable that a race or races of P. polysora pathogenic to NS I formed a larger percentage of the P. polysora population than in earlier trials.

The low incidence of infection exhibited by NS I at 9 weeks after planting may be due to the fact that strains of P. polysora pathogenic to NS I formed only a small part of the original inoculum, thus requiring a period of multiplication before heavy infection could occur. Lagos white being susceptible to all or most of the strains of P. polysora present in the inoculum would show heavy infection earlier.

APPENDIX V (cont'd.)

The yield of NS I sprayed with Dithane S-31 exceeded that of unsprayed NS I by 28.6% but this differences was not statistically significant. Lagos white sprayed with Dithan S-31 gave a statistically significant increase in yield of 43.8% over that of unprotected Lagos white.

It is of interest that the yields of NS I and Lagos white, 5043 and 3230 lbs. per acre respectively when protected from rust, exceed yields recorded for these varieties in previous trials in Western Nigeria where rust incidence is usually high (Craig, 1962; Craig, 1964), similarly high yields have been reported from Northern Nigeria where maize rust incidence is relatively low (Webster, 1965).

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SOROTI, UGANDA

H. Doggett, B. N. Majisu and Gilbert Schumaker

Improvement of Finger Millet

(1) Forty nine of the varieties from the Serere collection were grown in a yield trial on Serere. Yields ranged from 1,665 to 885 lb. of grain per acre.

Twelve of the best varieties were tested in variety trials at 8 sites in North and East Uganda. Variety yields at the sites varied between 2,500 and 270 lbs. of grain per acre. The best was Serere No. 1, selected by the Uganda Agricultural Department Botanist in 1942. It gave an average yield of 1,682 lb. of grain per acre over all sites. The estimated finger millet yield in farmers' fields in East Uganda averages some 750 lb. of grain per acre.

(2) Entries from the World Collection of finger millets grown at Serere totalled 598 accessions. One of these (604) failed to germinate, and 16 other entries gave poor stands. Observations were made on length of maturity, height, number of racemes, and leaf and stem diseases. The great majority of these entries showed little promise under East African conditions.

(3) The F_1 generations of 8 crosses of the blast resistant variety 359 x locally adapted finger millets were grown, and 37 backcrosses to the local types were made.

(4) Seed of varieties for the 1967 trial series was multiplied.

Improvement of bulrush millet

(1) Variety trials of the 6 Serere bulrush millet varieties and the 6 hybrids obtained from pollinating 23A with each of these varieties were planted at 8 sites in the second rains. The hybrid seed was made during the first rains, and seed yields were not good owing to wet conditions and to birds. Observations on the hybrids at Serere showed that the proportions of male-sterile plants was high in every one tested, varying between 10% and 30%. There should have been sufficient pollen for seed sets to be unaffected but there is an urgent need to sort out the restorer and sterile-producing genotypes. Yield results from most of the centres have not yet been received At Serere, the mean yield of the 6 varieties was 1,342 lb. of grain per acre, while that of the hybrids was 1,406 lb. of grain per acre. The best hybrid yield of 1,515 lb. of grain per acre was given by the hybrid of 23A x Serere 3A, but the variety Serere 17 gave 1,585 lb. per acre. The performance of the hybrids in this trial was much below expectation.

(2) The eleven inbred lines developed on Serere were crossed to 23A and evaluated for fertility restoration in the dry season nursery. Lines 26/9, 26/19, and *P. maiwa* showed a high proportion of fertility restoration.

Thirty three selfed heads of 26/19 were grown in the cage during the first rains, and crossed to 23A. In the second rains the 33 hybrids obtained, together with 3 checks, were evaluated in a 6^2 triple lattice. Only 2 hybrids showed no male-sterility at all, but 4 others showed extremely low levels of sterility. It should therefore be possible to extract a good restorer from this material this year. Grain yields in this trial averaged 727 lb. of grain per acre for the hybrids.

In the second rains, 21 selfed heads of 26/9, 45 selfed heads of P. maiwa, and 4 of Tift 239 were crossed to 23A to test for restoration in the next planting.

(3) Male-steriles from the cross 23A x Serere 10L were backcrossed to 10L in the dry season nursery, also in the first rains, and again in the second rains. They have sterilised well, and should shortly be usable as parents for test hybrids. In the second rains, the development of male-steriles by backcrossing from (23A x Serere variety) was continued in 14/2, 19/2, 2/1, 23/2 and 26/4, but these are 2 generations behind the 10L derivatives.

(4) Crosses between Dr. Burton's male-sterile 18A and some of the Serere varieties were planted in a randomised block trial to evaluate hybrid performance relative to Serere 17 and Serere 3A. The hybrid yields averaged 1,194 lb. per acre of grain, the varieties producing 1,042 lb. per acre.

