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FIFTH ANNUAL REPORT

of the

AID-ARS Project

Major Cereals in Africa
1968

TABLE OF CONTENTS

	Page
Introduction	1
West Africa	
Sorghum, Maize and Millet Breeding	4
Sorghum Regional Trials	4
Sorghum Breeding - Northern Nigeria	7
Maize Breeding - Zaria	12
Maize Breeding - Mokwa	16
Pearl Millet - Zaria	21
Pearl Millet - Northern Nigeria	26
Entomology	30
Plant Pathology	41
Soil-Water-Plant Relation	48
Soil Fertility Trials with Maize	49
Maize Improvement - Ibadan	51
Sorghums and Millet in East Africa	58
Sorghum Breeding	60
Millet Improvement	65
Cereal Agronomy	71
Cereal Entomology	75
Cereal Processing Technology	80
Maize Improvement	86

Maize Improvement

Breeding and Quantitative Genetics Research 87

Environmental Response 92

Incorporation of Qualitative Genes 107

Maize Agronomy 110

Seed Production and Distribution 118

Extension 121

Marketing and Utilization 121

East African Maize Varietal Trials 123

Regional Cooperation 129

Summary 136

FIFTH ANNUAL REPORT
of the
AID-ARS Project

Major Cereals in Africa
G. F. Sprague

INTRODUCTION

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

Current Status

This AID-ARS project was authorized in 1963 under PASA AID/Res 20. The initiation of research activities was delayed due to: (1) problems in obtaining formal approval of the African Governments involved, (2) the unavailability of local housing, and (3) difficulties in recruiting competent staff. The first staff assignments were made in July and September 1964.

The program, as initially outlined, has three major objectives: (1) to increase cereal production in Africa through cooperation with, and support to research organizations in Nigeria, Uganda, and Kenya; (2) to stimulate and sponsor cooperative research on all aspects of crop production throughout the area, and (3) to provide in-service training, at the headquarters stations, to individuals sponsored by their respective governments.

Regional centers were established in both West and East Africa to serve the differing ecological requirements. In West Africa the sponsoring agency is STRC authorized by OAU. Nigeria serves as the host country with the main center located at Ahmadu-Bello University, Institute for Agricultural Research, Zaria. Staff at this location are concerned with sorghum, millet and maize breeding, insect and disease control and soil-water-fertility plant relations. A smaller center is located at the Federal Research Station, Moor Plantation, Ibadan. Work at this location is limited to maize breeding and pathology. In East Africa the sponsoring agency is EAAFRO. Research work is concentrated at three locations; Soroti Experiment Station, Uganda; the National Agricultural Research Station, Kitale, Kenya; and the East African Industrial Research Organization at Nairobi, Kenya. Work at Soroti includes sorghum and millet breeding, soil-water-fertility-plant relations and insect control. The work at Kitale is concerned with maize breeding and production. Work on cereal milling and processing with primary emphasis on sorghum was initiated in July 1968 at Nairobi, Kenya.

It should be emphasized that the research activities of our staff are fully cooperative with and form a part of the total research effort at a given location. In the sections which follow some measure of the cooperation is indicated by the authorship of the individual sections of the report.

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

Name	Discipline	When Posted	Location
O.J.Webster 1/	Geneticist	Sept. 1964	Inst. for Agr. Res.. Zaria, Nigeria
S.B.King	Pathologist	April 1967	"
G.T.York	Entomologist	Febr. 1966	"
K.R.Stockinger	Soil Scientist	June 1966	"
A. Kosage 1/	Administrative Aid	July 1965	Kaduna, Nigeria
J. Craig 1/	Maize Path-Breeder	Sept. 1965	Federal Res. Sta. Ibadan, Nigeria
G.A.Schumaker 1/	Soil Scientist	May 1966	Serere Agr. Exp. Sta. Serere, Uganda
K.L. Starks	Entomologist	Jan. 1967	"
L.V. Peters	Millet Geneticist	March 1967	"
S.A.Eberhart 2/	Maize Geneticist	July 1964	Nat'l. Agr.Expt.Sta Kitale, Kenya
L.H. Penny	Maize Geneticist	Nov. 1968	"
Allen Shepherd	Cereal Technologist	July 1968	EAIRO Nairobi, Kenya
_____ 3/	Agronomist		Tanzania
_____ 3/	Agronomist		Malawi
_____ 3/	Agronomist		Zambia

1/ Now serving second tour of duty

2/ Completed 2 tours of duty, Dec. 1968

3/ Included in the FY-69 budget, but no authorization to recruit

Actual and proposed changes in policy deserve inclusion as background information. The original PASA was funded by AID/TCR (now War on Hunger). In FY-69 funding of the East African segment of this project was assumed by the African Bureau. It is proposed that the entire project will be funded by this Agency beginning with FY-70.

Efforts have been underway for several years to expand the East Africa segment to include all of Eastern Africa. The Ministerial Committee of EACSO (now East African Community) authorized the Director of EAAFRO to enlist the services of a scientist from an agency external to the region to study the existing program and to explore with officials of the various countries their interest in participating in a cooperative regional program on cereal crop improvement. Dr. Ralph W. Cummings of the Rockefeller Foundation was persuaded to accept this assignment. A report covering his survey and study has been submitted under the title "Report of a Feasibility Study on Cooperation Among Eastern Africa Countries in a Regional Cereal Crop Research Program". At the time Dr. Cummings' report was submitted (May 1968), countries expressing some interest in such an expanded cooperative program included: Ethiopia, Kenya, Malawi, Tanzania, Uganda, and Zambia. Since this date Republic of the Congo has also expressed interest in such cooperation and maize trials have been initiated.

No official action has yet been taken by the countries mentioned to implement the expanded program. The three new positions, included in the above listing, would represent implementation of the enlarged cooperative program.

Interest continues in the development of closer working relations between the research and educational institutions. Where suitable arrangements can be made, up-grading the technical competence of the local staff will be simplified and the efficiency of in-service training greatly strengthened.

Reports of the separate research activities will be presented in the following pages; responsibilities and cooperation involved are indicated by the authorship of each section or subsection.

Sorghum, Maize and Millet Breeding in West Africa

O. J. Webster

D. J Andrews, cereal breeder at the Institute for Agricultural Research, Zaria, is responsible for the sorghum improvement program in Nigeria. His main interest is in the development of varieties and hybrids for the Guinea Savanna zone, in which Zaria is located. When Ayo Abifarin returns to Kano upon the completion of his studies towards his Ph.D. degree at Purdue, Indiana, early in 1969, he will resume work in breeding sorghums for the Sudan Savanna zone represented by northern Nigeria. The improvement of pearl millet work in Nigeria is centered at Kano under the supervision of Dr. B. Bhardwaj. Andrews and Webster have a small breeding project on millet at Zaria. Franz de Wolff has completed his second crop season as maize breeder at Mokwa. This station is located about halfway between Zaria and Ibadan. Dr. Craig, maize pathologist for the major cereals project, not only conducts research in maize pathology at the Federal Department of Agricultural Research, Ibadan, but also coordinates the regional maize trials for west Africa. A. Ebong, also at Ibadan, has as one of his duties the organization of the zonal maize trials in Nigeria. Dr. Henry Wiggin, USAID maize breeder for the Western State, has taken the lead in developing high lysine maize varieties for southern Nigeria.

Each of the crops has its project leader who is responsible for the development of one improvement program for Nigeria for each crop. Annual meetings are held to discuss progress reports and plan for future work.

Sorghum Regional Trials. The first regional sorghum nursery was organized under this project in 1966. The cooperating countries in west Africa included Senegal, Upper Volta, Niger, Dahomey, Ghana, Nigeria, Cameroun Republic, and Chad. This nursery in 1966 included nine hybrids from India, four from the U.S.A., one hybrid and one variety from Uganda, and the remainder (nine varieties) from the cooperating countries. Since some of the cooperators asked to grow some of the Indian hybrids for a second season (1967), seed was requested but did not arrive in time for general distribution. This seed was planted in Nigeria and Niger.

Seed of the following varieties was distributed early enough in 1967 for planting at all locations:

Entry	Source
WX-60	Nigeria
Serena	Uganda
HX 57	Uganda
NK-300	U.S.A.

The results from the small trial revealed the necessity of setting up regional sorghum nurseries, one or more for the Guinea Savanna zone with 35 to 50 inches of rain falling over a 4½ to 5-month period and one for the drier Sudan Savanna with a rainfall of 25-35 inches in 3½ months.

Yield results from the trials conducted in Nigeria and Maradi, Niger (1967) are given in Table 1. The good yields reflect a favorable growing season in this part of Africa. Five of the hybrids from India grew over six feet tall and the stalks lodged before the grain was mature. Their height was relatively short when compared to that for the local varieties but the stalks were not sturdy enough to support the large heads. The hybrid from Uganda, HX 57, was superior in yield to its male parent Serena and seems to be well adapted to the Sudan Savanna. Unfortunately, seed is not available for distribution and grain quality is inferior to the traditional varieties of the area. The same applies to the hybrid NK-300. The trials at Maradi demonstrate the specific adaptation of the two indigenous varieties to the local soil types. Babadia Ja is well suited for the sandy soil while 137-67 does much better on the heavier, valley soil.

Mr. Andrews provided seed of nine dwarf and semi-dwarf photoperiod sensitive, long season types for the 1968 northern Guinea Savanna zone. One additional variety was contributed from Dahomey. Seed of five entries from Ghana and one from Upper Volta was mailed to me in March but did not arrive in Zaria until July. Seed for the Guinea Savanna yield trial was provided for 16 locations in ten countries: Ghana, Upper Volta, Dahomey, Senegal, Cameroun, Mali, Nigeria, Chad, the Gambia, and Togo. By mid-October at Zaria, Nigeria, the Dahomey variety had not headed. This illustrates the probable need of setting up two nurseries within the Guinea Savanna zone.

The Sudan Savanna yield nursery included the following entries:

Entry	Source
CK-60 x IS 84-2	India
172 x IS 84-2	"
3675 x IS 3691	"
172 x IS84-1	"
Meloland	U.S.A.
NK-300	"
E 57	"
F 65	"
E 61	"
Hegari	"

Table 1. Yields of the west African nursery grown at five locations in Nigeria and two in Niger, 1967. Yields - lbs. per acre.

			Nigeria					Niger(Maradi)	
			Zaria	Kano	Kasarawa	Tungun Tuda	Daura	Sandy soils	Valley soils
CSH-1	Ck-60 x IS 84	India	1829	2037	976	2239	1330	1157	1445
	172 x IS 84	"	2240	2279	1148	2360	1356	1381	3437
	CK-60 x IS 84-2	"	2392	2690				1339	3183
	172 x IS 84-2	"	2569	2230				1429	2825
CSH-2	Ck-60 x IS 3691	"	2278	1606	1348	1997	984	1236	1870
	3675 x IS 3691	"	2124	806				880	1888
	2219 x IS 3691	"	2003	1871	1548	2239	1485	1327	1680
	Ck-60 x IS 3691-2	"	3132	2632				1026	1148
	3675 x IS 3691-2	"	3337	1424	1493	1755	770	1098	1960
	172 x IS 3798	"	2243	2698	1211	1634	1473	1224	2036
	229 x IS 3541	"	2809	3057	1881	2118	1974	2013	2172
	3675 x IS 1122	"	----	1508	1813	1089	122	271	1866
Georgia 615	U.S.A.	2009	2009	1840	469	1815	1082	1449	1590
NK 300	"		3031	2963	2611	2541	1763	1348	3716
NB 505	"		1129	1802	----	----	----	----	----
RS 610	"		1317	1571	----	----	----	----	----
Hegari	"		1546	1506	1137	1634	433	1179	2086
Serena	Uganda		2359	1502	1414	1815	561	1303	1971
HX 57	"		3037	2888	1971	2723	1658	1906	2168
WX-60	Nigeria		----	752	----	----	----	169	211
137-62	Niger		----	----	----	----	----	833	2645
Babadia Ja	"		----	----	----	----	----	2075	818
Local			----	----	1509	1815	399	----	----

Seed of 39 varieties was provided for 15 observation nurseries in the Sudan Savanna zone. Of these, 23 were selected out of over 200 in the Uniform Asian Nursery growing at the Institute for Agricultural Research, Zaria, in 1967. The remainder were introduced hybrids. The purpose of this nursery is to visually screen a large number of varieties and select only those which show any potential for inclusion in yield trials. We hope to find varieties for this zone which are superior to those now being grown. Some of the hybrids show possibilities but seed is not available. Varieties are the only answer until seed production problems in the area can be solved. These problems are discussed by Mr. Andrews.

The rainfall in the Sudan Savanna zone in 1968 was below normal and crops failed in many areas. The yield nurseries in Nigeria were a disappointment when compared with the excellent trials in 1967. The "valley" trial at Maradi, Niger, was irrigated and good yields will be harvested. The dry land trial planted north of Bernin Konin, Niger failed to head, supposedly due to a Fusarium sp. At Kasarawa, south of Sokoto in Nigeria, 16 inches of rain was reported with the last effective rain falling on August 30. The nursery at this location was a near failure. The local variety will give a low yield but it will still be better than that from introduced varieties and hybrids. The results of the trials conducted during the past three years would suggest that it will be desirable to incorporate germ plasm of the indigenous varieties in breeding new varieties for this zone in West Africa. Such a program is being initiated.

Sorghum Breeding in Nigeria, 1967-68

D. J. Andrews

Plant breeding and associated studies for the improvement of grain yield in sorghum were continued according to the program described in the previous report. Research work was carried out at Samaru, Kano and Mokwa, and field trials conducted at locations in all the northern states of Nigeria.

Much of the findings reported here are from 1967 work, since the current crop, though planted in May, will not be completely harvested until December.

The Improvement of Indigenous Varieties

Yield tests on strains selected from the tall local cultivars have previously been concluded and recommendations made for the major ecological areas except the Southern Guinea and Derived Savanna zones. Here, Mokwa Farafara selection number C7-4-2 has, for the second, consecutive year given 26% more yield than the local checks which averaged 926 lb. grain per acre in experiments at six locations. The trials currently being grown will probably be the last on this type of material.

The Production and Testing of Dwarf Lines

A 48-entry trial of dwarf lines was located at seven provincial places in the Northern Guinea and Sub-Sudan savanna zone (between 5°20" and 13°30"E, and 10° and 11°40"N). Five similar trials of 30 lines of essentially this same material (from the 1966-67 dry season nursery) were planted within reach of Zaria. These twelve trials were carried out at a higher population level (19,360 plants per acre) and at higher fertilizer levels (40 lb. P_2O_5 and 66 lb. N per acre) than standard for trials on tall local varieties which are susceptible to lodging.

In the provincial series of trials, three failed and the average experimental yield over the other four was only 960 pounds of grain per acre, though the best variety (gSK-WX) gave twice this figure. Without comparison with the five similar Zaria trials, these results would not excite any particular interest. The comparison, however, shows that the yield potential of the dwarf lines was by no means realized in the provincial trials, and that this potential is considerable since the mean yield of the four successful Zaria trials was 1800 pounds per acre. Also, the same control variety (Short Kaura), while yielding 1880 pounds per acre in provincial trials, gave 3950 pounds per acre in the Zaria experiments, the highest mean yield so far recorded in variety trials on adapted sorghums.

As concluded from the first trial (1966) on these lines (which are still subject to pedigree selection), the highest yielding group are those lines derived from crossing Combine Kafir with Short Kaura and backcrossing to Short Kaura. Individually good lines have been selected from a number of crosses: irradiated dwarf Kaura by (Hegari x Farafara), Short Kaura x Makaho da Wayo, Combine Kafir by (Short Kaura x Makaho da Wayo), and Combine Kafir x Farafara. Short Kaura, having a high yield potential itself, has also proved to be a good yield parent in crosses for producing both stable varieties and F_1 hybrids.

The grain type of the lines in test ranges between the yellow endosperm grain of the Kaura type through to the superior white Farafara type. Crude protein analyses of the grain of eight high yielding lines showed values between 9.3 and 12.8 per cent. The parental varieties Short Kaura, Combine Kafir, and Farafara were 8.3, 9.6, and 10.0 per cent, respectively.

The results from some of the better lines in these trials are shown in Tables 2 and 3. In 1968 trials containing 32 entries have been planted at twelve locations. For various reasons four of these are known to have failed and yields on the remainder will be reduced by the widespread early cessation of the rains which has affected much of West Africa this year.

Table 2. Zaria Series

Line No.	Type	Mean Yield lb grain/ac 4 trials xxx	Agronomic Data - Samaru: Height cm xxx	Heads per plant xxx	Threshing % N/A	Grain/Straw Ratio N/A
5912	SK	4139	220	1.11	76	1: 2.68
4086	(CK-SK)SK	3301	223	1.26	78	4.67
SHI	Hybrid 93x5764	2923	150	1.19	79	1.89
4081	(CK-SK)SK	2886	160	1.39	79	1.79
4435	(CK-SK)SK	2818	182	1.08	81	2.48
4403	CK-Kur	2737	168	1.11	71	2.70
4392	(TS-SK)SK	2666	225	1.14	74	4.13
4087	(CK-SK)SK	2658	165	1.28	78	2.32
4431	(CK-SK)SK	2611	115	1.18	80	2.77
4070	(CK-SK)MDW	2576	190	1.26	78	2.87
4432	(CK-SK)SK	2548	115	1.17	74	2.42
4426	(CK-SK)SK	2420	130	1.03	75	1.90
4021	gSK-WX	2359	195	1.77	72	4.33
4427	CK-SK SK	2242	127	1.14	78	2.18
4427	(CK-FF)FF	2164	150	1.49	75	3.04
60	WX	2142	190	1.32	76	2.11
2743	SK MDW	2099	125	1.31	76	2.06
2123	CK-FF	2013	137	1.46	72	3.22
5764	(CK-SK)SK	1952	135	1.26	78	3.13
397	Heg - FF	1722	260	1.36	77	2.42
SE (80 entries) -		±234	±10.3	±0.19	--	--
5% LSD -		457	41.0	0.56	--	--

Table 3. Provincial Series

Line No.	Type(1)	Mean yield lb/ac 4 sites(2)	Related lines appearing in Zaria series (Table I)
Hybrid SK	93 x 5912	2499	--
51	gSK - WX	1887	4021
5912	SK	1886	5912
60	WX	1824	60
96	(CK-SK)SK	1345	(4239)
93	CK-Kor	1324	4403
3393	(CK-SK)SK	1284	4435
403	SKMDW	1065	2743
555	(CK-FF)FF	1036	(4223)
1275	SK-SKMDW	1017	4070
397	Heg - FF	866	397
1081	CK - FF	817	2123
SE (48 entries)	-	±141	--
5% LSD	-	392	--

(1) Abbreviations

SK = Short Kaura
gSH = Gamma Short Kaura (dwarf)
WX = Hegari x Farafara select.
CK = Combine Kafir 60
Kor = Korgi
MDW = Makaho da wayo
FF = Farafara
Heg = Hegari
TS = Tan Shallu (Table I only)

(2) Experimental sites

CM4(67)Bauchi
CP5(67) Darazo
ET6(67) Zuru
HP5(67) Hong.

The dwarf varieties being produced and tested fall roughly into two height groups, 6-8 feet (2-dwarf) and 4-6 feet (3-dwarf). At present, most of the high yielding lines are 2-dwarf, and, though this represents a great improvement over the tall (12 feet plus) local sorghums, further gains (in respect of fertilizer usage, grain/straw ratio, lodging resistance) should be obtainable from 3-dwarf types. 3-dwarf varieties would also be suitable for mechanical harvesting. However, to make full use of dwarf varieties, the agronomic problems of growing them need to be investigated.

Experimentation has been started on the population x N (P not limiting) response of four types of dwarf sorghums: a 3-dwarf line and a 3-dwarf hybrid and two 2-dwarf varieties, one of which tillers freely.

Striga species, mainly S. hermonthica, is a parasite of sorghum and other cereals in the savanna zones and greatly reduces yields. Striga nurseries have been established on infested sites to screen breeding material. In 1967 eighty lines were assessed for their reaction to heavy attack by Striga and this ranged (compared with yields at uninfested sites) from a 20% reduction in yield to total loss. Several lines were apparently more tolerant than the local varieties.

Recombination for the production of new varieties was continued both by making hand crosses and by the use of genetic male sterility. The latter is used to ensure random mating in a bulk planted in isolation, into which a wide range of genotypes have been placed. The numerous hand crosses made in 1967 were grown as F_1's in the dry season and seven acres have been planted at Samaru in 1968 to large population F_2's.

Hybrids

At Samaru, two trials with 24 and 25 entries, respectively, tested hybrids produced by crossing short lines onto a common female parent. Data from eight of the entries is given in Table 4. The means yields from these trials were 2910 and 2710 pounds of grain per acre. In trial I the best pollen parent was a Short Kaura x (Combine Kafir x Short Kaura) line, giving 3780 pounds per acre, and in trial II the hybrid with Short Kaura itself, at 3970 pounds per acre. Both these hybrids were 3 x 2-dwarf and were 6.5 and 8.0 feet tall, respectively. Several pounds of seed of the best 3-dwarf hybrid (4.5 feet) identified last year were produced and called Samaru Hybrid No. 1. This was entered in trial II and gave 2880 pounds of grain per acre at a population of 19,360 plants per acre (on 3-ft ridges). The same hybrid was also planted in an agronomy experiment and gave the top yield of 4570 pounds per acre at a population of over 60,000 plants per acre, the spacing being nearly 9 inches on the square. This difference emphasizes the need to find the best way of growing dwarf hybrids and varieties.

The best hybrid in trial II was also entered in the provincial series of dwarf lines trials reported in Table 3.. This hybrid was the highest-yielding entry in trial, averaging 2500 pounds per acre, 32 percent more than the best line.

Backcrossing was continued to produce other suitable female parents apart from the one already developed. Two groups of material show promise: a) lines derived from the cross Combine Kafir B x Korgi and b) from irradiated Short Kaura x (Hegari x Farafara). Other potential lines have had to be discarded because of the difficulty of eliminating partial male fertility in the A-lines.

Test plantings of production plots have indicated that planting in August could lead to good hybrid seed production. When planting is at the normal time (late May) the "nicking" of the parents is good because of the fixed relationship of their photoperiodic flowering response. However, seed set was only 50-70% on the seed parent. This was improved by the use of a motorized knapsack sprayer (empty) with the air-blast directed across the pollen rows. Plantings made in late October grew slowly and flowered irregularly. Also Kaura-type pollen parents do not shed pollen freely late in the dry season. The best results came from planting in late August when flowering takes place some 75 days later, which is before the dry season conditions become severe. Supplementary irrigation is necessary and control of shoot fly is advisable for a few weeks after planting.

Table 4. 1967 Sorghum Hybrid Trials, Samaru. Data of 8 of 45 entries.

Pollen Parent No.	Type	Grain yield lbs/acre	Grain to straw ratio	Wt. of 1000 grains (gm)	Mean No. Heads/ plant	Ht. cm	Days to Anthesis
Trial I							
4072	(CKA-SK)SK	3781	1: 2.62	21.5	1.37	193	121
4074	(CKA-SK)SK	3500	2.79	28.5	1.24	223	120
4285	(CKA-FF)FF	3094	2.30	21.5	1.12	150	125
S.E.(24 entries)		±290	-	-	-	-	-
5% LSD		578	-	-	-	-	-
Trial II							
SK 60	SK	3970	1: 2.48	28.0	1.13	213	120
R36	SK-MDW	3748	2.26	25.5	1.12	163	123
3404	(CKA-SK)SK	3097	2.44	27.5	1.14	173	118
-	Variety WX	2929	3.40	21.5	1.78	150	118
S.E.(25 entries)		±176	-	-	-	-	-
5% LSD		496	-	-	-	-	-

Maize Breeding in Northern Nigeria

O. J. Webster

About 12 million acres of sorghum and 8 million of millet are grown annually north of the Niger-Benue Rivers. The average acre yield for sorghum is about 600 pounds, and somewhat less for millet. Using seed of improved varieties of sorghum and with good management, yield increases of three-to-fourfold are possible. The yield potential of maize at Zaria is two to three times greater than that of sorghums.

The yields which may be obtained from maize in the Zaria area are illustrated by the results from the West African Uniform Maize Trial. These figures can be compared with those from other locations in Tables 14 and 15 of Dr. Craig's report.

Entry	Pounds of Grain per Acre		
	1967	1968	Average
NS-5	4855	5602	5229
H 59	4864	4780	4822
Jaune D'Ina	4855	4581	4718
NS-4	3594	5639	4617
NS-1	3748	5179	4464
H.J.	4138	3836	3987
ZM-10	3628	4247	3938

The above yields compare favorably with the best reported from East Africa. The question which follows is, "Why then isn't maize a more prominent food crop in at least the Zaria area of Nigeria?" The reasons given in the 1967 report included susceptibility to root lodging and striga, the people's preference for sorghum and millet for food, and, no doubt the most important is the sensitivity of the crop to a shortage of unbalance of soil nutrients. Sorghums and millet are generally grown without fertilizer but when maize is grown under the same conditions it will fail. In East Africa where maize is grown at high elevations, the soils are more fertile and in many areas good crops are grown without the use of inorganic fertilizers.

The land used for experimental purposes at the Institute for Agricultural Research (IAR), Zaria, has been in continuous cultivation for over 15 years with a rotation of sorghums, groundnuts, cotton, maize and cowpeas. Prior to 1965 farmyard manure (FYM) was applied each year at a rate of 3 tons per acre with 100 pounds of superphospate preplant, and sulfate of ammonia was added later in varying amounts depending upon the crop. FYM is no longer available for the fields planted to the cereals and now an additional 100 pounds of superphosphate is applied. For maize, the general practice is to apply 30 pounds of nitrogen at the time of thinning (3 weeks after planting) and an additional 60 pounds 5 to 6 weeks later. No plant residues are left on the experimental fields except from maize, which is harvested by mid-October and the stalks are chopped and left on the field. Dr. Stockinger will include in his report more detail about the work in progress with fertilizers on maize. In order for the crop to be grown in the area, a proper formulation of fertilizer must be determined for farmers to get economic returns.

At the present time there is no organized market or distribution system for the cereal crops as there is with cotton and groundnuts.

When the farmer is assured of a profitable cash market for his crop we can expect an increase in cereal production. At present only enough of the cereals are planted to take care of the local requirements for a year. Fortunately, in most of Nigeria the rainfall each season is in excess of the requirements for the cereals and, except in the extreme north, crop failures do not occur because of drought.

This project is concerned with the development of adapted maize varieties for northern Nigeria and learning what management practices must be followed to produce economic returns. Fortunately, the local population has not established a preference for the type of grain which is most acceptable as food. One village near Zaria was given seed of the variety V-10, which is a mixture of yellow and white dent. The people of this village like this variety because when milled, after the pericarp is removed the flour is as white as that from wheat. A flinty sorghum grain is preferred and if such a type of maize is acceptable, the damage from storage insects will be less than for floury or dent types.

There is a good correlation between the relative yields of maize grown at Ibadan and Zaria. This does not mean, however, that the best yielding varieties at Ibadan are agronomically the best for Zaria. The southern varieties, represented by NS-1, have tall stalks with high ear placement (5 to 7 feet). Our breeding program at IAR is aimed at developing varieties with an ear height of 5 feet or less, hopeful that this feature will help in reducing root lodging.

The present program is based on selection within three composites made up three years ago, mostly of introductions from Colombia. Their composition is as follows:

<u>Composite 1:</u>

F_1 Biu Yellow (U.S. Cornbelt dent composite) x Mexico-5
F_1 Mexico-5 x C-8(USA 342 x Diacol V206)-4 x Diacol V 254
F_1 Mexico-5 x C-18, Composite III Amarillo Centro America (Cuba 40-Hawaii 5-San Luis Potosi 104)-2
F_1 Mexico-5 x C-31 (Ven. 1-6 x Eto)-4

<u>Composite 2:</u>

F_1's involving
C-5 (Yotoco x Diacol V 351)-3
C-8 ((USA 342 x Diacol V206)-4 x Diacol V 254)
C-10 ((Cu. 325 x USA 342)-4 x Diacol V 254)
C-12 ((Yotoco x Diacol V 351-2 x Diacol V 254)
C-16 Compuesto Garibe Amarillo (Cuba-Puerto Rico)-2
C-18 Composite III Amarillo Centro America (Cuba 40-Hawaii 5-San Luis Potosi 104)-2
C-30 (D.V. 101 x D.V. 351)-4
C-31 (Ven. 1-6 x Eto)-4
C-33 D.V. 351
Biu Yellow (U.S. Cornbelt dent composite)

Composite 3:

F_1 Biu Yellow x C-8 (USA 342 x Diacol V 206) x Diacol V 254
F_1 Biu Yellow x C-18 Composite III Amarillo Centro America (Cuba 40-Hawaii 5-San Luis Potosi 104)-2
F_1 Biu Yellow x C-25(Mea. 9 Lineas Blancas x Mez. 5 variedades Blancas)-3

Mass selection has been practiced in these composites for 2 years. This year their yields in pounds per acre with Bulk 2 from Dr. Wiggin, Ibadan, and their F_1 hybrids were:

Composite 1	5862
Composite 2	5763
Composite 3	5826
Bulk-2	6035
Composites 1 x 2	6607
Composites 1 x 3	5872
Composite 1 x Bulk-2	5681
Composites 2 x 3	5254
Composite 2 x Bulk-2	6080
Composite 3 x Bulk-2	6244
Mexico-5 (ck)	5454

The composites were more productive than Mexico-5; but as might be expected due to similar genetic background, there was little heterosis in the hybrids between the three composites. Thehybrids with Bulk-2 were more productive as expected because the parents are genetically more diverse.

The three composites have been included in Composite A as described in Dr. Craig's report. They make up 3 of the 30 components in this very broad base composite. The first cycle was grown at IAR this season and the second will be produced under irrigation during the dry season. After 4 or 5 cycles of recombination, a selection program will be started to isolate varieties for the area.

Ear to row yield trials of 120 ears selected from Composites 1 and 3 were conducted in 1968 using the method outlined by Dr. Eberhart. The yields of the top 16 in Composite 3 ranged between 8700 and 9700 pounds per acre, a record for IAR. The yield of the check Mexico-5 was 5800 pounds. The top yielding entries will be the basis for reselection. In addition to giving high yields, the best "lines" also were low in number of root lodge plants.

Each year high lysine, and brachytic lines are planted with Composites 1 and 3 and detasseled. Grain from the detasseled rows is planted in the dry season irrigated nursery and selfed or sibbed. In the case of the high lysine selfs, the opaque kernels are separated out to be planted with the next wet season composite.

Among other introductions from the International Maize and Wheat Improvement Center, Mexico City, we received seed of Tuxpano br_2 br_2 (SRV 66 A 3454) this year. This brachytic is better adapted than those which were provided from Mississippi a year ago.

Because of the excellent performance of variety hybrids with Biu Yellow as one parent in 1967, a crossing block was set up this year to produce several pounds of seed of 11 hybrids for trial plantings in 1969.

IAR has been supplying seed obtained from East Africa for trials on the Mambilla Plateau, 4800 feet elevation. The annual rainfall is about 80 inches, falling from April through October. The yields have been relatively low, as shown by those of three entries grown in two years.

	1966	1967
Kitale Sny. III	1960	2715
H-632	4116	2860
V-10 x Syn. III	3354	2961

In 1968 the East African trial was grown on the Plateau. One report indicated that it had been eaten by goats but a later report stated that there would be some crop to harvest. Nearly 100 pounds of seed of KCE was increased at the Institute for a field scale planting on the Plateau in 1969.

Maize Program, Mokwa, Nigeria

F. deWolff

Mokwa is situated in the middle belt of Nigeria, latitude 9° 19' N, elevation 500 feet. The rainy season lasts from April till October, with an average rainfall of 42 inches. The season is long enough to grow two maize crops, with a possible third crop in the dry season under irrigation, which speeds up maize breeding considerably.

The main problems challenging breeding work are:

(1) The low yielding potential of the existing varieties under Mokwa conditions.

(2) Root lodging, caused by a combination of factors: tall plants (about 10 ft.), a sandy soil and the occurrence of heavy rain storms.

(3) Harvest of the crop in the middle of the rainy season. Moisture content of the grain at harvest lies between 30-40%, which makes artificial drying necessary.

There are no major disease or pest problems.

In 1968 a beginning was made with growing a broad based composite, Mokwa Composite A, similar to the composites A made up in Ibadan and Samaru, with entries mainly of Central American origin.

Colombian introductions put together by Dr. Webster at Samaru in three composites, were mass selected at Mokwa for two cycles. In the second cycle the composites were interplanted, keeping the entries separate, making selection possible within each composite. The second cycle selection is used as a source for full-sib family selection.

In 1967 Dr. Webster's Composite 2 was used to study individual plant characters. The plants under observation were open pollinated and their offspring were planted in 1968 in a 11 x 11 lattice design with 4 replications. The data from this experiment were used to calculate two selection indices:

(1) Selection index including yield:

$$y = 0.009\ b_1 + 0.787\ b_2 + 0.124\ b_3 \quad (1)$$

(2) Selection index without yield:

$$y = 1.039\ b_2 + 0.086\ b_3 + 0.046\ b_4 \quad (2)$$

in which

b_1 = yield of dry grain/plant in gram

b_2 = no of ears/plant

b_3 = no of days from planting to silking

b_4 = length of main ear in cm.

Expected progress from selection, compared with ordinary selection for yield is, for formula (1) 179% and for formula (2) 149%. Formula (2) will be used in selecting full-sib families and S_1's. Contrary with mass selection, selection with formula (2) is based on both parents, which should make it an efficient tool for selection.

Full-sib family selection is done as follows: In 1968, a number of full-sib families were made. Using formula (2) the best 144 were selected to be grown in a yield trial in 1969, to make a final selection of 22 full-sib families. The 144 entries will be planted in the nursery in time, so that as soon as the results from the yield trial are available, S_1's can be made from the 22 selected families. The S_1's again will be selected using formula (2). The results of the yield trial will be used to calculate formula (2) again, so as to get a more precise estimate. So, full-sib family selection consists of three stages, grown within one year, with two selections using formula (2) and one selection based on a yield trial.

Formula (1) will be used to continue mass selection in Dr. Webster's Colombian composites, comparing selection with and without a selection index.

The recommended Nigerian varieties, NS-1 and EAAFRO-231, are maintained with mass selection once a year. NS-1 is selected in three different ways.

(1) Selection for yield with 29,040 plants/acre
(2) Selection for yield with 14,520 plants/acre
(3) Selection for yield and two ears with 14,520 plants/acre.

Using 29,040 plants/acre, one cycle of selection gave a significant increase in yield from 3330 to 3600 lbs/acre, an increase of 8%.

Maize Agronomy

A planting dates observation trial in 1967 with three varieties planted at intervals of three weeks showed gradually decreasing yields, from 3-4000 lbs/acre from plantings in April to less than 2000 lbs/acre from plantings in August. In 1968 ten varieties of maize were planted every week for 5 weeks, starting on April 14, after the first rain, and ending on May 13. For all varieties, the first planting was not superior to the last one. Conditions were ideal for the experiment as no planting suffered from shortage of rain. Apparently postponing planting till a few weeks after the rains have started does not affect the yield.

A trial testing plant density x nitrogen with NS-1 gave no significant results in 1967. In 1968 a population of 19,360 plants/acre was significant over 14,520 and 10,890 plants/acre, with yields of 2721, 2564 and 2573 lbs/acre respectively. Applications of one hundred lbs N/acre was superior to 50 lbs. acre and to the control with yields of 2905, 2741 and 2212 lbs/acre. The interaction, spacing x nitrogen was not significant. The best combination, 19,360 plants/ acre with 100 lbs N, gave 3039 lbs/acre.

An experiment testing nitrogen, potash, trace elements and lime is being carried out at Mokwa by the soil chemist from Samaru. A small experiment with magnesium at two locations gave, at one location, a significant increase in yield of 25%.

Table 5. Uniform maize trial - West African material

Variety	Source	Stand in %	Days to Anthesis	Ear Ht. Cm	Broken & Lodging Plants %	Yield Lbs/acre
NS-1	Nigeria	78	66	122	22	3340 A
NS-5	Nigeria	85	64	104	16	3130 AB
NS-4	Nigeria	86	64	118	21	2590 BC
Comp. Yaune d'Ina	Dahomey	79	60	85	19	2540 BCD
HJ	Ivory Coast	82	64	98	12	2310 CDE
BDS	Senegal	76	54	50	8	1960 CDE
MTS - H 59	Ivory Coast	84	57	82	12	1920 DE
Dar Salam	Upper Volta	81	54	60	14	1850 E
ZM 10	Senegal	77	57	60	19	1790 E

Varieties with a letter in common are not significantly different at 5% level.

C.V. : 18%

Design: randomized block with 4 replications
Plot size: 2 rows x 21 ft.
Spacing: 1 x 3 ft. (42 plants/plot, 345.7 plots/acre)
Fertilizers: 1 cwt superphosphate/acre at planting
30 lbs nitrogen 2 weeks after planting
45 lbs nitrogen 6 weeks after planting

Table 6. Maize trial involving East African materials

Variety	Source	Stand in %	Days to Anthesis	Ear Height Cm	Lodging in %	Yield lbs/acre
SR 52	Zambia	80	55	97	11	3380
Embu Comp. I	Kenya	74	52	122	22	3300
Hybrid 632	Kenya	88	58	130	24	3220
Hybrid 511	Kenya	86	54	128	23	2640
Hybrid 613 B	Kenya	92	62	176	34	2560
Askari Comp.	Malawi	83	61	130	24	2530
White Star	Uganda	82	63	98	33	2430
Mokwa local	Nigeria	60	58	138	38	2430
LH 11	Malawi	89	60	126	15	2240
Ilonga comp.	Tanzania	65	54	111	16	2140
Ukiriguru comp. A	Tanzania	94	61	155	17	2060
Embu comp.II	Kenya	55	55	105	31	2030
Zambia local comp.	Zambia	80	58	111	6	1980
Katumani comp.B	Kenya	88	56	125	17	1950
Katumani V x Kat. VI	Kenya	79	55	75	10	1740
Kitale comp.E	Kenya	83	63	145	27	1430

Differences among varieties was not significant

C.V.:35%

Design: randomized block with 3 replications
Plot size: gross 4 rows x 11 ft., net 2 rows x 11 ft.
Spacing: 1 x 2.5 ft. (22 plants/plot, 792 plots/acre)
Fertilizers: as for above

Table 7. Varietal response in a date of planting trial

Varieties	Stand in %	Days to Anthesis	Ear ht. Cm	Broken & Lodging Plants %	Yield lbs/acre
NS-1	89	58	137	33	3761 A
Bulk-2	93	56	108	25	3698 A
H 503	83	59	120	34	3546 AB
EAAFRO 231	831	61	143	30	3512 ABC

Continued on next page

Table 7. cont'd

	Stand in %	Days to Anthesis	Ear ht. Cm	Broken & Lodging Plants %	Yield lbs/ acre
Comp. II	86	55	98	23	3275 BCD
Comp. I	87	56	94	28	3208 CD
V 56	88	57	98	24	3183 D
Comp. III	86	54	87	23	3048 DE
Mokwa local	91	57	131	35	3042 DE
C 7	87	57	97	23	2843 DE

Varieties with a letter in common are not significantly different at 5% level.

C. V. (varieties): 17%.

Design: 5x5 latin square with split plot arrangement
main treatment: planting dates
sub-treatment: varieties
Plot size: main plots, gross 12 rows x 29 ft., net 10 rows x 21 ft.; sub-plots, 1 row x 21 ft.
Spacing: 1 x 3 ft. (21 plants/subplot, 691.4 subplots/acre)
Fertilizers: as for Table 6.

Pearl Millet

O. J. Webster

The work on improving pearl millet in Nigeria is directed by Dr. B. D. Bhardwaj, Institute for Agricultural Research, Kano. Dave Andrews and I cooperate with Bhardwaj and carry on small breeding projects at Samaru. This report briefly covers only the phase of the work for which I am directly responsible.

The major objectives of the Nigerian project are to develop productive lines, with resistance to lodging and resistant to downy mildew and smut. The local early varieties (gero) which are grown throughout Nigeria appear to be a similar heterogenous population. Collections of these populations have been yield tested at several locations in northern Nigeria, and one from Bornu Province in most trials was superior to the others. The Ex Bornu populations has been the source of local material used to improve the early millet.

Andrews and Curtis began a mass selection program in Ex Bornu in 1965. Even after four cycles of 10% selection there is still considerable phenotypic variability within the population. While these breeders were mass selecting I began an inbreeding program in the anticipation that after two or three generations of inbreeding, the plants with low potential yielding ability could be eliminated and the better lines composited. The yield results of the 2nd and 4th cycles of mass selection were compared with intercrosses of S_2 lines (table 8). The trial was not precise enough to measure any difference in yield. A few hybrids and composites from India were also included in this same trial. Except for entries L 101 A x BIL 3-B and Tift 23 A x BIL 3-B, they were highly susceptible to downy mildew. The L 101 A composite had the fewest lodged stalks.

Crosses between lines from Ex Bornu and the cytoplasmic sterile line 23 A have given both F_1 sterile and fertile progeny. A few A lines are being developed by backcrossing, but these will be of little value since they are not of the plant type we are looking for. Several lines have been crossed to 23 B and large populations are being grown to identify short plants, four to six feet in height, that produce numerous tillers which develop simultaneously. Dr. Bhardwaj has a number of good F_3 lines.

My breeding work in 1967 included the advancement of numerous inbreds from Ex Bornu. One hundred twenty-nine lines were "top crossed" to plants grown from seed of the 4th cycle of mass selection. This was done by planting the lines in alternate rows with the male. The tillers were removed from the plants in the lines to reduce the frequency of sib pollinations within the rows of inbreds. The purpose of this crossing plot was to produce top-cross seed for conducting progeny trials to identify the lines potentially the most productive.

Seed from 35 top-crosses and with that of Ex Bornu (5th cycle of mass selection) was planted in a 6x6 lattice design, four replications in 1968 (table 9). Stands were nearly perfect and yields were exceptionally high for this crop. The average yields of 10 of the top-crosses were significantly better than that of Ex Bornu. Remnant seed of these lines will be planted in a crossing block in the 1968-69 dry season to produce seed of a synthetic for trial plantings in 1969. We hope that Dr. Bhardwaj will also have a "dwarf" synthetic ready for testing, and if the performance of the dwarf comes up to expectations it will no doubt be the one released.

Hundreds of spikes were covered with kraft bags in 1967 and 1968 for selfing and very few were found after the bags were removed which were not partially or completely smutted. This is quite disturbing since the smut of millet is supposedly floral infected. We may be able to capitalize on this problem of producing selfed seed by using it as a means of screening for resitance to smut.

In addition to my work with Ex Bornu population I have also made crosses with Ex Bornu lines and strains of late millet (maiwa) from Upper Volta which may have resistance to downy mildew. No conclusions are available from this work.