(5) Seven lines from India, reputed to be good restorers, were selfed and crossed to 23A and to 18A to assess their performance as hybrids next season.

(6) Much of the Serere material produces hybrids which are rather tall, so Tift 238 is being used to introduce shortness. Short plants segregating from the F_2 generations of 238 crossed with P. maiwa, 10L, 26/9, 26/19, 14/2, and 23/2 were backcrossed to their respective Serere parent in the second rains.

(7) The main breeding effort is being directed towards recurrent selection programmes. Owing to the absence of a plant breeder to handle the millet work it was considered impossible to do very much selfing, so S_1 testing has been abandoned for the present, and Lonnquist's improved ear-to-row method has been adopted. In the second rains 648 selfed heads from the Serere varieties were planted in a compact block. They were supposed to go in as 3 replication of 3 cubic lattices, but unfortunately this was not done. However, the 2 or 3 best heads from each of the top 75 entries are being kept to go into a trial block next season on Lonnquist's system. S_1 testing can be added to this system at any time. The 648 entries were assessed for agronomic characters as well as yield, and final selection will be based on both.

(8) In the world collection, 1,384 entries were planted, but only 1,015 germinated and established. Selfed material was obtained from all of these, and in addition many were crossed to 23A, and also to Serere variety 17. Next season, it will be possible to separate the world collection into restorers and non-restorers on the behaviour of the hybrids with 23A. It will also be possible to divide the material into 2 main breeding populations on the basis of the performance of the crosses with 23A and with Serere 17. In this way, material giving poor performance with both 23A and Serere 17 will be discarded: that showing good heterosis with 23A but little with Serere 17 will go into one population for recurrent selection: and that showing good heterosis with Serere 17 but little with 23A will go into a second population for recurrent selection. This seems to be the most realistic method of handling the world collection with the resources available here.

Improvement of Sorghum

(1) Selections from the backcrossing programme to improve existing pollinator parents were grown in the dry season, and planted in a 5^3 cubic lattice in the first rains, followed by a 4^2 triple lattice in the second rains. In the first rains, derivatives of 4DX 77(based on SB 79, Serena and CK 60) performed some 20% better than Serena, but in the second rains' trial Serena gave the better yield. This was in part due to its greater resistance to leaf blight. In a 9 x 9 simple lattice, the same material again performed well, but the top 6 entries were Serere hybrids, H x 61 giving 60% more grain than Serena.

(2) A 216 entry cubic lattice of selections from the backcrosses to hybrid parents was grown in the first rains, and further backcrosses were made. The backcrosses from the Buganda type Namatare showed promise, the top 10 entries in the trial containing 6 Namatare derivatives. The best yields were some 20% above Serena.

(3) A fresh series of 39 hybrids from promising varieties in the collection was made, and tested against checks in a 64 entry triple lattice in the second rains. The best yielding hybrid was 45% above H x 57, and 89% above Serena. Eight hybrids outyielded H x 57, and 15 hybrids outyielded Serena. Good parents were E 169, a Serere selection from a natural Caprock cross: E 142, Wad Fahl from the Sudan; and E 300, a Feterita from the Chillicothe collection (C 1 182). There was no evident yield difference between the CK 60 A and the corresponding Redlan A crosses.

A second series of first rains hybrids made between 18 good pollinators and 5 male-sterile varieties was evaluated in a 121 tripple lattice in the second rains. The hybrids showed Redlan A as best, White Wheatland and CK 60 A only slightly lower, with Cody Midland A and Sooner Durra Millo A substantially below. The best hybrids on the top three male-steriles came from E 148 (a selection from a Congo Hegari type) and E 277 (a Feterita) which were 67% and 65% better than the hybrids with SB 65 on which H x 57 and H x 301 are based.

Nineteen male-steriles were crossed with Serena, SB 65 and SB 79 in the first rains, and the hybrids evaluated in the second rains using a 9 x 9 triple lattice and the corresponding Redlan A and CK 60 A crosses as checks. Four of the male-steriles were developed on Serere, and the remainder were developed by Dr. A. J. Casady at Manhattan, Kansas from crosses with the Nigerian type short Kaura. All the four Serere male-steriles gave hybrids which outyielded the CK 60 A and Redlan A crosses by from 6% to 26%, the best being the hybrids from 2DMS 7, which is male-sterile Grohoma. None of the male-steriles derived from Kaura showed promise, the mean yield of the 3 hybrids from the best Kaura entry being 86% of the corresponding Redlan crosses.