When Dr. Burton visited Nigeria in 1965 we found an area between Pankshin and Langtang where a yellow seeded, late pearl millet is being grown. A chemical analysis made at IAR revealed that these lines contained carotene and xanthophylls. The discovery of a source of yellow endosperm in millet was published in Crop Science. Nothing was done with this collection in 1966, so Mr. Andrews, Dr. King and I made another collection in October of 1967. Samples from three spikes with yellow seed and a sample of grey millet, together with seed of a yellow endosperm sorghum (Kaura) and a white seeded sorghum (Farafara), were sent to Dr. G. E. Inglett, U.S.D.A., Northern Utilization Research and Development Division, Peoria, Illinois, U.S.A., for analysis. He returned the following information:

Sample	Carotenes, p.p.m.	Xanthophylls, p.p.m.
Yellow Millet 1	0.3	10.6
Yellow Millet 2	1.9	5.3
Yellow Millet 3	1.3	8.7
Pearl Millet	0.3	2.2
Sorghum, Short Kaura	0.9	5.7
Sorghum, Farafara	0.6	1.0
"Average" U.S. Hybrid Maize	2.5	23.2

Table 8: Yields and other agronomic data from a pearl millet trial, Samaru, Nigeria, 1967. Planted May 25. Plot size 4 rows spaced 3' apart by 25' long.

Entry	Source	Days to bloom	Plant height	Mildew	Yield per acre
		No.	cm	pct.	lbs.
General Composite	India	48	165	49	831
L 101 A Composite	"	50	170	65	860
L 101 A x BIL 3-B	"	48	170	3	1340
Tift 23 A x J 88	"	46	130	89	870
Tift 23 A Composite	"	46	180	65	795
H B-1	"	47	160	7	1728
2nd Cycle Ex Bornu	Samaru	58	300	6	1608
4th Cycle Ex Bornu	"	62	300	7	1575
Intercrosses of S_2 lines	"	59	300	13	1694

Description of entries in yield trial (table 8)

General Composite:

This consists of the fourth unselected block generation of a complex consisting of approximately 600 of our best inbred lines. Selected at Coimbatore in 1965, it has subsequently been grown there in three consecutive seasons each year to maximize outcrossing.

L 101 A Compo.

This is a block of 30-40 advanced generation hybrids with L 101 A, a Ludhiana GMS line having large, spindle-shaped earheads and large grains. Plants producing seed from selfing in this material should automatically restore fertility on the Georgia CMS source, since it carries the sterile cytoplasm background.

L 101 A x BIL 3-B:

This has been one of the better hybrids in India, although it did not perform as uniformly well during this past year. It is similar in some respects to HB-1 Tift 23 A x BIL 3-B) in general performance and adaptation, although plant, earhead and grain characters are different.

Tift 23 A x J 88:

This is a slightly earlier hybrid developed in Gujarat for somewhat limited moisture conditions in western India. The derivation of J 88 is of the same source as BIL 3-B, viz., from S 350 (an improved Punjab strain).

Tift 23 A Composite:

This is similar to L 101 A Composite described above, except that it consists of advanced generations of about 50 elite hybrids with Tift 23 A.

H B-1 (Tift 23 A x BIL 3-B)

2nd Cycle Mass Selection Ex Bornu

4th Cycle Mass Selection Ex Bornu

Intercrosses of S_2 lines from Ex Bornu

Table 9. Topcross trial of S_1 lines from Ex Bornu, Samaru, Nigeria, 1968. Date planted, May 17. Plot size, single rows 3 feet apart x 20 feet in length.

Entry number	Plants		Yield per acre
	Total	Downy mildew	
	No.1/	Pct.	Lbs.
51	81	4	3602
59	84	10	3599
88	82	9	3526
48	81	5	3483
64	83	8	3480
117	84	1	3831
89	84	2	3394
50	84	4	3340
39	84	1	3337
40	84	6	3260
55	82	16	3060
35	84	14	3057
60	81	9	3033
48	84	1	3032
118	84	12	2993
87	84	11	2954
61	84	13	2947
82	84	4	2927
98	84	8	2905
60	84	17	2868
45	84	6	2859
91	84	11	2849
106	84	7	2827
116	84	2	2782
94	84	10	2736
74	83	14	2734
88	84	10	2718
46	84	10	2680
Ex Bornu	84	8	2627
94	84	6	2560
43	83	11	2554
53	83	17	2521
70	84	11	2449
41	82	10	2384
118	84	7	2236
87	83	5	2212

1/ Full stand = 84 plants
LSD - .05% = 543 lbs per acre C.V. = 6.5%

Pearl Millet Improvement in Nigeria

Bhup D. Bhardwaj

The objective of the millet research program at Kano is the production of improved varieties or hybrids for extension in the savanna zones. Work was continued both on "gero" (P. typhoides) and "Maiwa" (P. Maiwa). The program was carried out in close cooperation with the personnel of the OAU-STRC Joint Project 26 and Dave Andrews stationed at the Institute for Agricultural Research, Zaria.

A. Yield Trial

1. Gero. Testing of selected Nigerian millet populations was continued in 1968 at 13 locations. Results from the outstations are still awaited but the results obtained at Kano are given below.

Gero Grain Yield in Pounds Per Acre

Ex Bornu	Ex Bauchi	Ex Benue	B5	N6	Samaru bulk	Local
340.8	494.0	257.3	317.8	277.5	200.4	235.1

These yields are about half of last year, which may partly be attributed to late planting and partly to the drought condition during early August.

2. Maiwa. Yield testing of maiwa populations was continued and tests were carried out at 5 locations. Being a late season crop, the results are still awaited.

B. Breeding

1. Isolation of Inbred Lines

a. Further inbreeding of gero and maiwa was continued. Because of limited resources only part of the lines of gero isolated last year were carried on to S_3. The remaining lines will be sown next year. All the maiwa inbreds were, however, carried on to S_2. The total number of inbreds now available at the station are:

Crop	No. of Inbreds	Stage of Inbreeding
Gero	874	S_2
Gero	1,279	S_3
Maiwa	211	S_2
Total	2,364	

All the S_3 gero inbreds have been evaluated for maturity, height, tillering, downy mildew resistance, lodging, etc.

b. Further inbreeding was carried out in gero inbreds with bristled spikes. Ten S_2 lines of gero having varying density and length of bristles have been isolated.

c. Further inbreeding was also carried out to isolate inbreds with the red venation character.

d. Fourteen S_1 Dwarf lines of maiwa have been isolated. The height of these inbreds ranges from 85 cm to 125 cm, the average height of the maiwa crop being 245 cm.

2. Tift 23 A x gero variety Ex Bornu crosses

The crosses made in the 1967 dry season were carried through F_3 during the 1968 wet season. The F_3 progenies were evaluated for a number of characters and the promising ones selected to be carried on to F_4. Range of variability of the various characters in the selected progenies is given below.

Character	Minimum	Maximum
Days to 50% flowering	51 days	75 days
Height	91 cm	275 cm
Primary tillers	5	37 (per plant)
Total spikes	5	54 (per plant)
Length of spikes	12 cm	53 cm
Girth of spikes	5 cm	12 cm

While most of the lines were resistant or tolerant to downy mildew, there were a few which were mildly susceptible. None of the lines was completely susceptible to downy mildew. Since there is very little variability within each line, it is proposed to multiply these lines during the 1968-69 dry season so as to have enough seed for yield tests during the 1969 wet season.

3. Production of cytoplasmic male sterile lines in gero

Tift 23 A is highly susceptible to downy mildew in Nigeria, especially during the regular growing season of the millet crop. For this reason it is necessary to develop female parent lines with more tolerant Nigerian varieties. Selected F_2 plants from Tift 23 A x gero crosses were crossed onto Tift 23 B during the 1967-68 dry season. The progenies were grown during the 1968 wet season and the plants showing tolerance were selfed. The progenies of the selfed plants will be grown during the 1968-69 dry season. Each plant in the progeny will be crossed with Tift 23 A so as to check the fertility status of each plant during the 1969 wet season. This eventually should result in isolation of A and B lines with some degree of resistance to downy mildew.

4. Tift 23 A and 23 B x maiwa crosses

Crosses were made during the 1967-68 dry season between Tift 23 (both A and B) and maiwa with a view to evaluating material for the male sterility genotype and also to assess the possibility of producing hybrids and male sterile lines in this crop. It is also expected to obtain short season day neutral segregations from these crosses which can be used in the gero program.

Five populations of maiwa were used in making these crosses. A sample consisting of about 70 plants from each population was selected at random and these were individually selfed and crossed onto Tift 23 A and 23 B lines. The progenies of resulting crosses and selfs were evaluated during the 1968 wet season. The number of selfs and crosses studied in each case is given below.

Population No.	Number of selfs	No. of crosses with Tift 23 A	Tift 23 B
100	57	57	57
200	59	59	59
300	53	53	53
400	51	51	51
500	50	50	50
Total	270	270	270

The results are summarized below.

a. Height. All F_1's were of medium height whereas the selfs were very tall.

b. Photoperiodic sensitivity. Tift 23 A and 23 B lines are day length neutral whereas maiwa is day length sensitive. The F_1's were all neutral to day length and the selfs were all sensitive. As a result, F_1's matured earlier than selfs.

c. Downy mildew reaction. Reaction of F_1's to downy mildew ranged from complete susceptibility to resistance. There were very few F_1's in the latter class.

d. Sterility*. F_1's between Tift 23 A and maiwa segregated for sterility as indicated below:

Population No.	All fertile progenies	All sterile progenies	Progenies segregation for sterility
100	16	1	29
200	23	2	30
300	26	1	18
400	33	1	12
500	23	1	21

* Includes only those progenies which survived till flowering.

These results suggest that genes for the maintenance of cytoplasmic male sterility are present in the five populations of maiwa.

3. Yield. Some of the F_1's were extremely vigorous and productive. Yield data were taken on some of the most promising ones. The per plant grain yield of the top 10 F_1's is given below.

Pedigree	Per plant yield of selected F_1's in lb. grain		
	** Average over healthy plants per row	Average over total plants in row	Total plants per row
23 A x 148	0.54	0.54	8
" x 166	0.85	0.78	12
" x 236	0.92	0.46	12
" x 308	0.55	0.38	13
" x 322	0.51	0.36	10
" x 340	0.48	0.32	15
" x 364	0.45	0.34	16
" x 511	0.46	0.39	11
" x 557	0.25	0.22	17
" x 560	0.47	0.42	10

** Excludes plants which did not form any spikes due to downy mildew attack.

Performance of some of the F_1's seems to be extremely encouraging and it is proposed to produce hybrid seed of these combinations in larger quantities for regular yield trials next season. If the performance is as good as it appears to be, further yield tests will be carried out.

Selected F_1's between Tift 23 B x maiwa will be carried on to F_2 for further evaluation during the 1969 wet season. Steps are also being taken to test cross the F_2 with a view to isolating male sterile lines and maintainers.

5. Other breeding projects

a. Evaluation of modified mass selection method. Second cycle of selection has been completed in gero population of Ex Bornu. It is proposed to advance it further by one or two cycles of selection before finally evaluating the effectiveness of this method.

b. Study of inbreeding depression in maiwa. Third cycle of inbreeding has been carried out in five populations of maiwa. It is proposed to estimate the inbreeding depression in this crop during the 1969 wet season.

c. Miscellaneous.

1. Different populations of gero and maiwa millets were multiplied in isolation for future use.

2. Seed of Tift 23 A and Tift 23 B was multiplied during the dry season.

Entomology

G. T. York

As mentioned in previous Annual Reports, the entomological work is of two types: (1) the protection of valuable experimental material with minimum regard for costs and (2) the suppression of insect damage to local low yielding varieties where expenses are of vital concern. To this should be added a third phase dealing with the eventual development of high yielding varieties grown under conditions differing from the normal situation now prevailing in West Africa. Different and undoubtedly more severe insect problems will arise with these changed conditions.

Work during the past year has been concentrated on the three major groups of insect pests, the shoot flies, the stem borers, and the sorghum midge. Points of major interest concerning these follow.

Shoot flies

The work on shoot flies was a cooperative project, as was the case last year, including Mr. J. C. Deeming, Mr. Richard Langham, and myself.

In the Third Annual Report of 1966 we reported our first work on the shoot fly *Atherigona varia soccata* Rond., previously classified as *A. indica infuscata* v. Emd. The following year, (the Fourth Annual Report) we had to revise our thinking from one species of shoot fly to several species of shoot flies. At that time nine species had been collected from northern Nigeria.

Work this year has again greatly expanded our knowledge of the shoot flies. At the present time we have collected 30 species, seven of these being new species. Table 10 prepared by Mr. Deeming, lists the species and gives pertinent data regarding each.

Another phase of our work was the seasonal abundance of the shoot flies. Plantings of three varieties of sorghum, one of millet and one of maize were made at weekly intervals. Collections of infested plants were made at biweekly intervals, and these were brought to the laboratory and the larvae reared to adults. On the basis of material from sorghum (guinea corn) the following chart was prepared.

Table 10. Species of Diptera Reared from Cereals Showing Deadheart (1966-68). (All from Samaru unless otherwise indicated).

Species	Season: Rainy	Season: Dry	Crop: guinea corn	Crop: millet	Crop: maize	Alternative hosts: Nigeria	Alternative hosts: Elsewhere	Parasites (Nigeria)	Distribution	Importance as a pest in Nigeria
MUSCIDAE: ANTHOMYIINAE										
1. *Delia arambourgi* Seguy	x		x	x		*Dactyloctenium aegyptiacum*, *Eleusina indica*	Barley, wheat, *Pennisetum typhoides* & *clandestinum*	Opius sp. (Bracon.)	Old World tropics	Major
COENOSIINAE										
2. *Atherigona varia soccata* Rond. = *indica infuscata* van Emden	x	x	x	x				*Phaenocarpa* sp. (Brancon.)	Africa, Mediterranean	Major
3. *A. lineata* Adams var.	x		..						Africa	Some, sporadically
4. *A. l. ugandae* van Emden	x		x	x				? *Opius* sp.	Africa	Considerable, sporadically
5. *A. ponti* sp. nov.	x	x	x	x					Nigeria	Some
6. *A. pseudonaqvii* sp.nov.	x			x					Nigeria	Considerable, sporadically
7. *A. tomentigera* van Emden	x		x						Africa	Minor
8. *A.* sp. nn *ruficornis* Stein	x		x	x					Nigeria	Minor

Table 1. continued

Species	Season Rainy	Season Dry	Crop guinea corn	Crop millet	Crop maize	Alternative Hosts Nigeria	Alternative Hosts Elsewhere	Parasites (Nigeria)	Distribution	Importance as a pest in Nigeria
9. A.(Achritochaeta) enigma	x	x	x	x					Nigeria, Kenya	Advantageous if a predator
MYDAEINAE										
10. Helinella lenticeps Thoms.=propingus Stein	x		x				Various fruits		Old World tropics	None
CHLOROPIDAE:CHLOROPINI										
11. Mepachymerus sabroskyi sp.n.	x		x	x					Nigeria Cameroon	Minor
12. Lasiosina sp. nov.	x		x			Hyparrhennia dissoluta			Nigeria, Sudan	Minor
13. Elachiptereicus abesaynicus Becker	x			x					Africa	Minor
OSCINELLINI										
14. Scoliophthalmus micantipennis Duda	x		x	x	x			Pseudeucolia sp. (Cynipoid)	Africa	Major
15. S. trapezoides Becker	x	x	x		x[A]				Africa	Considerable
16. S. femoralis Becker	x		x						Africa	Some
17. Anatrichus erinaceus Becker Loew	x	x	x				maize		Africa	Some
18. Anacamptoneurum obliquum Becker	x	x	x			wheat[B]	maize		Africa	Some

Table 1. continued

Species	Rainy	Dry	Guinea corn	millet	maize	Alternative Hosts Nigeria	Alternative Hosts Elsewhere	Parasites (Nigeria)	Distribution	Importance as a pest in Nigeria
19. *Oscinella* sp. nr. *dimidiofrisa* Becker	x		x			*Dactyloctenium aegypriacum* *Eleusina africana*, *Andropogon gayanus* var. *bisquamulatus*, *Eragrostis pilesa*				
20. *Oscinella* sp.	x		x						Nigeria	Some
21. *Elachiptera scutellaris* Adams	x				x				Africa	Minor
22. *Aprometopsis flavofacies* Becker		x		x					Africa	Minor
23. *Polyodaspis* sp.nov.		x		x			guinea corn		Nigeria Kenya	Minor
24. *Epimadiza gallicola* Seguy	x		x			Mahogany fruits & rama, both when damaged	*Phaseolus lunatus*, rotting cotton boll, rotting castor seed		Africa	None
25. *Conioscinella* sp.1	x		x						Nigeria	Minor, if any
26. *C.* sp. 2	x		x[C]	x[D]					Nigeria Niger	Minor, if any

Table 1. continued

Species	Rainy	Dry	Guinea corn	millet	maize	Alternative Hosts Nigeria	Alternative Hosts Elsewhere	Parasites (Nigeria	Distribution	Importance as a pest in Nigeria
LONCHAEIDAE										
27. ? *Dasiops* sp.	x		x						Nigeria	Advantageous if a predator
DIOPSIDAE										
28. *Sphyracephala* sp.	x		x		x[D]				Nigeria	Prob. none
AGROMYZIDAE										
29. *Agromyza* sp. nov. nr *intermittans* Becker	x		x		x				Nigeria	Prob. none
30. *Pseudonapomyza* sp.	x		x						Nigeria	Prob. none

It may be noted that numbers were quite low in July, increased greatly in August, and dropped off again in September. This season's work, added to that of last year when heavy infestations were noted by mid-July, clearly indicates a heavy build-up of the shoot flies during the mid-season growing period. This in turn points out the serious hazard from shoot flies for any mid-season plants of short season sorghum if they are to mature at the end of the rainy season.

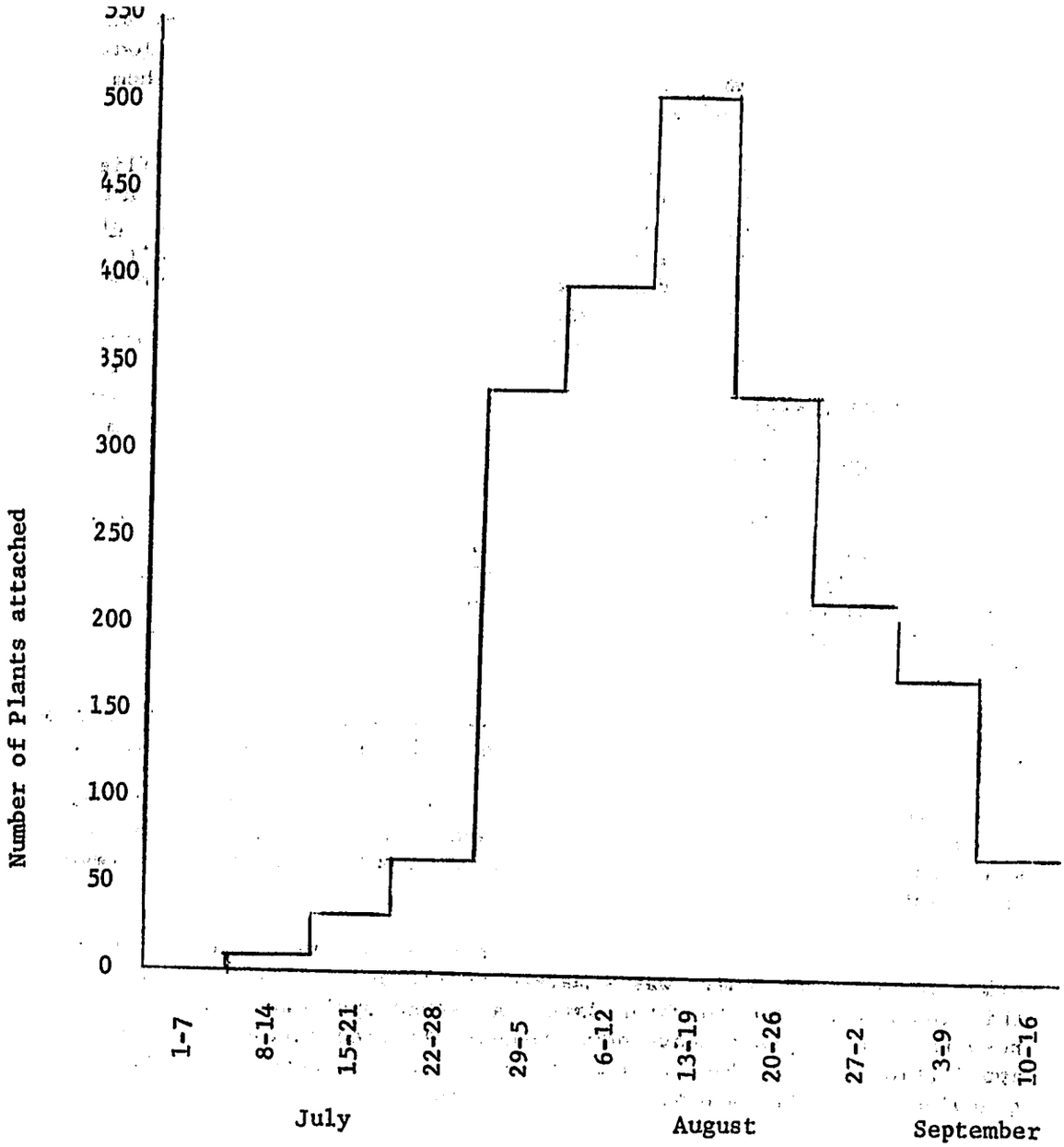
Some preliminary work was done on egg deposition by shoot flies. Of the more abundant species it was found that each had a distinct and recognizable egg when seen under sufficient magnification. Eggs of Atherigona varia soccata were the most conspicuous, being a shiny white, and were always laid on the undersurface of the leaf. Although one egg per plant was the usual thing, two and three eggs per plant were also fairly common. Eggs of Delia arambourgi were cream colored and were laid on either leaves or stems in various numbers. These were easily detached from the plant, while with the previous species they were quite firmly attached. It was found that accurate egg counts were virtually impossible, especially when rains splashed soil on the plants.

Chemical control of shoot flies has been on a very limited scale. Phorate (Thimet) which was shipped air freight early in the year had not arrived by November. This material when applied in the soil at planting time is considered one of the best methods of control for shoot flies. It was needed for trials in West Africa and also to serve as a standard for comparing other materials.

Five percent Azodrin granules applied to the soil at planting time in a small trial did not appear to materially reduce the infestation.

Five percent endosulfan (Thiodan) granules applies to plants one to two feet high appeared to control shoot flies. However, this was a small patch of experimental sorghum and no checks were left for comparing treated and untreated plants.

In another test with endosulfan granules on small plants four to eight inches high, there was a marked reduction of infested plants but this lasted only two to three days. A second application gave similar results. Small plants have never been considered suitable for the application of granules, as they do not catch and concentrate the granules as is the case with larger plants.



Plantings commenced June 12 of 100 seeds each of Farafara, Maldandi and Short Kaura at weekly-intervals. Attacked plants removed at bi-weekly intervals.

Figure 1. Number of young plants of sorghum on W7 field attacked by shoot flies during growing season 1968.

Stem Borers

An outstanding control for the stem borer Busseola fusca (Fuller) has been found through work this season. Although experiments have not been of the caliber that one would like for scientific purposes, the results have been sufficiently clear cut to demonstrate the remarkable properties of one material and possible utilization of a second material. Thiodan (endosulfan) as a five percent granular formulation gave outstanding results, while five percent Azodrin granules might also be an acceptable commercial control.

As indicated above, difficulties were encountered in setting up experiments. The sorghum originally intended for insecticide tests had such a poor and uneven stand that only a small portion of the field could be used. Another small plot, donated by the Botany Department, was only large enough for two replicates. A third field, made available when it was thought to be too late for proper testing, was actually the most spectacular of the three tests. In addition to the problem of obtaining fields, the rather crude method of applying the granules was further complicated by muddy areas in the fields, thus giving an uneven distribution of insecticide on the plants. The granules were applied by two methods. In one they were allowed to flow by gravity through a small funnel, thus simulating a machine application. In the other the "pinch" method was used, a small amount applied by hand to indivudual plants. Single, double and triple applications were made in the first experiment, single and double applications in the second, and only one application in the last test. Dates of application and sampling are given with the tables of the different experiments.

Table 11 gives data pertinent to the first experiment. A glance at the amount of material applied indicates the difficulty encountered in trying to get the same amount of each material at each application. The Azodrin granules were of good, free flowing quality and fairly uniform applications were made. Thiodan granules had a tendency to form lumps and clog the discharge tube. The first application was considered too light and in attempting to compensate for this an excess was used on the other two applications.

Results of the early application indicate quite clearly that Thiodan was the superior material. Other applications might well be biased by the fact that more Thiodan was applied than Azodrin.

Table 11. Azodrin and Thiodan, both 5% granules, for control of the stem borer *Busseola fusca* (Fuller) on sorghum variety line 5764 (Ck x Sk) Sk.

Treatment*1	Material	Amount per acre E	I	L	Total	Borers*2 L	M	S	Total
1 E	Azodrin	16.7			16.7	3	63	15	81
2 E I	"	16.7	17.5		34.2	0	36	15	51
3 E I L	"	16.7	17.5	19.4	55.5	0	3	24	27
4 I	"	--	17.5		17.5	1	32	9	42
5 I L	"	--	17.5	19.4	36.9	0	5	24	29
6 L	"	--	--	19.4	19.4	0	7	18	25
7 Ch	-	0	0	0	0	45	45	5	95
8 E	Thiodan	13.6			13.6	2	11	13	26
9 E I	"	13.6	29.4		43.0	0	1	5	6
10 E I L	"	13.6	29.4	30.0	73.0	0	0	1	1
11 I	"	--	29.4		29.4	0	1	5	6
12 I L	"	--	29.4	30.0	59.4	0	0	0	0
13 L	"	--	--	30.0	30.0	0	0	0	0
14 Ch	-	0	0	0	0	37	32	3	72

*1. E = Early, July 10, 1968
I = Intermediate, July 17, 1968
L = Late, July 24, 1968

*2. Counts of borers made August 6 through August 10, 1968. Numbers are the borers from 20 stalks, 10 from each of the two replicates: L = large, M = medium, S = small.

In the second experiment, shown in Table 12, the pinch method was used and the applications of the two materials were considered equal. In both the single and double applications the Thiodan was much better than the Azodrin. It was also noted in this test where the sorghum variety Hegari was used, some of the leaves of plants treated with Azodrin turned a deep red a few days after treatment. Colored photographs were taken of this condition. No adverse effect on plant development was noted.

Table 12. Azodrin and Thiodan, both 5% granules, for control of the stem borer Busseola fusca (Fuller) on sorghum variety Hegari.

Treatment applied	Material	Borers[1] L	M	Total
July 11	Azodrin	41	65	106
July 11 & July 18	"	12	32	44
July 11	Thiodan	5	15	20
July 11 & July 18	"	2	1	3
Check	-------	156	40	196

[1] Counts based on 3 replicates of 10 plants each for a total of 30 plants. L = large, M = medium.

A third test was made using only Thiodan, since all of the Azodrin had been used in other experiments. The variety was Short Kaura line 5912. The insecticide was applied on July 25, following completion of the other experiments. It was considered too late for satisfactory stem borer control. However, treated plants showed a remarkable recovery and in two weeks' time were in excellent condition. Sampling for borers was done on August 19. Twenty treated plants had a total of four borers while untreated plants had 37. The untreated counts were considered low, as several plants had been killed but no borers remained in them. Regardless of borer counts, this was an outstanding demonstration of borer control, and was particularly significant for the fact that the application was late in the season when borer control was considered impossible.

Sorghum Midge, Contarinia sorghicola (Coquillet)

Although no counts were made of midge abundance, the population on the experimental plantings increased greatly toward the end of the season and caused considerable damage.

Plant Resistance to Sorghum Pests

Scientists in India have noted varying degrees of resistance to the sorghum pests while working with the World Collection being grown there. More detailed tests are also made of selected varieties.

In order to test some of the more promising varieties under West African conditions, samples of 54 varieties were obtained. These included 11 for shoot flies, 29 for stem borer, and 14 for sorghum midge

These were planted at two different times to check performance under the different growing conditions. The first planting was made June 14 and 15, and the late planting on August 6. All varieties were checked for all of the insects without regard to their previous record of resistance to specific pests. Considerable time was spent in developing methods for the proper evaluation of insect damage. Poor germination of some varieties further complicated the evaluation.

The first planting had relatively little shoot fly damage, but was subjected to a heavy infestation of the stem borer Busseola fusca. Most varieties had 75 to 100 percent of the plants infested. Varieties IS 1501, IS 1044 and IS 1568 appeared to be less susceptible but size and condition might have had some influence on egg laying. There were also differences in tolerance to the infestation.

The second planting had a heavy infestation of shoot flies. Varieties IS 1044, IS1099, IS 1061 and IS 1034 (Maldandi 35-1) showed moderate resistance. Selection of the most susceptible variety for future reference work was IS 464, which was previously reported to have resistance to the shoot fly and stem borer.

The stem borer attack was quite light on the second planting, even though there was a heavy moth flight while plants were at a susceptible stage.

Sorghum midge damage has not been evaluated.

Summary

Thirty species of shoot flies have been collected from northern Nigeria. Pertinent data on these are given in Table 11.

Eggs of the more abundant species of shoot flies could be distinguished when properly magnified.

Shoot flies reach peak abundance in August.

Five percent Thiodan (endosulfan) granules gave only temporary control of shoot flies on small plants.

An outstanding chemical control for the stem borer Busseola fusca was found this season. Five percent Thiodan granules gave excellent control with residual action. Even late applications, when stem borer control was considered impossible, gave outstanding results. Five percent Azodrin granules, although not as effective as Thiodan, might be an acceptable control practice.

Studies of sorghum varieties resistant to attack by insect pests showed differences but no outstanding varieties yet.

Plant Pathology

S. B. King

Research on the pathology of sorghum, millet, and maize is directed toward the identification of the major disease problems of West Africa and finding methods for their control. For the most part, resistant varieties constitute the most practical approach toward the control of diseases on these crops. However, in addition to locating sources of resistance, investigations are being conducted to obtain information about certain pathogens and diseases which in turn might lead toward other practical and economic methods of control.

Touring

Touring makes it possible to become better acquainted with the various practices and problems of agriculture in West Africa. In addition, touring provides an excellent opportunity to meet and exchange pertinent information with research workers in other countries. Countries visited during the past year include Ivory Coast, Ghana, Niger, Chad, and Cameroun. Several shorter trips were also made within Nigeria.

To my knowledge, there are very few research plant pathologists in West Africa, and none outside Nigeria who are devoting full time to research on the diseases of sorghum, millet, and maize. Plant breeders, for the most part, are those best acquainted with the disease problems. On the basis of personal observations and discussions with research personnel, it appears that the disease problems on sorghum, millet, and maize in West Africa are generally the same as those in Nigeria. Hence, it is felt that information obtained from pathology research in Nigeria will be transferable directly, or with few alterations, to other countries in West Africa.

Sorghum Pathology

Leaf Diseases

Since 1965, parts of the world sorghum collection have been grown annually for the purpose of locating resistance to certain leaf diseases. Due to its large size, approximately three seasons are required to observe the reactions of all entries at least once. This necessitates maintenance of seed viability for at least three years. The improved seed storage facilities under construction should ease this problem in the future.

This year over 1300 entries of the world collection were planted and their reaction to leaf anthracnose (colletotrichum graminicola), sooty stripe (Ramulispora sorghi), oval leaf spot (R. sorghicola), and zonate leaf spot (Gloeocercospora sorghi) were recorded. There have been good natural infections of these diseases during both 1967 and 1968. Only that portion of the collection planted in 1965 has been scored for reaction to downy mildew (Sclerospora sorghi) since that was the only year of an epidemic.

Leaf diseases generally appear not to be serious in farmers' fields, although occasional exceptions including oval leaf spot, leaf anthracnose, and gray leaf spot (Cercospora sorghi) have been noted. In the Samaru area grey leaf spot usually does not become apparent until mid-August, but within a matter of two weeks can become serious. Leaf anthracnose, though usually associated with physiological maturity, has been observed as a serious problem on 4 to 6 week-old plants. Research workers in Niger, Chad, and Cameroun have indicated that leaf blight (Helminthosporium turcicum)can be a serious problem.

It is believed that two factors are responsible for the low incidence of leaf diseases in farmers' fields. These are 1) the fact that local varieties have built up a certain amount of tolerance through many years of selection, and 2) the fact that low plant populations associated with peasant agriculture do not provide as suitable a microenvironment for infection on the leaf surface as do high plant populations. Although leaf diseases presently are not a serious problem on peasant grown sorghum, they could become more significant in the future as farmers change to new, higher yielding varieties and higher plant populations. All the above mentioned leaf disease organisms as well as Helminthosporium rostratum, Ascochyta sorghina, and Pseudomonas and ropogoni are present in farmers' fields and conceivably could rapidly build up to epidemic proportions on susceptible hosts.

Smut

All the smuts commonly reported on sorghum are found in Nigeria and likely are present through West Africa. Yield losses from smuts in Nigeria approach the 8-10% figure generally reported for West Africa. Most of this loss could be avoided if seed were treated with fungicides prior to planting. Inexpensive fungicidal seed treatments are available in Nigeria, but poor distribution coupled with insufficient extension have greatly limited their usefulness.

While touring in Nigeria, certain observations were made on the different smuts with respect to geographical location. In brief these are as follows. Long smut (Tolyposporium ehrenbergii) was primarily found in areas of low rainfall. Covered smut (Sphacelotheca sorghi) was prevalent in the higher rainfall areas between Samaru and points such as Gusau, Kano Kaduna, Jema's, Jos, and Mubi, but was almost absent in the low rainfall

areas near Sokoto and between Kano and Maiduguri. Loose smut (S. cruenta) was found to a limited extent in all areas observed, although in the drier sandy areas, loose smut was generally confined to tillers. Head smut (S. reiliana) was more common in cooler areas such as those on the Jos Plateau and in those parts of fields shaded by trees.

This year an effort was made to obtain information on the reaction of selected sorghum lines representing a wide range of genetic material to long smut, covered smut, and loose smut. The long smut trial planted at Kano was a failure due to insect damage and drought. At Samaru, two identical sets of 55 sorghum selections were inoculated with single isolates of loose smut and covered smut. Inoculation involved dusting seed prior to planting with spores at the rate of one gram of spores to 100 grams of seed. Milos, feteritas, and White Yolo were highly resistant and Pierce Kaferita was moderately resistant to both loose smut and covered smut. Kafirs, hegaris, and kaoliangs ranged from moderately resistant to highly susceptible to both. Three selections of sumac appeared immune to loose smut and moderately resistant to covered smut. Single entries fromNigeria, Mali, Sudan, and India were found to have a high degree of resistance to both smuts. On the basis of the results of these trials it hasnot been possible to determine the specific races of the smuts involved. It would appear, however, that the smut isolates used represent races different from those already described in the literature.

On the basis of symptoms alone, there appear to be two, and perhaps more, types of covered smut in Nigeria. One is characterized by a long (up to 3/4 inch), narrow, pointed sorus and the other by an almost spherical sorus which attains a diameter of up to twice that of the grain. Both types have been found on the local Kaura and Farafara varieties in farmers' fields, and both types produced like sori on several other varieties in experimental plots. There is some indication that these types constitute separate physiologic races.

Variations in loose smut symptoms were also noted. Smutted plants were observed in which one or more heads produced sori with distinct soral membranes and columella, while other smutted heads on the same plants had no apparent columella or membranes. Smutted heads having characteristics of both loose and covered smut were also observed.

Hybridization likely occurs between loose smut and covered smut. Future research on these two smuts will be directed toward their identity and the amount of variation which occurs. This information will be useful in breeding varieties resistant to these diseases.

Research on head smut primarily involves the development of a satisfactory inoculation technique. Hypodermic injection of sporidia into the growing point has given moderate results on one occasion and has failed to result in any infection on three other occasions.

Ergot

It has been demonstrated in Nigeria that male sterile sorghum lines are highly susceptible to ergot (Sphacelia sorghi) This disease is of particular concern to plant breeders who anticipate using male sterile lines for the production of hybrid seed.

The suggestion has been made that the problem of ergot in hybrid seed production could be avoided by timing flowering to occur either before or after the normal period in late September and October. This would require planting early and supplementing with irrigation before the rains, or planting late and irrigating after the rains. In order to determine whether natural infection is confined to the period of normal flowering, the A line of Combine Kafir 60 was planted at 2-week intervals beginning on May 1, about one month earlier than the normal planting date. Heads suitable for infection have been in flower in at least two locations on the I.A.R. farm from July 1 to the present (mid-November). Ergot infection as expressed by the "honeydew" phase was first observed on September 14 and became serious by September 25. At the time of this writing new infection is still occurring.

Witchweed

Witchweed (Striga hermonthica), a parasitic weed found in almost all sorghum fields in Nigeria, is a serious problem on sorghum in most West African countries. During the past year a survey was begun to locate resistance to witchweed in the world sorghum collection. This consisted of planting a once replicated trial including over 3000 entries in fields which were heavily infested with witchweed during the 1967 growing season. Susceptibility was scored on the basis of the degree to which chlorotic and necrotic lesions formed on the sorghum leaves. These symptoms first became apparent on certain entries within a month after planting and before the parasite had emerged above the soil surface. Entries varied considerably in their reaction to witchweed. Due to apparent uneven distribution of S. hermonthica in the field, it was difficult to say whether symptomless sorghum entries were resistant or merely escapes. We do know for certain, however, some of these entries which are highly susceptible. It was interesting to note in some instances that the degree of lead symptoms was not correlated with the number of witchweed plants located at the base of the sorghum plant.

Millet Pathology

Downy Mildew

Downy mildew (Sclerospora graminicola) is the most serious disease on millet in Nigeria and this probably holds true for all of West Africa. It is estimated that annual losses to "gero" (early maturing millet)

approach 10%. "Maiwa" (late maturing millet) is less severely attacked by this disease.

There is no known source of resistance to downy mildew in Nigeria. The variety, Tift 23, which was developed in the United States and which has been successfully used in millet breeding programs in the U.S. and India, is severely attacked by the downy mildew fungus in Nigeria. For these reasons a considerable portion of the time spent on the downy mildew problem has been devoted to finding sources of resistance and incorporating them into the millet breeding program. Much of this work is being conducted at Kano in cooperation with the millet breeder, Dr. B. D. Bhardwaj.

This year a part of the world millet collection was again screened at Kano for reaction to downy mildew. Some entries have remained free of downy mildew through two seasons at both Kano and Samaru. The F_2 and F_3 generations of crosses between Tift 23 A and certain gero selections were also scored for downy mildew. There still appears to be a considerable amount of segregation for downy mildew reaction in these crosses, but some of the material looks quite promising.

A pot experiment was conducted to determine if Sclerospora sorghi will infect millet and if S. graminicola will infect sorghum. Observations made in 1966 suggested that S. sorghi, or at least a species with very similar behavior, was infecting millet. No cross infection was obtained. Microscopic examination of the sporangia on naturally infected millet always indicated that S. graminicola was the causal organism.

Ergot and Smut

Ergot (Claviceps microcephala) is commonly found on millet in northern Nigeria, and is a serious problem on breeding material. The honeydew phase of the disease was first observed this season in early July, shortly after the first flowers had formed, and new infection was continually present thoughout the remainder of the rainy season. Cross infection studies with millet ergot and sorghum ergot on sorghum and millet, respectively, resulted in no infection.

Smut (Tolyposporium penicillariae) is also commonly found in Nigeria. This disease, though generally not a serious problem for farmers, impairs the work of breeders because of its high incidence on heads covered with pollinating bats. It is not uncommon to find 100% infection on bagged heads. Two systemic fungicides, Vitavax and Plantvax, reportedly gave some control of smut when used as foliar sprays in the U.S. A similar test was tried this year at Samaru, but significant differences were not obtained between treated and non-treated plots. Variations within treatments were large and can likely be attributed to the difficulty involved in applying spray to the rather rangy and partially smut tolerant variety of millet used. Seed of a highly susceptible dwarf selection is being multiplied for use in a similar test in 1969.

It would seem that with the advent of new millet varieties, ergot will be more of a problem in commercial millet production than will smut. However, programs are being initiated whereby selection for ergot and smut resistance will be incorporated into the breeding program.

Seed-Borne Fungi on Sorghum and Millet

A study has been initiated to determine the seed-borne fungi on sorghum and millet grown by Nigerian farmers. It is hoped that this exercise will provide information helpful in controlling diseases on these two crops.

Market samples which are collected monthly from approximately 40 locations in the six northern states are sent to Samaru for testing. These locations represent most of the ecological zones in which sorghum and millet are grown in West Africa.

To date, 150 samples of sorghum have been tested. Viable spores of each of the four smut fungi have been found on the seed surface. Although *S. reiliana* and *T. ehrenbergii* spores have appeared on only a limited number of samples, spores of either *S. sorghi* or *S. cruenta*, or both, have been found on all samples. Seed-borne spores of *S. sorghi* and *S. cruenta* are the source of inoculum for the covered smut and loose smut diseases, respectively.

Species of *Fusarium* and *Curvularia* were the most commonly found fungi in surface sterilized seed. Other fungi frequently found included species of *Helminthosporium*, *Alternaria*, *colletotrichum*, *Phoma*, *Aspergillus*, and *Nigrospora*. Of these, *Fusarium*, *Helminthosporium*, *Colletotrichum*, and *Phoma* are all known to cause diseases on sorghum in Nigeria. All the fungi found could conceivably reduce seed viability and/or seedling vigor.

Preliminary tests with millet samples indicate that species of *Pyricularia* and *Fusarium* are commonly seed-borne.

Once it has been determined which fungi are seed-borne, experiments will be conducted to determine the extent of damage which these fungi cause and methods of control.

Maize Pathology

Practically all the maize pathology work for this project is handled by Dr. J. Craig at Moor Plantation, Ibadan. Diseases have not presented much of a problem on maize growing at Samaru. Root, stalk, and ear rots are practically unknown. Rust is the most prominent leaf disease, but good sources of resistance have been found in material from Central and South America.

An effort was made to clarify the exact species of rust found on maize growing in the Samaru area. Last year it was thought to be Puccinia sorghi. However, frequent and more careful observations this year, including comparisons with P. polysora uredospores from Dr. Craig, make us believe that the species involved in P. polysora rather than P. sorghi. Moreover, P. sorghi generally requires a cooler temperature than occurs during the growing season at Samaru.

Other diseases found to a much lesser extent at Samaru include leaf blight (Helminthosporium turcicum) and maize streak. Maize streak is a virus disease which is generally only found on isolated plants. However, this disease reportedly did become serious on irrigated maize grown at Tunfafia during the dry season last year.

Some serious attacks by witchweed (Striga hermonthica) were noted on maize growing in the Samaru area. An attempt to test several selections of maize for witchweed resistance did not succeed apparently due to a poor infestation of the parasite.

Training

Two students from Ahmadu Bello University received training in plant pathology during the summer vacation this year. Mr. Ekele, a Part II student in Botany with a special interest in mycology, was given experiience testing sorghum samples for the presence of seed-borne fungi. His main responsibilities involved making media and processing and incubating seed. In addition, he gained experience in the use of keys for the identification of fungi. The other student, Mr. Erinle, was given various problems concerned with downy mildew of millet. These involved both field and laboratory observations, laboratory exercises, and library research. Mr. Erinle has completed his course in Agriculture at A.B.U., and is presently pursuing a graduate degree in plant pathology at Kansas State University.

Summary

Research was directed toward the identification and control of important disease problems on major cereal crops of West Africa. Sorghum pathology dealt primarily with the location of resistance to leaf diseases and witchweed the control of ergot, and the identity of and host response to the sorghum smuts. Millet pathology was concerned with ergot and smut and the location of resistance to downy mildew. Studies on the seed-borne fungi of sorghum and millet were initiated. Touring provided valuable in making research contacts and acquiring a more thorough understanding of disease problems as they occur in Nigeria and other West African countries.