(4) In the regional trials, results from eleven planted in the 1965 second rains were received too late for inclusion in the previous report. Yields in lb. of grain per acre were as follows:- Serena, 2,104: hybrid H x 57, 2,341: hybrid H x 58, 2,198: Maize, 1,490. Serena came top in two trials, H x 57 in 5 trials, H x 58 in 2 trials, and maize in 2 trials. Maize gave the lowest yields in 3 of the trials: at one dry site in Kenya, Kambi ya Mawe, where the maize was a special short-term Katumani type bred for the area, the maize was outyielded by every sorghum entry, giving 52% of the yield of H x 57 and 67% of the yield of Serena. The H x 57 yield was 2,750 lb. of grain per acre.

The results from 11 of the 1966 regional trials so far received gave mean grain yields in lb. per acre as follows: Serena, 1,820; H x 57, 2,485; SB 79, 1803. There is thus further confirmation that Serena averages 1,800 - 2,100 lb. of grain per acre in East Africa, and that the hybrid H x 57 gives a mean increase of from 10% to 35% over this, on average. The general yield superiority of sorghum over maize at the majority of our testing sites has now been established, and the comparison will not be repeated at most centres for another 5 years, when new material of both crops will be available. The policy of continuing work with hybrids and the development of locally adapted male-steriles is clearly correct.

(5) A 216 entry cubic lattice of high grain quality selections was planted in the bird cage during the first rains. Thirteen entries equalled or outyielded Serena, one of them by 36%. This represents some progress, as generally the high grain quality types yield poorly here.

(6) The introduction of the Coes genetic male-sterile ms_3 made it possible to commence a recurrent selection programme, designed in conjunction with Dr. S. A. Eberhart of U.S.A.I.D. Two main groups of sorghum, restorers and sterile-producers, which have shown promise in our trials were crossed on to the ms_3 stocks in the dry season. Each main group was subdivided into high grain quality and average types. The F_1 generations were grown out in the first rains, and some of the male-steriles segregating in the F_2's were pollinated by further varieties. In all, 245 varieties have been crossed and backcrossed to ms_3. Details of the breeding system are being published.

(7) The introduction of the genetic male-sterile has also made it possible to handle the collection on a reasonable basis. Sixteen hundred entries were grown in the first rains, and screened. Those of little interest were discarded; those showing promise under Serere conditions were crossed to Redlan A. In the second rains, a lattice trial of the 81 best entries was carried out, and the hybrids with Redlan were grown in observation rows. All the material of interest was crossed to Redlan A if this had not already been done, and to ms_3. The collection will now be handled as a cross-breeding gene pool utilising the ms_3, and in addition the most promising types will be grown as separate entries until they have been evaluated.

The Ethiopian material from the Sugar Cane and Sweet Sorghum collection in Beltsville was crossed to ms_3. Some of this material is of great interest, but is so tall and late maturing that it will take a year or two to get its main characters into the breeding populations.

(8) The Indian nursery supplied by Dr. L. House of the Rockefeller Foundations New Delhi programme was grown in the second rains, and some of the entries were of interest. Dr. House also supplied seed of some of the pollinators of hybrids which have done well here. This was multiplied in the second rains. The West African regional trial was also grown in the second rains. Two entries failed under our conditions, and two are very late maturing.

(9) The development of Central Shoot Fly resistant types showed promising progress. Four balanced lattice squares of 121 or 169 entries each were grown in the first and second rains and evaluated. It is clear that the early assessment of Central Shoot fly attack is of far less practical use than a later assessment of the proportion of plants that grow through and head normally. It is also clear that a lot of replication is necessary to detect varietal differences.

(10) The progress with the tetraploid programme was particularly encouraging. Dr. B. N. Majisu is now here to give proper attention to the cytological aspects of the work. The derivatives of the 2ADX cross series are basically good grain sorghums, and the crosses of these to a much wider range of autotetraploid types has led to the production of a useful 5ADX series. Several breeding bulks are in operation, and the ms_3 is being added in to the programme. A yield trial of tetraploid and diploid sorghums was done in the second rains. Five of the tetraploid entries came within 85% of the yield of the diploid Serena control, two of them giving yields 96% and 98% of that of Serena. Four of these entries were from the cross 2ADX 4/3/4. This is a very encouraging result, and high yielding tetraploid grain sorghum is now within our reach.

(11) With the help of Dr. Eberhart the trials are now analysed on the Nairobi computer, or at Rothamstead by courtesy of Dr. Yates. This has been an invaluable aid which has enabled far more trials to be carried out.

(12) The greatest lack at present is the almost complete absence of a seed multiplication and distribution system for sorghum. An attempt was made to multiply H x 301 on a Group farm, but this failed owing to the poor farming standards of the members. We were informed that Tanzania could have used 200 tons of Serena seed last year, had it been available. The Tanzania Agricultural Department propose to multiply some of our hybrid H x 301 next year.