Soil-Water-Plant Relationships

K. R. Stockinger and Jan Kowal

At the end of the 1967 rainy season the hydraulic weighing lysimeter had been repaired and was just starting to give valid evapo-transpiration readings, when the rainy season ended. In 1968 the lysimeter and surrounding area was planted to Short Kaura, a medium tall local sorghum. Evapo-transpiration readings were made for the period from mid-April to the end of September and the water budget is given in the following table.

Month	Rainfall in.	Deep Percolation in.	Evapo-transpiration in.
April 19-30	2.79	0.00	1.81
May 1-31	6.68	0.00	4.15
June 1-30	4.78	0.00	4.02
July 1-31	7.74	2.51	4.42
Aug. 1-31	11.61	8.31	3.31
Sept. 1-30	6.05	1.24	5.69
Total	39.65	12.06	23.40

4.19 inches of water were stored in the soil on 1 October 1968 as compared to 18 April 1968.

Since there are no provisions for runoff in the lysimeter, all excess water is removed by drainage of the deep percolation losses. The distribution and total rainfall were ample to take care of the needs of sorghum during this period and the sorghum plants were never stressed by the lack of available water. However, rainfall ceased as of the first of October and the sorghum plants were just starting to flower. The plants had to mature their grain on the stored water in the soil profile. In the lysimeter this would mean that the crop must be matured on 4.19 inches of water of a 6-week period of high evaporative demand.

Because of the poor stand and stunted growth due to a severe infestation of stem borers within the lysimeter, the crop was removed on the first of October. The results prior to this date are probably low. The site was prepared for winter wheat, which was planted on 5 November 1968 and sprinkler irrigated to measure evapo-transpiration during the dry season.

Additional information is needed as to the amount of water needed to mature a crop of sorghum after flowering. In the last two years the rains have stopped about the same time as the day-length sensitive sorghums flower. The sorghum plant must develop and mature its seed on the stored water in the soil. On some soils this has been insufficient, resulting in reduced yields. Next year the quantity of water used after flowering will be measured with the lysimeter, and also under field conditions with different varieties and plant population using the neutron moisture meter. This

should answer questions as to the ability of the new varieties to extract as much water from the soil as the old varieties and whether high population densities require more water than the low populations.

Soil Fertility Trials with Maize

K. R. Stockinger and R. G. Heathcote

During the past year a number of trials were initiated to discover which factors were limiting crop yields in northern Nigeria. Previous work had shown that phosphorus was severely limiting on nearly all soils, and yields of maize were practically nil without the use of phosphorus fertilizer. Nitrogen was also a limiting factor but not nearly as great as one would expect considering the low level of organic matter in the soils. Potassium, lime, and trace elements had not shown any yield responses in very limited previous work.

Because of the high rainfall and thorough weathering of the soils of northern Nigeria it was felt that potassium, lime, and trace elements would become limiting under continuous cropping at higher yield levels. To test this hypothesis three trials were planned at different locations in northern Nigeria. The factors to be tested were the need for nitrogen, potassium, trace elements, and lime with a crop which had a high yield potential. Since phosphorus is such a severely limiting factor, it was not included in the experiment but a high level was applied to each experimental area. The three principal trials were carried out at Kano, Mokwa, and Samaru. Nitrogen, potassium, and lime were applied to the soil, and trace elements were sprayed on the plants twice during the growing season.

At Samaru there was a 50% increase in yield from the nitrogen fertilizer and a 25% increase from the trace elements. When lime is added the trace element increase is reduced to 10%, while there is a 10% increase in yield from potassium. Other work indicates that molybdenum is the trace element which is limiting. Availability of molybdenum is increased by liming. These results show that the fertility picture is very complicated at Samaru.

At Kano nitrogen gave a 580% increase in yield and potassium 140%. The effect of the potassium was much greater in the presence of lime and nitrogen. The site at Kano was a piece of heavily cropped land on which maize was a total failure in 1967. This year the best treatment gave yields of 1700 lbs. per acre.

At Mokwa nitrogen gave a 73% increase in yield and potassium an increase of 11%. The effect of potassium was much greater in the absence of nitrogen and in the presence of trace elements.

In general, lime does not seem to be needed in the soils tested. On the Samaru soils its principal function appeared to be to increase the availability of molybdenum. These soils were not very acid but it would be desirable to test these soils with an aluminum sensitive crop to check aluminum toxicity. Trace element responses were found in two of the three soils indicating a deficiency of trace elements may be quite important in limiting yields, especially in continuously cultivated soils.

In past years moisture has not been a limiting factor on the yield of sorghum. This year the rains slowed down in September and stopped altogether in October, resulting in a shortage of water for sorghum during plant maturation and a reduction in yield. Plant density appears to be related to the severity of this yield reduction. Stands of about 14,000 plants per acre have normal size grains while thicker stands have shriveled, smaller grains. Also, thick stands are fired to the top of the plant while thin stands still have a few green leaves at harvest. The relationship between soil moisture, stand density and variety needs to be investigated. It may be necessary to be sure that soils have adequate moisture holding capacity to assure maximum yields at high densities and high fertility.

Another factor which needs to be investigated is the importance of planting date. Late planting results in reduced yields of maize and sorghum. It is thought that this may be due to the effect of rain on the dry soil, or that delay of planting allows diseases and insects to build up and concentrate on the late plantings. To separate these effects, 19 lysimeters will be covered with polyethylene sheeting to control the timing of the first rains. Maize will be planted on three dates of planting: April 15, June 1, and July 15, on wet and dry soil. Observations on diseases and insect attack under these conditions will be made by the entomologist and plant pathologist. Nitrogen, phosphorus, potassium, and trace elements will be supplied to all treatments for optimum growth. Plant height, soil temperature, date of tasseling, and other observations will be made. Growth will be related to temperature and sunlight as well as soil moisture conditions. Early plantings will be supplemented with irrigation water to insure that water is not limiting plant growth.

Maize Improvement, Ibadan, Nigeria

J. Craig

The objective of this program is to improve maize in West African countries. Program activities are concerned with conduct of regional maize trials, development of maize composites for use in West African maize programs, studies of maize diseases, development of disease resistance and the training of personnel in maize improvement techniques.

Uniform Regional Trials

These trials were initiated in 1967 for the purpose of improving the exchange of seed and information among West African research workers and identifying high yielding maize varieties and their zones of adaptation in West Africa.

Participating countries send seed to Moor Plantation where sets of entries are made up and mailed to participants. Maize entries are grown in a randomized complete block design with 4 replications. Plots are two rows 25 ft. in length spaced 3 ft. apart. Plants are spaced one foot apart in the row. Time of planting and rate of fertilizer application is decided by the trial supervisor at each site. Trial results are sent to Moor Plantation for preparation of a report which is distributed to all interested parties.

Eight countries, Cameroun Republic, Dahomey, Ivory Coast, Liberia, Nigeria, Senegal, Sierra Leone and Upper Volta participated in the 1967 trial. For various reasons trials in the Cameroun Republic, Ivory Coast, Sierra Leone and Liberia were not completed. The results from Dahomey, Senegal, Upper Volta and Nigeria are summarized in Table 13.

Observations by trial supervisors indicate that drought was a limiting factor in maize trial yields at Senegal, Dahomey and Nigeria. Rainfall was more favourable in Upper Volta but plant populations were too low for high yields.

The yields of variety Composites Jaune D'Ina and Massayomba equalled or exceeded those of other entries at all locations.

The regional trials were repeated in 1968. Results from sites other than Ibadan, Nigeria (Table 14) were not available at the time of this report. Interest in these trials is increasing among west African countries. Research officers in Gambia and Ghana have expressed a desire to participate in the 1969 regional trials.

Table 13. Yields of 1967 West African uniform maize trial entries at 4 locations.

		Locations and yields lbs./acre				
Entry	Origin	Senegal	Dahomey	Upper Volta	Nigeria	Mean*
Composite						
Jaune D'Ina	Dahomey	2536	2715	2300	3448	2750 A
Massayomba	Upper Volta	2341	2800	2320	3250	2678 AB
Aldiobla Mais Blanc	Upper Volta	2581	2460	2360	2681	2520 AB
NS 5	Nigeria	2492	2310	1800	3127	2432 AB
NS 4	Nigeria	3097	1850	1540	3003	2372 ABC
NS 1	Nigeria	2127	2260	1495	3052	2233 ABC
Darsalam	Upper Volta	2314	2100	2040	2442	2224 BC
ZM 10	Senegal	2848	1810	1440	1460	1890 CD
Jaune Flint De Saria	Upper Volta	2358	1550	1520	1039	1617 D
Mean		2522	2206	1868	2611	2302

* Means that do not have an alphabetical letter in common are significantly different at the 5% level. Means that have an alphabetical letter in common are not significantly different at the 5% level.

Table 14. Yields of 11 maize entries in west African uniform maize trial at Ibadan, Nigeria early season 1968.

Entry	Origin	Yields*
H.J.	Ivory Coast	3020 A
NS 5	Nigeria	2730 B
NS 1	Nigeria	2381 C
H59	Ivory Coast	2294 C
Massayomba	Upper Volta	2265 CD
Jaune D'Ina	Dahomey	2178 CD
NS 4	Nigeria	2004 DE
Aldiobla Mais Blanc	Upper Volta	1859 E
Darsalam	Upper Volta	1510 F
BDS	Senegal	1452 F
ZM10	Senegal	1365 F

* Yield in lbs. of shelled grain per acre at 12% moisture. Yields that do not have an alphabetical letter are significantly different at the 5% level. Yields with one or more letters in common are not significantly differentat the 5% level.

Nigerian Zonal Maize Trials

These trials are carried out by Federal Department of Agricultural Research to evaluate yields of selected maize varieties at a large number of sites in Nigeria. These sites cover the range of ecological zones in which maize production is possible. The results of the 1967 zonal yield trials are presented in Table 15.

The performance of the local maize type at Samaru in Northern Nigeria relative to the other maize entries makes an interesting contrast to the poor showing of the local maize types at Ibadan and Ipokia in Southern Nigeria. The local maize types in Northern Nigeria are white or yellow flint and dent grain types. Local maize in the South is usually a white floury grain type. It is possible that the yielding ability of the Northern local maize is due to introgression with high yielding dent or flint grain type maize introductions. Preference for the white floury grain type in the South would prevent or reduce the level of such introgression of flint and dent grain types.

Table 15. Yields of 9 maize entries at high, intermediate and low yielding sites and mean yield of entries for 16 sites in 1967 Nigerian zonal yield trials.

Entry	Site			Mean yields* at 16 sites
	Samaru	Ibadan	Ipokia	
H507	4980	3480	1570	3180
Diacol V153	5000	2780	1670	3110
EAFRO231	5030	2910	1290	2940
H503	4600	3100	1350	2930
V1	4730	2890	1290	2900
NS5	5310	2730	1480	2890
NS1	5030	3170	1520	2810
NS4	4220	2080	840	2420
Locals**	4690	1810	960	2060
Location Mean	4820	2770	1330	2803
L.S.D. 5%	487	450	158	370

* Yields are given in lbs. shelled grain per acre at 12% moisture.
** The local maize type grown by farmers at each trial site.

Maize Composite Program

In view of the success of the maize composite program in East Africa it appears that a similar approach would be of great value to the maize improvement programs of West African countries. Accordingly a conference of maize breeders to discuss a maize composite breeding program for West Africa was held at Moor Plantation on February 5-7, 1968.

Participants at this Conference:

Mr. J. E. Y. Hardcastle,
Director
Federal Department of Agricultural Research
Nigeria

Mr. B. D. A. Beck
Deputy Director,
Federal Department of Agricultural Research
Nigeria

Mr.U. U. Ebong
Principal Research Officer,
Federal Department of Agricultural Research,Nigeria

Mr. J. LeConte
Chief of Maize - Millet Research
Institute De Recherches Agronomiques Tropicale,
Paris, France

Dr. S. A. Eberhart,
Maize Geneticist
AID-ARS Major Cereals Project,
Kenya

Dr. H. C. Wiggin
Maize Breeder
USAID Ibadan, Nigeria

Dr. K. Kopf
Chief of Crop and Soils Section
USAID Lagos, Nigeria

Mr. D. Andrews
Plant Breeder,
Institute of Agricultural Research
Zaria, Nigeria

Mr. F. de Wolff
Plant Breeder
Institute of Agricultural Research,
Mokwa, Nigeria

Mr. O. A. Ojomo
Research Officer
Ministry of Agriculture and
Natural Resources
Western State, Nigeria

Mr. Okusanya
Research Officer
Ministry of Agriculture and
Natural Resources
Western State, Nigeria

Professor D. C. Arny
Head, Department of Plant Science
University of Ife
Nigeria

Dr. F. A. Bliss
Plant Breeder
University of Ife
Nigeria

Mr. T. Fatula
Research Officer
Ministry of Agriculture and
Natural Resources
Western State, Nigeria

Dr. O. J. Webster
Coordinator
ARS-AID Major Cereals Project
Zaria, Nigeria

Dr. S. King
Plant Pathologist
ARS-AID Major Cereals Project
Zaria, Nigeria

Dr. J. Craig
Plant Pathologist
ARS-AID Major Cereals Project
Ibadan, Nigeria

During this meeting Dr. Eberhart of AID-ARS major cereal improvement project in Kenya discussed the details of maize composite formation and results of maize selection procedures in Kenya.

Mr. Le Conte, Chief of millet-maize research for French speaking West African countries and one of the pioneer maize breeders in west Africa discussed past and present maize improvement activities in his program. Mr. Le Conte expressed enthusiasm for the regional maize composite program and its future effects on maize improvement in west Africa.

After further discussion among participants of the results of maize improvement programs in west Africa it was decided to expand the 1967 maize composite program with the formation of 3 composites, Composite A consisting of selections from Colombia and the United States, Composite B of selections from Mexico, Central America and West Africa and Composite C of material from Kenya, South Africa, Central America and Nigeria.

Fortunately the combined experience of the participants at this meeting provided information on which to base the selection of a large number of maize varieties for each of the composites. The entries in each composite were chosen with the intention of providing genetic variability within the composite and genetic divergence among composites. This should result in appreciable heterosis in crosses among selections from these composites.

These composites are expected to offer good selection potential for yield, disease resistance, lodging resistance and grain type. In addition the opaque-2 gene is being incorporated into all composites in order to increase the protein quality of snythetics or hybrids which may result from this program.

The formations of the three composites was started in the early season of 1968. Composite A was grown at Moor Plantation, Mokwa and Samaru, Composites B and C were grown at Moor Plantation. The entries making up the composites were planted in single row plots with four replications. These plots were detasseled and pollinated by border rows planted to bulk seed of the entries. At harvest the heaviest 25% of the ears (12) in each female row were selected to provide seed for female rows and male bulk for the next cycle of synthesis and selection.

The installation of irrigation equipment, expected in late 1968, at Moor Plantation and Mokwa will permit 2 cycles of composite synthesis and selection each year. Using this system the composites will have undergone 4 cycles of synthesis by the end of 1969. In 1970 the composites will be distributed to participating countries in west Africa for further selection under their environmental conditions.

Such a system should result in the production of maize synthetics of F_1 hybrids tailored to the growing conditions of the country involved.

Disease Resistance

Maize rust (Puccinia polysora) and Southern maize leaf blight (Helminthosporium maydis) are major problems affecting maize production in West Africa. Resistant maize varieties offer the only economically practical means of reducing the losses caused by these diseases. Much of the maize improvement work at Moor Plantation is concerned with the selection of maize lines carrying resistance to both of these diseases and the combining of this resistance with other desirable agronomic characteristics.

Studies of races of P. polysora in Nigeria continued in 1968 but no races other than the two, NPP1 and NPP2, reported in 1967 were observed. Research on the inheritance of resistance to P. polysora indicate at least 2 types of gene action among the rust resistant maize selections in this program. One type is dominant to susceptibility and the other exhibits intermediate dominance. In each case resistance appears to be conditioned by one gene or by two or more closely linked genes. An investigation of the relationship of these factors for resistance has been started.

The development at Moor Plantation of a maize inbred with chlorotic lesion resistance to Southern leaf blight was reported in 1967. Studies to determine the inheritance of this type of resistance was started in 1968. These studies have not been completed but present results indicate that resistance is conditioned by two linked recessive genes.

Hypersensitive resistance to maize rust and chlorotic lesion resistance to leaf blight have been combined in one maize inbred line. This maize line, Rb, is now being grown in other west African countries to test its resistance against the strains of P. polysora and H. maydis foun elsewhere. If the resistance of this maize line proves effective over a wide area it will be of great value to maize improvement in west Africa and other areas where these diseases are important.

In response to requests seeds of disease resistant maize selections were sent to Senegal, Ivory Coast, Gambia, Cameroun Republic, Dahomey, Liberia, Kenya, Brazil, Australia and the United States.

Training

Two research officers of the Federal Department of Agricultural Research have been assigned to the maize improvement program. These officers are receiving training in techniques of maize selection and studies of maize diseases.

Travel

I attended the conference on Agricultural Research Priorities for Economic Development in Africa held by the National Academy of Sciences at Abidjan, Ivory Coast in April. The conference was very interesting and provided an opportunity to discuss aspects of maize improvement with most of the maize specialists in Africa.

Visits to maize improvement projects in Liberia and Dahomey are planned for December of 1968.

SORGHUM AND MILLETS IN EAST AFRICA

H. Doggett
EAAFRO Sorghum Research Division

The programme of sorghum and millets improvement based on the Uganda Government Agricultural Research Station at Serere receives support from the three East African territories through E.A.A.F.R.O.; from the British Ministry of Overseas Development through E.A.A.F.R.O.; from the Rockefeller Foundation: and from U.S.A.I.D. in conjunction with the U.S. Agricultural Research Service. Much help is furnished by the Uganda Government in the form of station services, and there is close co-operation with the government research workers on this station.

The place of sorghum and millets in East Africa

Substantial acreages of sorghum and millets are grown in East Africa, where there is a wide range of ecological conditions. Thirty five percent of the East African land area receives less than 50 cm. of rain per year, and 55% receives less than 75 cm. in 4 years out of 5. Maize should be grown wherever it gives reliable yields, as it does over large areas of the country. However, there still remain substantial regions of low or ill-distributed rainfall where sorghum and Pennisetum millet are the more reliable cereals. There are also areas of high rainfall, notably in Uganda, where either soil conditions become too wet for maize, or else the drying of the crop presents problems for the small grower. In such places, Eleusine millet is widely grown, its very small grain drying rapidly and being immune to attack by storage pests which develop within the grain.

Relative yields of the cereals

Data on the relative yields of the cereals under the wide range of East African conditions are sparse, and much more information is required. Only then will it be possible to make an objective assessment of the East African cereals position. In the highland areas, maize has as yet no rival. In the wetter lowland areas, mainly in Uganda, Doggett and Jowett (1966) found that in 22 trials maize outyielded sorghum, and in 28 trials sorghum outyielded maize. In the dry areas of Eastern Kenya, where the rainfall seasons are short, the new maize types have proved a great success at the higher altitudes. At the lower altitudes, however, as typified by Kambi ya Mawe, (Makueni) the sorghum continues to show relative superiority (table 16).

Table 16. Mean grain yields at Kambi ya Mawe, kg./ha., seasons per year.

	Maize	Sorghum	
		Serena variety	H x 57 hybrid
1963 - 1964	2,254	3,341	3,922
1965 - 1967	1,961	3,069	3,857

In 5 of the 1965 - 1967 seasons the maize used was Katumani Composite A or B, and in the 6th season Katumani Synthetic IV was used. In only 3 out of 13 seasons of testing at this site has maize outyielded a sorghum variety, and in only one season has it outyielded a sorghum hybrid. There are objections to direct comparisons between maize and sorghums in such trials, but the relative results from the two time periods may be compared.

Factors determining the grower's choice of cereal

Yield and price will ultimately determine which cereal is grown in any area, as is the case in the U.S.A. At present, maize production is encouraged in Kenya by an artificially high internal price, while sorghum commands world prices. Maize has important advantages in convenience, and the grain is often preferred to that of many sorghum types. The work of Mr. Alan Shepherd (U.S.A.I.D.) who arrived in East Africa in July will be of great value in developing simple methods of processing the sorghum and millets, which are basically good food grains. The support being given to programs for reducing the numbers of grain eating birds will be important in enabling much larger areas of palatable sorghum and millet grain types to be grown: the birds can be devastating on these.

The objectives of the work

The objectives of the sorghum and millet work are therefore clear, namely, to obtain the highest possible yields through plant breeding, agronomy and pest control, coupled with good grain quality. This work is basic to development: the subsistence farmer gives highest priority in labour and time to the provision of food (and drink) for his household. Reliable, high yielding cereals grown with the minimum of labour will release much more of the small farmer's labour and time for the development of a better living standards.

Some valuable results

Among the highlights of the work reported here might be mentioned the development of locally adapted parents for Pennisetum millet hybrids: the good yields obtained in the plant population and fertilizer studies: the discovery of the importance of stem borer in imposing a ceiling on sorghum yields: the success attained in the breeding for resistance to sorghum shoot fly: the excellent performance of hybrid sorghum under adverse growing conditions: and the development of population breeding systems for the millets and for sorghum.

SORGHUM BREEDING

H. Doggett, B. N. Majisu, S. Mukuri, R. Okello,
H. Ojulong, P. Ajau, and B. Okwi

Hybrid sorghum. Yield data from 123 trials through East Africa showed that the yield of the best hybrid (H x 57) was always about 520 kg./ha. above the yield of the variety Serena. The regression value of b = 0.962 ± 0.070 is not different from unity. Hybrid sorghum will therefore be most valuable under difficult growing conditions, where it gives proportionally its greatest yield increase over sorghum varieties, as shown in table 17.

Table 17. Relative grain yields in kg./ha. of the hybrid H x 57 and the variety Serena over 123 locations in East Africa. (b taken as unity).

Variety yield	Hybrid yield	Percent increase of hybrid
500	1,020	+ 104
2,000	2,520	+ 26
4,000	4,520	+ 13.

Hybrid sorghum is therefore complimentary to the maize composites and hybrids, the latter giving their best advantage under high yield conditions, the former doing so under low yield conditions.

The corresponding yield difference between the hybrid RS.610 and the variety Martin in the U.S.A. is about 1,000 kg./ha. There is therefore much room for improvement in the yields of East African hybrids. A major advance in yield will come from replacing the present exotic male-sterile female parents of East African hybrids by locally developed male-steriles showing better adaptation. Two lines developed at Serere and now under test, 2DMS 1 and 2 DMS 7, appear promising, as shown in Table 18.

Table 18. Comparative grain yields of hybrids invovling U.S. and locally developed male-steriles, in kg./ha.

	Male sterile	Pollinator E 277	SB 79/3/4	E 170	Mean yield
U.S.A.	(CK 60	6,650	6,180	5,750	6,193
	(Redlan	5,250	6,910	4,320	5,493
East African	(2DMS 1	7,590	7,580	7,700	7,623
	(2DMS 7	7,950	7,990	6,320	7,420

The mean yield of the hybrids from the 2 East African male-steriles in table 18 (7,521) was 29 percent greater than the mean yield of the hybrids from CK 60 and Redlan (5,843). The yield of H x 57 in these trials was 4,720 kg./ha. The yields of the new hybrids being developed are therefor substantially greater than that of H x 57.

Excessive height leading to lodging, due to complimentary gene action, is the main fault of the East African hybrids. Identical height genes are therefore being transferred to both parental groups, and this program has reached the stage of the second back-cross.

A grain quality of the Shallu type (rather similar to a flint maize) is popular in many places, and a series of hybrids with such grains have been made for yield testing next year.

Yield trials and observation plots on 815 new hybrid sorghums were grown in 1968. The pollinators were from the World Collection, and it is hoped that the parents of the best hybrids will be available next year as dwarfs from the height reduction program currently being carried out in Puerto Rico.

Varietal improvement. Lines from the traditional breeding program developed by the crossing and backcrossing of chosen good varieties were tested in variety trials. Objectives include high yield, resistance to pests and to leaf diseases, medium to short height, good grain quality and tan straw, available over a range of maturity lengths. The present recommended varieties are Serena (60 days to flower) and Dobbs (75 days to flower). Yields of a few of the best entries from the yield trials are shown in table 19.

Table 19. Grain yields from variety yield trials (kg./ha.).

Variety	Trial 1	2	3	4
Serena	3,635	3,910	4,395	3,450
Dobbs	4,005	4,500	4,625	4,960
3DX 57	---	6,250	---	---
5DX 36	5,825	---	6,960	---
5DX 134	8,350	---	---	---
5DX 160	---	---	---	7,120

Both 5DX 36 and 3DX 57 are of Serena maturity length, and some lines from them have white grains of satisfactory quality. 3DX 57 also performed well in trials in Tanzania: it has good leaf disease resistance. 5DX 36 has a better grain and tan straw, but is susceptible to Colletotrichum. Dobbs is one parent of 5DX 160, and this cross has yielded very well in past trials, but shows susceptibility to stem borer. 5DX 134 is derived from the Buganda beer sorghum Namatare, and the grain would be unsuitable for food. Real progress has been made in developing high yielding sorghum varieties, as can be seen from table 19. New varieties should be ready for release next year.

Population improvement. Conventional sorghum breeding programs seldom utilize a wide range of the available genetic variability. The crop is largely self-pollinated, and the most usual breeding approach consists in intercrossing proven good varieties, and selecting within their progeny. However, now that the genetic male-sterile ms_3 is available, it is relatively easy to arrange for the intercrossing of a large number of varieties, since all seed on a male-sterile head results from cross pollination. Random mating populations can be composed, and recurrent selection practised within them, through repeated cycles of intercrossing and selection. To compose these populations at Serere, varieties have been crossed to ms_3, and this has been followed by 3 generations of intercrossing, selecting only the male-sterile plants. Selection is then applied. In this way, a much larger part of the available crop variability can be utilized, and the continued crossing and selection should result in much rearrangement of linkage groups and the selection of favorable gene combinations. The following populations have been developed and selection within them commenced:

(a) A restorer populations based on 40 varieties, divided into coarse and quality grain sub-populations.

(b) A similar non-restorer population.

(c) A restorer population based on 100 varieties, sub-divided into coarse and quality grain types.

(d) A similar population to (c), but based on non-restorers.

The restorer and non-restorer populations are kept isolated from each other, and the improved varieties obtained from each should be good potential parents for hybrids.

Good progress is being made in crossing the World Collection entries in to the genetic sterile. Backcrosses have been made from 788 entries, and 2 broadly based composites can now be formed. These will consist of restorers in one composite and non-restorers in the other, the material having already been classified by crossing to the cytoplasmic sterile Redlan A.

A collection of our 1,000 varieties brought in from Ethiopia has been crossed on to the genetic sterile, as far as this proved possible. Some of the varieties were too late maturing for crossing to be done. The range of grain present in this collection will be very useful in developing larger grain of better quality for East African sorghums.

A composite population is also being developed from 120 of the best performing hybrids, utilizing the cytoplasmic sterility which is already present.

Sorghum Shoot Fly. The progress in selection for resistance to sorghum shoot fly has been dealt with in Dr. Starks' report. The most resistant lines identified by him have been put into a crossing block with some of the best yielding Serere lines which contain the genetic sterile. A new composite will be formed for selection under conditions of heavy shoot fly attack. The fly can cause serious yield losses, and the inheritance of resistance does not seem to be simple. Recurrent selection should be effective in improving the levels of resistance in good yielding sorghums.

High altitude sorghums. In several areas of Eastern Africa sorghum is grown at altitudes of between 1,600 and 2,400 metres. The lowland sorghums are quite useless at these altitudes, presumably owing to high threshhold temperature requirements for growth. In Uganda there is one group of high altitude sorghums which have proved to be mainly non-restorers. These have been crossed to the genetic sterile, and the F_1 backcrossed to the high altitude varieties. The first generation of compositing has also been grown.

There is another population of high altitude sorghums in Ethiopia, and these have proved to be mainly restorers. Similar crossing and backcrossing using the genetic sterile has been done within about 100 of these varieties, and the first generation of compositing has been grown. These two composites will be planted at Kitale and selected in isolation. New varieties and new hybrid parents will be developed from them, suited to high altitude conditions. The hybrids will be based on using the Uganda derivatives as female parents and the Ethiopian derivatives as pollinators.

Sorghum x sudangrass hybrids. There is some interest in sorghum x sudangrass hybrids in parts of the Kenya highlands. It should be advantageous to use a high altitude variety as the sorghum parent for making this cross Dr. Eberhart has screened a number of Uganda high altitude varieties at Kitale and "Mabere" with the accession number E 1291 yielding quite well. This variety is being sterilized at Serere by crossing to CK 60A, and the 2nd backcross has been made. Meanwhile, test crosses of high altitude sorghum x sudangrass were made at Serere and sent to Kitale for observation.

Tetraploid grain sorghum. Good progress in the development of tetraploid grain sorghum has continued. The genetic male-sterile ms_3 was obtained at the tetraploid level, and crossing to a wide range of tetraploid grain sorghums was commenced. Populations for recurrent selection will be established in the same way as for the diploids.

Three of the 4th backcross derivatives from cultivated autotetraploids (cultivated $4n^4$ x S. almum) gave similar grain yields to Serena in the trials as shown in table 20.

Table 20. Grain yields and days to flowering of tetraploid sorghum.

	Diploid Serena	5ADX 243	5 ADX 206	5ADX 241
Yield	4,280	4,860	4,180	4,040
Days to flower	62	68	65	65

Summary

(1) Sorghum hybrids have given large yield increases under difficult growing conditions. Hybrids from new male-steriles developed in East Africa are giving some 30 percent yield increase.

(2) Improved varieties show 40 - 60 percent yield increases over the current standard varieties.

(3) Population improvement methods are being successfully applied to sorghum, using a genetic male-sterile. Much more of the available variability can be used in this way.

(4) Improved sorghum varieties and hybrids are being developed for high altitudes.

(5) Tetraploid grain sorghums have now reached the yield level of good diploid varieties.

MILLET IMPROVEMENT

LeRoy V. Peters

The millet breeding phase of the co-operative program for the improvement of cereals, although centered at the Serere Research Station in Uganda, is intended for all of the East Africa countries. The two millets, Finger millet, Eleusine coracana and Bulrush millet, Pennisetum typhoides are both very important cereal crops in several East African countries, and are thus being improved under this program. Although finger millet is not as extensively grown in Kenya and Tanzania, over one and one-fourth million acres are grown in Uganda, where it is the staple food for more than 50 percent of the population. Thus, the importance of this crop cannot be underestimated. Improvement in both quantity and quality of grain are being studied which will greatly enhance the economy and health of the people. Bulrush millet is grown extensively on the more sandy soils of Northern Uganda, and it is the second most important cereal crop in Sudan. This crop is grown in Kenya, Ethiopia, and also quite extensively in Tanzania. Not only is the Serere Research Station ideally located geographically to serve the East African countries, but the climatic conditions are such that three generations of either of these two millets can be grown within each calendar year.

Finger Millet Trials

There have been over 300 local and introduced varieties of finger millet grown and observed by previous workers at Serere Research Station. Only 52 varieties, however, had been retained on the basis of yield, disease resistance and other desirable characteristics. Based on observations and past yield trials, 12 varieties have been selected and included in yield trials at 15 District Variety Trial Centers (D.V.T.C.) during the first rain season in the Northern Area and 4 D.V.T.C. during the second rain season in the Southwestern Area of Uganda. Although yield data from all of the Centers have not arrived, preliminary results show that at some centers where nitrogen was applied as either ammonium sulfate or ammonium nitrate at from 47 to 52 kilograms of nitrogen per hectare (42-46 pounds/acre) and single super phosphate at 36 to 40 kilograms of water soluble P_2O_5 per hectare (32-36 pounds/acre), yields of over 50 quintals per hectare (4460 pounds/acre) of clean dry grain were obbained. Although these yields are much higher than have been reported in the past, the Variety Trial Observers have been encouraged to have adequate plant populations, a good level of soil fertility and to be very precise and meticulous in carrying out each operation of the experimental trial. Threshing percentages of 80 to 82 percent clean seed was reported by a number of centers. This is about 10 percent higher than has previously been reported.

Two additional yield trials were conducted at Serere during the first rain season. One trial which contained 81 entries in a 9 x 9 balanced lattice, will serve as a screening trial for the district trials. The top yield in

this trial was 45.4 quintals/hectare (4040 pounds/acre). Notes on a number of additional phenotopic as well as agronomic characteristics, other than grain yield, have been taken on each entry which will also be valuable in our evaluation. One important characteristic of the high yielding entries was that they all had broad or wide leaves which were erect or upright in growth as contrasted to being narrow and arched or curved. Some of the high yielding strains and hybrids of corn, sorghum and wheat also have this erect or upright leaf growth thus allowing better photosynthesis. It was also noted that the closed type head generally was better yielding than the open type head.

The range of days from planting to anthesis for these 81 entries was from 54 to 78. The number of days to anthesis for the top entries ranged from 61 to 72. The second trial at Serere was a 6 x 6 triple lattice which contained entries from the World Collection with a range in anthesis from 54 to 89 days after planting. Although yield data are not yet available, the early maturing entries will definitely be the lowest in grain yield production. Information on adaptation will be very useful from this trial.

Finger Millet Breeding

The damage caused by blast, Piricularia oryzae, was much more evident in 1968 than in the previous year. Continuing emphasis will be placed upon transferring of resistant genes from a selected line, Serere 359, which was initiated in 1965. There were 68 second backcrosses and 57 third backcrosses made to the five susceptible high yielding parent varieties.

A gene pool is being developed with the 597 entries available from the World Collection of the finger millets. An intensive crossing program was initiated and although 371 hot water emasculations were made, only 263 pollinations were possible. With anthesis notes taken on this collection the previous year, staggered plantings could be made for crossing some of the very early accessions with the very late ones, tall with short, different head types, seed colors, etc. Although a diallel or partial diallel crossing program is planned, selection within the segregating material can be started at any time.

An additional 155 new introductions from Ethiopia were grown and observations taken on a number of agronomic characteristics. Those showing good lodge resistance plus good grain yield potential were selected for testing in 1969. It appears that a number of promising lines may come fromthese introductions.

The original World Collection contained two white grain types. These have also been increased for testing and evaluation in 1969.

Bulrush Millet Trials

Selection for adapted strains of bulrush millet at Serere has generally been toward the medium to early maturing types. Eight bulk populations have been developed which are also good restorers. These eight strains and their hybrids, using Tift 23A as the seed parent, are being evaluated at 16 D.V.T. Centers in Northern Uganda and one Center in the West. Although no yield results are yet available, the previous year's results showed that although some hybrids were not as productive as their pollinator parent, other hybrid combinations have proved to do better in grain production than their pollinator. Although the average grain yield in 1967-68 was 23 quintals per hectare, yields approaching 36 quintals per hectare were obtained for some entries. We are expecting better yields in this year's trials.

In another trial at Serere, 36 entries are being grown in a 6 x 6 triple lattice. This trial contains two entries of finger millet, one maize, one sorghum, and the 32 remaining are bulrush millet hybrids and strains. Due to the moisture stress in late August, part of September and also in early October, it appeared that some of the late maturing millets from Nigeria and less drought tolerant crops might be greatly reduced. However, these entries have recovered since the rains of late October and yields should be quite good.

Bulrush Millet Breeding

The World Collection of bulrush millet has been obtained at Serere and is being crossed onto Tift 23A. All of the available accessions from the World Collection, as well as the Serere selections, India selections and New Introductions will eventually be crossed onto Tift 23A. The primary purpose of this cross is to separate the selections into either restorer or non-restorer groups, as determined by the performance of the 23A hybrid. However, those which produce good fertile hybrids could also be used directly in our hybrid testing program. The outline for this program as illustrated in Figure 2 shows the development of both the restorer and non-restorer populations.

There were 759 entries from the World Collection of bulrush millet which were planted for crossing onto Tift 23A during the second rain season of 1968. Forty-five new introductions from Ethiopia were also included. A total of 1070 crosses were made. The F_1 progeny of these crosses will be grown during the first rains of 1969 for the purpose of classifying the pollinator as a restorer or non-restorer line.

Last year there were 321 entries from the World Collection crossed onto Tift 23A. These hybrids, grown this season, were classified as being fertile or sterile. However, some contained plants of both types. Results from these crosses show 68 percent of these 321 pollinators carried fertility restoration genes, 3 percent were non-restorers and 28 percent indicated the pollinator carried both restorer and non-restorer genes.

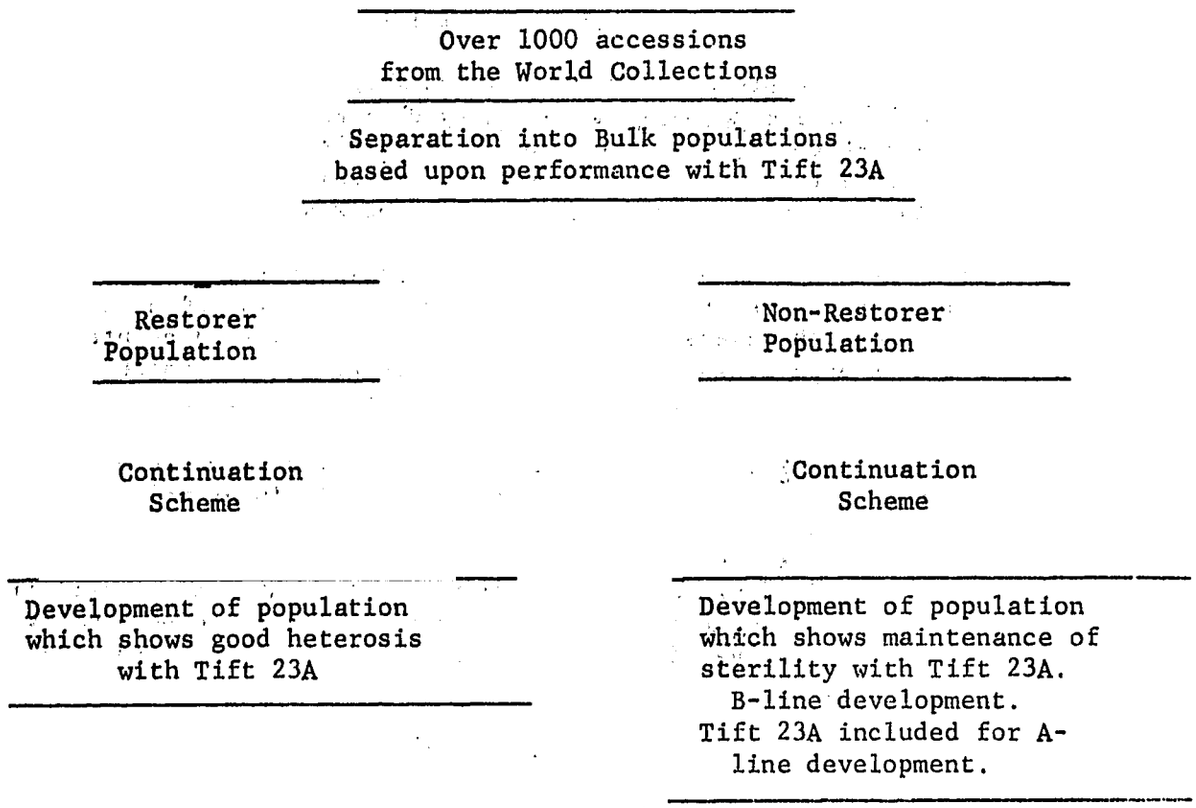


Figure 2. Recurrent selection program for the World Collection of Bulrush Millet.

There were 1104 Serere selections crossed onto Tift 23A last year which were also classified during this season. Results indicate that 85 percent were good restorers, 4 percent were non-restorers and 11 percent were both of the restorer and non-restorer genotype. Fifty-eight selections, crossed onto Tift 18A, showed 48 (83 percent) were good restorers, 1 (1 percent) was a non-restorer and 9 (16 percent) contained both genotypes. An additional 150 selections from the Serere material were crossed onto Tift 23A for classification during the next rain season.

Although Tift 23A is serving as the seed parent for much of our breeding studies, effort is being made to develop seed parents which will be better adapted to East African conditions. Seed increase is now being made for Serere 10L for use next year. A paired mating system of backcrossing is being carried out in the sterilization and development of the A and B lines of six additional strains.

Most of the bulrush millet lines are tall and when grown under good moisture and fertility conditions the plants lodge quite severely. The dwarf genetic factors from some of the U.S. Introductions is being incorporated into the more advanced material.

Diseases of bulrush millet, both the inflorescence and foliage types, are present in East Africa. The honeydew head disease is present but as yet is not too serious. Leaf rust is present at Serere and has been reported at other sites. Downy mildew was observed last year in Northern Uganda in one of the Serere varieties. This was probably the first report of this disease in East Africa. It was noted this year for the first time at Serere. Although the characteristic "green ear" symptom was found within various strains, the Tift 23A hybrids showed the highest incidence of this disease. Breeding and selection for resistance to these diseases will be continued.

A recurrent selection method of breeding has been initiated in the long-range breeding program. Twelve Serere Bulk Populations developed from a number of local and introduced varieties which had previously been grown and observed at the Serere Station served as the basic starting material. The most important of these was of the Zuarungu type introduced from West Africa. As illustrated in Figure 3, 648 open pollinated head selections were made in 1966. These were grown as head rows in 1967 and over 1200 plants were selfed. Eight hundred forty-seven were selected for S_1 testing in the first rains of 1968 with 113 being selected from recombination using remnant self seed, during the second rain season of 1968. The continuing scheme for each calendar year illustrates that with S_1 testing, the three seasons per cycle can be obtained within each calendar year at Serere. Mass selection for the bristle and non-bristle types will also be continued during the two rainy seasons each year. These two pools can also serve as "back-up" populations if genetic variance is lost because of intense selection in S_1 testing.

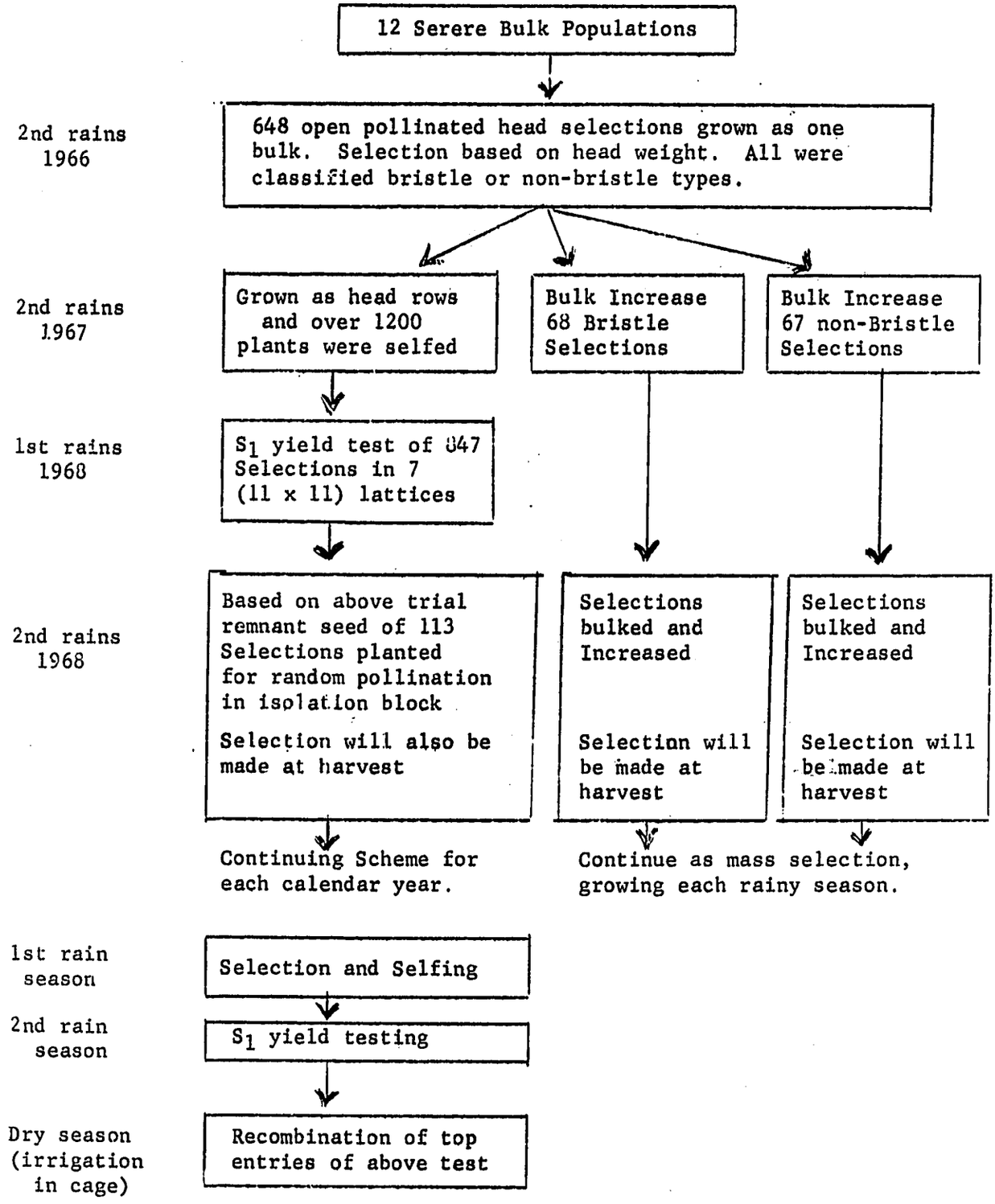


Figure 3. Recurrent selection program for Bulrush Millet

CEREAL AGRONOMY

G. Schumaker

Farmer Fertilizer Trials

Co-operation with progressive farmers in the area was obtained once again in 1968 and numerous fertilizer trials were carried out on their land. This type of study is essential for making recommendations on the use of fertilizers to farmers. Such trials also serve as a means of demonstrating to the farmer and his neighbors the increased benefits he can obtain by supplying the proper nutrients to his soil. The primary food crop in the area of study is finger millet, sorghum is also an important food. Since a high level of management is necessary in order to obtain the most efficient use of fertilizers progressive farmers in the counties concerned were selected and trials were sited on their land.

Excellent yields were obtained in 1968 from finger millet when both nitrogen and phosphorus were applied. Averages from the trials in Kumi county showed an increase in yield of 2.5 times by applying 40 lbs. of actual N and 40 lbs. of P_2O_5 per acre, table 21. Yields reported are for an average of 15 trial sites. Good increases were noted on the Ngoro trials as well. However, average yields for the various fertilizer treatments were at a lower level than in Kumi county. This was largely due to poor emergence on a number of trials. A period of dry weather occurred just after planting and many seeds which germinated did not survive. Undoubtedly land preparation, depth of seed placement and other factors were related to the poor emergence.

Combined statistical analysis of 1968 sorghum yields from the two counties is not yet complete, the individual trials in Kumi county show significant responses with both nitrogen and phosphate fertilizer. Sorghum experiments in Ngora county were badly affected by stalk borer and a number of the trials did not produce grains for harvest. Apparently the number of insecticide sprayings were not sufficient for adequate control of the borer.

The 1967 trial results also demonstrated the necessity of applying both nitrogen and phosphate fertilizer in order to produce the highest crop yields. However, the costs of fertilizer must be given consideration before the farmer can realize any profit from this practice. Economic optimums have been determined from the trial data based on current costs of fertilizers and price of product.

Table 21. 1968 finger millet yields for Kumi and Ngora counties. Average of 15 farmer fertilizer trials.

	Lbs. per acre N	Lbs. per acre P_2O_5	Kumi yields lbs./acre	Ngora yields lbs./acre
1	0	0	803	491
2	0	40	990	535
3	0	80	946	580
4	40	0	1,079	919
5	40	40	2,061	1,365
6	40	80	2,239	1,463
7	80	0	1,133	1,070
8	80	40	2,373	1,873
9	80	80	2,766	1,838

1967 Kumi county finger millet yields have been selected for presentation here for the purpose of illustrating the levels of optimum fertilization, and the profits that can be realized. The farmer can usually sell his crop for .20 shillings a pound and very often local prices are more than this. Current costs of fertilizer are 1.36 shillings per pound of actual nitrogen in the form of calcium ammonium nitrate, and .87 shillings per pound of actual P_2O_5 in the form of single super phosphate. Based on these costs the optimum level of fertilization is 70 lbs. nitrogen and 67 lbs. phosphate per acre. Larger yields can be obtained with more fertilizer but at less profit. Using the optimum levels of fertilizer the expected yield is 2,163 pounds per acre. The cash value of this yield is a little more than 430 shillings while the fertilizers needed cost the farmer 150 shillings. The profit excluding other incidental costs would be 280 shillings. Using yield figures from the trials where no fertilizer was used 950 lbs. were produced per acre representing 190 shillings in cash. Based on these figures the application of fertilizers can mean an additional 90 shillings per acre to the farmer.

Fertilizer Population Trials

Does the use of high levels of fertilizers necessitate adjustments in planting rates in order to get maximum use of the fertilizer applied? Such trials were repeated in 1968 with this objective in mind.

Sorghum

Results from a sorghum trial conducted in the 1st rains showed no differences in yield even when stands ranged from 19,000 plants up to 68,000 plants per acre. Yields were not exceptionally high and it is very likely that the

stand factor is most critical for high levels of production. It was noted that the sorghum produced very vigorous tillers at the low populations providing N and P_2O_5 were present. This would help to compensate for fewer plants of sorghum on the low population plots. Plots receiving high levels of N and P_2O_5 yielded 3,000 pounds per acre while the average for the nil treated plot was 1,050 pounds of sorghum grain. The application of nitrogen and phosphate fertilizers gave significant responses. Investigation is continuing, however, results for the second rains are not available.

Maize

Several fertilizer population trials were conducted in the Northern Region of Uganda. Excellent yields were obtained from the Aduku trial with the primary response being from nitrogen. Stand was not a factor in this trial although populations were as high as 34,000 plants per acre. Results from a 1967 trial at a different center showed a significant difference in yield due to plant population. Yields in the 1968 trial were 3,750 lbs. of maize with no fertilizer compared to 6,400 lbs. per acre with 200 lbs. N and 150 lbs. P_2O_5.

Date of Planting Trials

Sorghum date of planting trials were initiated at Serere in 1968. Currently very little information is available with regard to the ideal planting dates for sorghum. The first rains trial was designed to include two varieties with dates of seeding two weeks apart and covering a period of twelve weeks. The first dates were very early for the season and the last dates being later than normal. Very poor germination was obtained from one of the selections in the trial and yields are not reported. Yields from variety L 28 are shown in table 22.

Table 22. Yields of sorghum at Serere Research Station for 6 dates of planting.

Planting date	Yield lbs./acre
February 26	3,389
March 11	3,527
March 25	2,540
April 8	1,031
April 22	00
March 5	00

The data indicate that the March and late February plantings were by far the most suitable. Observations taken within the experiment showed a greater incidence of leaf disease on the late planted plots, also

Sphacelia had seriously affected the setting of grains on heads from the later plantings. This seemed to be the main reason that no grains were harvested from the April 22nd and May 5th dates. It is possible that infestation had come from adjacent early planted plots which had escaped the disease. If this is the case the results do not necessarily give a true indication of the optimum date of planting for sorghum. Investigation will be continued with attempts to control fungal diseases and Sphacelia.

Evapotranspiration

A hydraulic weighing lysimeter was installed in late 1967. Investigation with regard to moisture as a limiting factor in sorghum yields and study of water requirements of the sorghum crop are the main purposes for the installation. Measurements taken during the second rains covered a period when the crop was under stress. During the first days of the drought period E_T was as high as 8 mm. per day. Just prior to relief from the drought E_T had dropped to 3 mm. per day indicating crop stress. The total moisture required to mature the sorghum crop was 15.7 inches. Grain produced from the lysimeter was equivalent to 5,400 lbs. per acre. Studies on the water requirements for sorghum are to continue for a number of seasons in order to cover a wider range of climatic variation.

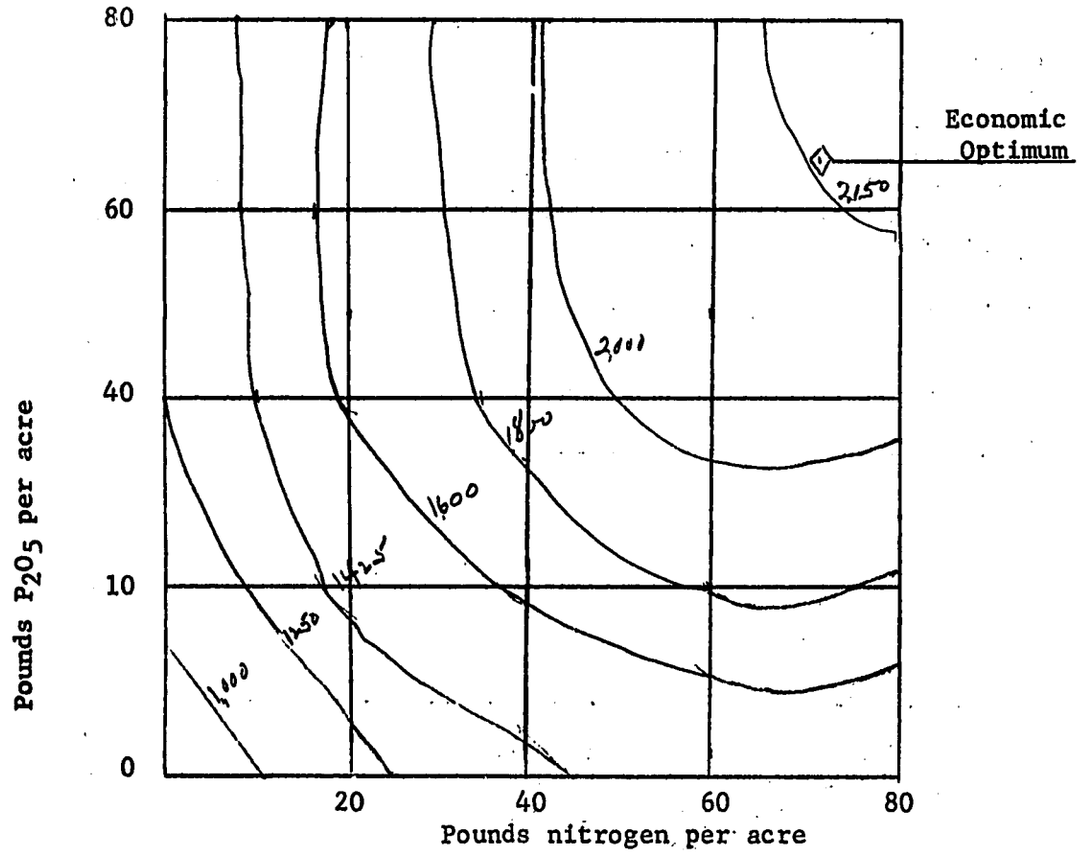


Figure 4. Response of finger millet to increasing levels of nitrogen and phosphate fertilizer. Economic optimum shown as yields of 2,162 pounds per acre from applications of 70 pounds nitrogen and 67 pounds P_2O_5 per acre.

CEREAL ENTOMOLOGY
(K. Starks assisted by C. Muhwana)

At the time of this report research on insect pests in connection with the project in East Africa has been in progress for about two years. After a survey of reports on prior research an effort was made to determine insect problems of potential economical importance on a regional basis. Although insect species are largely different from those in the Western Hemisphere, techniques have been borrowed from successful programs on cereal crop pests in the United States and other countries. The limitation of research personnel has necessitated the restriction of research approaches. Most work could be considered as applied research and the control approach has mainly concerned plant resistance to the sorghum shoot fly, Atherigona sp. on sorghum and the pink stalk borer, Chilo partellus on sorghum and maize. There is little duplication of the entomological work in West Africa on the Project although similar work on some control aspects seems justifiable since problems are not entirely the same. Most experimental data still awaits final statistically analysis, often because trials have been repeated to gain additional information. The appreciated cooperation of other research workers and administrators connected with the Project cannot be overemphasized.

Insect Damage to Sorghum and Maize - An effort has been made to obtain information on the extent and nature of insect damage to sorghum and maize. A test with a natural infestation of stalk borers in sorghum indicated that tillering probably compensates for slight borer damage by producing a larger number of stalks with heads. However, heavy borer infestations over a period of time can cause almost a complete loss of the grain crop (This field yielded only about 285 kilograms of threshed grain per hectare instead of an estimated 2000 k/ha.). Although the length of stalk tunneling appears to have a relationship on yield, other factors such as the relative stem diameter and the portion of the stem attacked also influence grain loss. Tunneling in the upper part of stems with comparatively small diameters can increase seedless heads and broken peduncles.

Some data from a seed production field of sorghum are given below:

Entry	C/o Stand reduction mainly by Sorghum Shoot Fly	C/o Stalk length tunneled	C/o Plants with grain on heads	Calculated grain yield (g/ha.
CK-60	50	42	16	53
Redlan	41	39	26	98
SB-65	14	78	43	296

Both CK-60 and Redlan are considered susceptible to the sorghum shoot fly whereas SB-65 usually rates as more resistant to this pest. The reverse situation has been found in regard to Chilo damage to these sorghum varieties. Nevertheless, heavy attacks of these insect pests combined with infections of Sphacelia disease on CK-60 and Redlan reduced grain yield to the extent that the field was judged unworthy of harvesting although the hybrid seed was much needed.

A test composed of a variety and a hybrid of both sorghum and maize was grown in two trials and artificially infested with Chilo egg masses. Each of the 4 plant entries had 4 different infestation treatments; no infestation, infestation at 20, 30, and 40 days after average plant emergence. Part of these data are given below:

Treatment	Plant height (cm)	Length tunneling per hill (cm)	Heads/Plot		Stalks/Plot	
			Number	Weight (dg)	Number	Weight (dg)
Uninfested	148.4	16.3	41.3	29.2	38.8	43.4
20 days	124.8	108.2	26.7	16.8	32.6	31.4
30 days	141.4	102.9	30.2	21.9	33.0	35.7
40 days	137.3	122.0	31.3	23.1	30.6	32.9
C.V. (C/o)	6.8	30.7	20.5	20.1	18.5	24.6

The infestation of larvae at 20 days gave the largest reduction in plant height, the number and weight of seed heads, and the weight of stalks in comparison to the other treatments. However, the infestation at 40 days gave the greatest length of tunneling. Although not shown in the table the hybrids of both sorghum and maize had more borer injury than the varieties but were better able to withstand the damage and to subsequently produce higher yields of both grain and fodder. In comparison with maize, sorghum had more borer damage and was more adversely effected when considering plant height and yields of grain and fodder.

Sorghum shoot fly resistance in sorghum. (H. Doggett and K. Starks)

Attacks by the larvae of the sorghum shoot fly cause the death of the growing point of sorghum. This injury is most noticeable 2 to 4 weeks after plant emergence. Differences among varieties have been found in the number of eggs deposited and the number of plants killed. These factors had a high positive correlation ($r = 0.375$, $n = 258$). The main factor determining good grain yield has been shown to be the ability of some lines even under repeated attacks to produce tillers that can escape further injury and subsequently have large grain-filled heads with comparatively even maturation. This type of resistance, commonly called recovery resistance has had a slight negative correlation with both the number of seedlings damaged ($r = 0.162$) and the latter visual effect,

rosetting (r = -0.130). Thus, it would seem to be independent of other measurements of resistance. Doggett has been successful in incorporating recovery resistance into the high-yielding variety Serena in parts of East Africa. The intent of the present program is to increase the level of resistance, to get resistance into other high yielding varieties and hybrids adapated over a wider range of conditions, and to incorporate a wider gene basis as work in Nigeria indicates that several species of shoot flies are involved. Starting in 1964 Serena and the fly-resistant beer variety Namatare were crossed with lines representing good yield and/or quality potentials. Somewhat improved infestation techniques have at present permitted the segregating populations to be screened for recovery resistance through the S_4 generation. Individually selected heads have been composited and put onto a genetic male sterile for use in a recurrent selection program. Indications are that progress has been made providing the resistance can be transferred. In addition, selections from the World Collection of sorghum have been screened and another composite has been made of lines showing good recovery resistance. Remnant seeds will be used to determine progress.

Chilo Resistance in Maize and Sorghum (S. Eberhart and K. Starks)

Entries from the Kitale Maize Program have been screened for Chilo resistance by artificially infesting with egg masses at the Serere Research Station. Although differences can be assessed in inbred lines by using leaf feeding ratings, the variations within composites may be too large to allow a comparison of groups without using an excessively large number of plants. At least such was the case with the Embu material. The East African variety trial was grown and rated under natural infestations of borers but so far no entry has had less injury than White Star, a local variety.

Efforts to use leaf feeding ratings with sorghum have so far been unsuccessful, presumably because of the wide variation in plant types and the confounding leaf injury by diseases. Measuring the length of tunneling, a more laborous technique, has indicated that differences do exist although a highly resistant variety has yet to be found. Lines with short head exsertion such as Dobbs may be more subject to grain loss due to a reduced number of normal size heads. On the other hand CK-60 and Redlan have less borer injury than lines such as SB-65 and Serena although all are considered to have adequate head exsertion.

Insecticidal Control. The control of the sorghum shoot fly on sorghum has proven to be difficult, presumably because there are repeated attacks starting as early as one week after plant emergence and continuing for 4 to 6 weeks on susceptible varieties of sorghum. Endosulfan has been demonstrated to give roughly 80-90% reduction of damaged growing points, but 4 to 6 applications at 3-day intervals were necessary to reach this level of control and thus the procedure seems impractical except for the protection of experimental plantings such as valuable nursery lines.

None of 10 experimental insecticides has indicated promise of effective control at single applications except for 2 systemic organophosphates of unfavorable mammalian toxicity, phorate and "Temik", which can be applied in the furrow at time of planting. Two foliar systemics give severe phototoxicity and little shoot fly control. Seven experimental insecticides gave a statistically significant reduction in the number of sorghum plants injured by the pink stalk borer, Chilo sp. There is considerable doubt, however, that any of these insecticides could be used by the "small" farmer in the near future because of the unavailability in East Africa, the excessive cost in proportion to the return from use on a "non-cash" crop, the unacceptable residue deposits in some other countries, and other factors. Although DDT and to a lesser extent toxaphene have given satisfactory control of Busseola fusca, the maize stalk borer, in Kenya, these insecticides have seldom been successful against other borers in experimental tests, especially Sesamia spp. and would also be expected to eventually be limited in use because of residue levels.

The control of termites damaging cereal crops has been successfully obtained on a non-experimental basis by finding the "nest" and treating it with dieldrin. Considering that research is being done on the Project in Nigeria, this serious problem would seem to need little further attention here at present except on an extension basis.

Chemical Lures for the Sorghum Shoot Fly (M. Beroza, P. Luginbill, and K. Starks). - A higher than usual incidence of sorghum shoot fly damage was found in sorghum after ground-up dried fish had been banded on rows of sorghum about 10 days after plant emergence. Chemicals possibly related to some of the ones in fish meal, such as organic acids, amines, and sulfides, as well as some compounds attractive to other insects, were sent by the Synthesis Investigation, Pesticide Chemicals Research Branch, Entomology Research Division, to be screened for attraction to sorghum shoot fly adults. These were tested in field traps over a period of about 6 weeks. None of the purified chemicals proved to be consistently more attractive than moistened fish meal (14.8 flies per trap), a substance of many chemicals of changing composition. Ammonium sulfide was better in 1 of 14 tests and ranked second from the top in the average number of flies trapped (5.5 flies per trap). None of the 55 compounds tested was highly attractive but nearly one-half of the materials lured some flies into the traps. Possibly a better designed trap would increase the measurable efficiency of some of the materials.

Effects of Soil Fertility on Stalk Borer Damage in Sorghum (G. Schumaker and K. Starks). - A test with 3 levels (None, 80 lb., and 160 lb.) each of N and P_2O_5 in all possible combinations was done during both the first and second rains of 1968 to study the relationship of fertilizers on borer damage in Serere sorghum. The 9 fertilizer treatments were put in 2 groups; one group was sprayed at weekly intervals and the other group was infested with egg masses of Chilo partellus, the pink stalk borer. Complete statistical analysis is not available but the yield data from the first trial are shown in the following table:

Insecticide Treated

NO_2 lb/A			
160	39.4	55.1	56.8
80	37.2	44.5	54.1
0	43.5	40.4	46.4
	0	80	160
	P_2O_5 lb/A		

Borer Infested

NO_2 lb/A			
160	32.0	36.3	36.2
80	28.4	33.7	36.6
0	35.3	38.7	37.5
	0	80	160
	P_2O_5 lb/A		

Avg. yield of threshed grain (q/ha)

Indications were that the combination of nitrogen and phosphate fertilizer could significantly increase sorghum grain yields. However, these increased yields could not be realized when plants were subjected to a stalk borer infestation. The borers significantly reduced plant height, slightly increased the time to flowering, and increased the number of seedless heads. Also, there was an increase in the number of borers per stalk in the high fertility plots. Additional results will be reported upon completion of the test.

Release of Parasites of *Chilo* (A.I. Mohyddin and K. Starks). - During the year 5 shipments of *Apanteles sesamiae*, a parasite of stem borers in India, have been sent for release at Serere Research Station. Each batch of parasites has been increased to about 400-600 individuals and released in the adult stage in a field known to contain *Chilo* in sorghum stalks. Later, *Chilo* larvae were collected and sent to the Commonwealth Institute of Biological Control at Kawanda, Uganda as the released parasite is difficult to distinguish from an endemic species, *Apanteles flavipes*. It is not yet known if the released parasite will establish here in field population of stem borers but infested larvae have been recovered.

CEREAL PROCESSING TECHNOLOGY

A. D. Shepherd, A. H. Woodhead, and J. Kapasi-Kakama

If one is to enhance the utilization of sorghum in the eara of East Africa, one must understand the present situation with respect to its use, then devise means to capitalize on its strong points and overcome its weak points insofar as is possible. Much of this period has been devoted to obtaining information on the present usage situation but in addition equipment has been received, installed and tested, sources for samples of sorghum uniform as to type sought, and contacts with cooperating groups established.

Much time was spent on developing contacts with people in government and out who are interested in the project and in a position to be helpful by providing information or working cooperatively with the group. Contacts were made in all three of the Community countries although proximity made those in Kenya more numerous.

The Ministry of Agriculture, Kenya, has been most cooperative. Visits were arranged to the Eastern Provincial office, Embu, and the District offices within the province at Embu, Kitui, and Machakos. The later point included visits to the Farmers Training Centre and Katumani Experiment Station, where the dry area maize was developed. Nyanza province was also visited with stops at the Provincial offices in Kisumu and the Farmers Training Center at Maseno. The Provincial offices in Kakamega and District offices at Busia were visited in the Western Province. According to the Kenya Department of Agriculture these three provinces (Eastern, Western and Nyanza) account for about 99% of the sorghum entering the market in Kenya, Western Province alone accounting for about 80%. Statistics on total production are more difficult to obtain but it is likely that Nyanza actually out-produces Western Province.

Through discussion with the Provincial and District Agriculture officers, Provincial Home Economists and women on the farms, these visits provided useful information onsorghum, such as how it is used, what people like and dislike about it as a food, and how it is processed at the farm and village level.

Miss Grace Wagema, Home Economist in the Ministry, was also contacted and agreed to help with recipe development and extension through the farmers training centres at points within Kenya when developments warrant such action.

Unga Millers have been contacted and an agreement on their part to participate in milling experiments on sorghum obtained, although some of the details remain to be worked out. Mr. J. Ward, Chief Chemist, Unga Millers Ltd., has agreed to undertake some experimental milling of sorghum

in their laboratory scale mill (a Buhler). Fifty pound samples of each of two sorghum types has been provided to UNGA for preliminary establishment of milling conditions. The samples are of a white seed coated, Wiru type which was found to debran well in the rice-polisher and a white seed-coated variety with a dark testa. These two samples should provide a good preliminary test.

Once milling conditions have been approximated then it is believed milling characteristics can be established from much smaller samples.

Mr. Ward has also agreed to do a limited number of proximate analyses for us in their analytical laboratory. Furthermore, he is agreeable to help us establish certain of the same analytical methods at EAIRO (probably fiber, nitrogen, and moisture) even to training an operator in the Unga laboratories. To this end he has provided copies of the methods used at UNGA and we are ordering the necessary equipment, and chemicals.

At Unga, Mr. F. T. Holden, Managing Director, Unga Millers Ltd., and Mr. J. Jones, Managing Director of Unga Ltd., were also contacted for executive clearance. Mention was made in a proposal two years ago that compensation of a fee for service basis might be paid. The possibility of doing this has not been cleared and the cooperation may be limited until this point can be clarified.

Mr. Ward is also interested in the possiblity of providing a wheat protein concentrate by the remilling of certain fraction or fractions of the by-products from wheat flour milling. He will provide us with samples representative of their by-product streams and we will try to estimate their value for producing wheat protein concentrates by remilling and sifting.

Wheat protein concentrate may provide a relatively cheap binder for use in extruded pasta-type products containing substantial quantities of cereals other than wheat.

Miss E. Ricketts, Chairman, and Mrs. Rodrigues, of the Domestic Science Department, University College, Nairobi, also expressed an interest in helping with recipe development and perhaps some taste evaluations among the students of the products that we may develop.

Contact was made with the other USAID personnel working on the Major Cereals Project on a trip that included stops at Kitale, Kenya and Serere, Uganda. At Serere discussions were held as well with Dr. Hugh Doggett, Research Officer-in-Charge, Sorghum and Millet Unit, relative to the program. Arrangements were made for Dr. Doggett to provide about fifty pounds each of ten samples of sorghum representing different types, classes or varieties for delivery after the first of the year. Small lots of three varieties, Serena, Wheatland, and Redland, were returned to Nairobi for immediate use.

The capabilities and limitations of the Amino Acid Analyzer for use in conjuction with the sorghum breeding work were discussed. The question of providing means for screening a larger number of samples than within the capabilities of the present instrument on a limited basis (i.e.content of a single amino acid, probably lysine, plus total nitrogen) was opened. More information was to be obtained on costs for this kind of equipment and more details of method. This was done and copies sent to Dr. Doggett.

On the occasion of a second trip to Serere the question of screening for high lysine was again discussed. It was agreed that more information should be obtained regarding several points: (10 simpler alternate screening methods for use in East Africa; (2) possibility of samples being submitted to U.S. for screening; (3) practicability of lysine fortification (i.e. of grain directly or addition of lysine to common salt.

Also on this trip the great variability in sorghum available for selection was pointed out in a trip to the Ethiopian sorghum collection. The selection for characteristics useful for processing was recognized as important and to be considered along with agronomic characteristics and disease and pest resistance in any selection. Some processing quality attributes were tentatively assigned for a pearled (rice-like) sorghum. (These are discussed later in this report).

Also at Serere, a decision was made to use the UDY analyzer to determine the protein content of sorghum samples from the fertilizer trials to determine the influence of nitrogen fertilization upon protein content. Food and Agricultural Officer, U.S.A.I.D. A conference was arranged involving Mr. A.D. Shepherd with Ministry of Agriculture and Cooperatives personnel. Mr. A. Mushi, First Assistant Director of Agriculture, Dr. W. W. Peek, Chief Research Officer Agriculture Division (A.I.D.) and Mr. D. N. Sutherland, Economic adviser to the Ministry (F.A.O.). Some important facts were brought out relevant to the EAIRO project.

The emphasis, which originally after independence, was placed upon the expansion of export cash crops, has been dropped in favor of emphasising food crops, among which they believe sorghum to be extremely important. Tanzania also is trying to build institutions for foods science. They have made a small start at the station at Illonga (Dr. Peek made available a list of projects which are listed later) and have proposed an FAO project to establish a "National Food Science and Nutrition Institute", at Morogoro (a copy of the proposal was obtained). They also pointed out that the station at Ukiriguru, near Mwanza was also very interested in our work.

The order of production of cereals in Tanzania as assessed by this group was said to be maize first, paddy (rice) second, and sorghum third. This is somewhat surprising because sorghum was thought to be a food crop of prime importance in Tanzania. They suggested that statistics should be obtained from an FAO staff member in the Ministry.

Mr. Girouard (FAO) of the Ministry agreed to provide statistics on total harvest and marketed quantities for the last three years for five cereal crops, maize, sorghum wheat, rice and millet according to regions. Based on average total harvest for the last three years maize is indeed first by a substantial margin followed by sorghum, millet, rice and wheat in that order. However the marketed average for the last three years show a different order - maize first again but followed by rice, wheat, millet and sorghum in order. This points up the importance of sorghum at the subsistence level. Based on three year averages for total harvest, sorghum is produced in larger tonnage than maize in three regions, Kogona, West Lake, and Mtwara. Production was very nearly equal for the two cereals in the Coast region. Three regions produce over 20,000 tons of sorghum per year, Kogona, Morogoro and Shinyanga. Tabora and Singida regions each produce about 15,000 tons per year which represents about 10% of Tanzania's annual total of 144,260. Based on the above, sorghum assumes a very important role in perhaps seven of the seventeen regions in Tanzania.

Mr. G. Semiti, Senior Research Officer, Ministry of Agriculture in Dar es Salaam, was mentioned as being particularly interested in food technology and as being responsible for the work at Ilonga. However, Mr. Semiti has been detailed for an extended period to a group which is evaluating research projects in East Africa. Fortunately he was in Dar es Salaam to attend a scientific meeting and had a short time to spend with Mr. Shepherd. Mr. Semiti believes that sorghum must be used more extensively as food for many reasons, but outstandingly, it is cheaper than maize to produce. The Msumbiji variety with white flinty grains and quite weevil resistant is very popular here.

He is interested in a blended baby food based on sorghum. The product will not be precooked, but will be only lightly toasted (probably to inactivate enzymes). The reasoning behind a product requiring cooking is to provide reasonable assurance that it will be safe.

Mr. Semiti believes that recipe development following along with product development is highly important. He would stress this for maize as well as sorghum. He believes recipes for flat breads would be good (e.g. tortillas). At Ilonga they have a taste panel. He agreed to evaluate product samples we might provide, if we would provide recipes.

Mr. Semiti expressed a desire to have some samples of products run through the amino acid analyzer when it becomes operative.

In private conversation with Dr. Peek, Chief Research Officer, Ministry of Agriculture, Mr. Shepherd found that the food science project at the Central Research Centre, Ilonga, had the following projects (a) Chemical Analysis of Fresh Preserved Food for their Nutritional Value and Safety for Human Consumption (b) the Reconstitution and Utilization of Preserved Foods (c) The Storage and Marketing of Preserved Foods (d) A Study of Microbiological Aspects of Food Preservation (e) The development

of Cheap Equipment for Food Preservation at both the Home and Village Level (f) The Production of Protein Rich Foods from Non-conventional sources (e.g. Yeast, F.P.C. Oil Cakes), and (g) The enrichment and fortification of staple foods and the development of baby foods and food supplements.

Dr. Peek suggested at a minimum that Mr. Shepherd visit Ukiriguru Experiment Station, Mr. Auckland, Senior Research Officer, and Ilonga, Frank Ringo in charge of the station but that this latter trip should be made in the company of Mr. Semiti and therefore would have to wait until he is free from his current special assignment. Other contacts might be suggested at Ukiriguru. Dr. Peek also suggested that they would be willing to grow sorghum for us for a fee at the station at Urambo, Tabora region, where sorghum trials are run.

Some additional contacts with interested and perhaps useful people were made in Dar es Salaam. Dr. Ahdo El-Mahandes an FAO Food Technologist stationed at the Industrial Studies and Development Centre has had experience with sorghum products in Egypt and Sudan. He compared flat breads from maize and sorghum and found sorghum to be superior. He also did rat feeding studies which showed the nutritional superiority of sorghum. He feels that it is important that a hybrid not be used because the farmer should be able to save seed over from one crop to plant the next. El-Mahandes provided recipes for flat breads.

Mr. Zakaria, Assistant General Manager, Chande Industries (Mr. Chande, General Manager) met with Mr. Shepherd. The milling industry has been nationalized and those of Chande group (Mr. Chande and Mr. Zakaria) are in charge of all milling in Tanzania (ex Unga Mill, etc.). Mr. Zakaria said that Mr. Semiti of the Ministry of Agriculture has requested that they attempt to blend sorghum flour with maize or cassava flour. Actually they do not mill sorghum and some laboratory scale milling runs were disappointing using a red seeded variety. The flour was too dark. However the tests were not extensive. He was favorably impressed with the possibility of using white seeded varieties. He believes that it will be a difficult task to change the peoples' preference for maize.

Dr. Roig, in charge of the WHO regional office headquarters in Dar es Salaam, met briefly with Mr. Shepherd. However, two men, Dr. Burgess and Dr. Lema, who are doing nutritional studies were out of town. Dr. Roig suggests that Mr. Shepherd visit them on his next trip to Dar es Salaam.

Some major pieces of equipment were in hand before the beginning of the quarter, the amino acid analyzer, the pasta extruder, the rice polishing machine and the UDY analyzer. The rice polishing machine has been installed [illegible] used to a considerable extent for experimental work and preparatio[illegible] samples. The pasta extruder has been set up but some rewiring has been required to adapt motors to the power supply available. It is now believed to be ready to go when new coils are obtained for the starter

switches. The amino acid analyzer is believed to be ready to go once the reagents, buffers, etc. are received. By early January we hope to have secured a technician to operate the analyzer and to be ready for the service engineers from the supplier to start us up and check operations. The UDY analyzer has been set up and checked out on a wheat sample of known protein content. Another major piece of equipment, a dough mixer has been acquired for use in support of the rice polisher and pasta extruder.

Considerable familiarity has been acquired in the operation of the rice polishing machine for the debranning of sorghum. When the machine is run on a continuous basis the variables which influence throughput rate and degree of bran removal are (1) feed gate opening, (2) spacing between abrasive cone and screen and (3) resistance to discharge (applied by increasing effective weight on discharge gate).

A run was made starting with a 25 lb. quantity of a white sorghum obtained from a shop in Nairobi. The feed gate setting was ½" open. The spacing between the abrasive cone and screen was a reproducible setting about mid-range and the weight on the discharge gate was full in (i.e. as light as possible with the weight on the arm).

Four successive passes were made recording the yield of grain and fines obtained after each pass. Two ounce samples of grain were removed after each pass and the balance was run through again. A summary of the four passes follow:

	Grain					Fines			
Run No.	Feed		Yield		%Yield	Yield		% Yield	
	lb.	oz.	lb.	oz.		lb.	oz.	Individual	Comulative
1	25	0	20	15	83.8	3	8½	14.1	14.1
2	20	13	18	12	75.4	2	0	8.0	22.1
3	18	10	17	½	68.6	1	4½	5.2	27.3
4	16	14½	15	14	64.0	0	15½	3.9	32.2

From the first run, the fines obtained were largely bran and the grain was almost completely debranned. The fines from runs two through four were progressively finer in texture, lighter in color and smaller in quantity.

Annually the East African Industrial Research Organization has a display as part of the East African Community booth at the Nairobi show (very much like a state or county fair in the US). This year the rice polishing machine was featured in the display. It was run on a continuous recycling basis for a very large proportion of the five days of the show. This exposure acquainted people with the Cereal Processing Project. Included in the visitors were two important ones from the United States, Dr. Lester Brown, Administrator, International Agricultural Development Service, and Dr. Brooks James, USAID Assistant Administrator, War on Hunger.

MAIZE IMPROVEMENT, KITALE, KENYA

S. A. Eberhart

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.); CIMMYT (Ford and Rockefeller Foundations); and the U.S. Agency for International Development and the Agricultural Research Service of the U.S. Department of Agriculture in cooperation with the East African Agriculture 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 1,200 (4,000) and 2,300 meters (7,500'). The senior staff at Kitale includes the Senior Maize Research Officer, F. Ogada; the CIMMYT regional Coordinator, Mr. M. N. Harrison; Maize Geneticist, S. A. Eberhart; Maize Agronomist, A. Y. Allan; Maize Breeder, S. Njuguna; Seeds Officer, G. Ravagnan; Asst. Maize Geneticist, C. Ndegwa; Asst. Maize Breeder, C. Nyambare; Asst. Maize Agronomist, B. Masyanga, and Asst. Seeds Officer, J. Wakhungu. The Asst. Maize Breeder at the Kakamega substation is B. Wamalwa. Breeding and Agronomy 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 Agronomist is T. Gathechah and Asst. Maize Breeder is B. Gichuhi. The drier parts of this region also require much earlier maturing varieties to escape the drought. The improvement of early maturing varieties is done at the Katumani Research Station near Machakos by the Asst. Maize Breeder, H. M. Mauuye.

Close cooperation is being maintained with other Eastern African Maize Breeders. These include the following:- A. Bolton, Ukiriguru, Tanzania; D. Haswell, Ilonga, Tanzania; G. Selley, Lilongwe, Malawi; J. Abington, Chilanga, Zambia; and Y. K. Musisi, Kampala, Uganda.

When one studies the methods used to obtain maize improvement throughout the world including the United States, Mexico, and now more recently Kenya, there appear to be five major factors essential for this improvement. These factors are as follows:-

(1) Breeding research to develop superior varieties.
(2) Agronomic research to find the cultural methods required to get maximum economic yields.
(3) Seed production and distribution to make improved seed and fertilizer readily available to farmers at a reasonable cost.

(4) An effective extension program to show the farmers how to grow the improved varieties using the recommended husbandry practices and to give advice as to the economic levels of fertilizers.
(5) Marketing facilities to ensure that the farmers will find a ready market for their crops at a price that gives them the incentive to get better yields.

This report will be broken down into these five major sections to show how Kenya is making progress in Maize Improvement.

BREEDING RESEARCH

Although the inbreeding-hybridization method of maize breeding will produce a large initial yield increase, long term improvement has been disappointly small wherever it has been used. Recent developments in the United States suggest that population improvement by recurrent selection should be the basis of a modern breeding program. This is the basis of a Comprehensive Breeding System as outlined by Eberhart, Harrison, and Ogada (Der Zuchter 37:129-74:1967). This system is being used throughout Kenya and has been adopted by most of the breeding programs in Eastern Africa.

Nomenclature becomes important in identifying the improved varieties. Dr. J. Lonnquist in consultation with othermaize breeders is proposing a standard system, and this nomenclature has been used in this report. The name of the variety is followed by a letter identifying the method of selection and Cn for the cycle of selection. The following symbols are used:-

M	Mass selection
MC	Mass selection during composite formation
E	Modified ear-to-row selection
H	Half-sib selection and recombination using S_1 seed
F	Full-sib selection
S	S_1 testing <u>per se</u>
HL	Half-sib selection using a low yielding tester
HI	Half-sib selection using a low yielding inbred line as tester

The experiment number is also added to the method of selection in the Maize Genetic program. For instance Kitale II (E1)C2 is the population developed by ear-row selection in experiment 1 after 2 cycles of selection in Kitale II. KCC(S)C1 is the product of 1 cycle of S_1 testing in KCC.

Results are presented in quintals per hectare (q/ha) where 1 q/ha = 1.59 bu/acre.

QUANTITATIVE GENETICS

S. A. Eberhart

Because further improvements in yield of hybrid varieties produced by the Comprehensive Breeding System depend on the improvement of parental populations through recurrent selection, the method used for the recurrent becomes extremely important. If a certain method will give 25% faster gain at no extra cost than another method, the greater progress during a ten year period becomes extremely important. The information obtained from the comparisons of recurrent selection methods at Kitale should be extremely valuable to maize breeders throughout Africa.

Even though it will require the years of recurrent selection with the various methods before differences will be great enough to compare empirically, the estimates of genetic parameters obtained during the first few years can be extremely useful in making decisions at this time. The formula to predict gain (G) from selection from the various breeding methods is given below:

$$G = \frac{K(x) \quad \sigma A^2}{y. \sqrt{\frac{\sigma e^2}{rp} + \frac{\sigma ge^2}{p} + \ldots \sigma g^2 \ldots}}$$

where k is a constant determined by the selection intensity; x is the proportion of the additive variation among families; σA^2 is the additive variance; y is the number of years required per cycle; σe^2, σge^2, and σg^2 are the environmental variance, genotype by environmental interaction, and genetic variance among families; and r and p are the number of replications and locations (places) used in yield trial evaluations.

Studies in North Carolina suggest that observed results compare very closely with gain predicted with this formula. Consequently, the relative progress in most of the methods is merely a function of genetic parameters and constants such as k (the selection intensity factor) and the years (y) required per cycle. Very good estimates of these parameters are now available in KCA and have been used to give comparisons among the several breeding methods as shown in table 23. S_1 testing is the only method from which it is difficult to obtain reliable predictions. This is because the genetic parameters change with inbreeding; and in S_1 testing the progenies under evaluation are S_1 lines which are 50% inbred.

Table 23. Expected gain per year at Kitale in Kitale Composite A (KCA)

Method	3 seasons in 2 years		2 seasons per year: non-similar seasons		2 seasons per year: similar seasons	
	q/ha	%	q/ha	%	q/ha	%
S_1 testing (S13)	5.38		5.38		7.17	---
Half sib (H14)	4.67	9.7	4.67	9.7	6.23	12.9
Full sib (F18)	3.39	7.0	6.73	14.1	6.73	14.1
Ear-row (E7)	3.23	6.7	3.23	6.7	6.46	13.4
Mass (M9)						
no irrigation	1.63	3.4	1.63	3.4	3.27	3.4
with irrigation	3.27	6.8	3.27	6.8	--	--

The annual expected gain is given for two different situations. The first (in which there are three seasons possible in two years through irrigation) is the situation that exists at Kitale. Because we are using the late maturing varieties at a high altitude, it is impossible to get yield test evaluations and obtain four crops in two years. However, with irrigation it is very feasible to get the three seasons. Under this situation S_1 testing will probably give the most rapid improvement in yield but only slightly greater than half-sib family selection. As seen in figure 5, if enough sites are used, half-sib family selection can be made as effective as S_1 testing. Because the genetic variation among S_1 families forms the biggest part of the phenotype variance, it is not economically feasible to use more than three or four locations for the progeny evaluation. In contrast, the genetic variation among half-sib families forms a small part of the phenotypic variance, and the gain from selection can be increased with increasing numbers of trial sites. In such a situation the full-sib selection is much less effective because only half the additive variation is present among full-sib families compared to all the additive variance with S_1 testing. The phenotypic variance is large because it contains half the additive and one quarter of the dominance variance, whereas in half-sib testing the phenotype variance only contains one quarter of the additive variance.

If conditions existed at Kitale whereby one regular season yield trial could be conducted and an off-season irrigation nursery could provide an opportunity for recombination (this is the situation at Mwanza, Tanzania; Kawanda, Uganda; and many other breeding centers), the relative efficiencies change completely. In such situations full-sib family selection becomes most effective because a complete cycle can be obtained in a single year. The comparison of full-sib testing and S_1 testing is given in figure 6 for varying numbers of locations under these conditions.

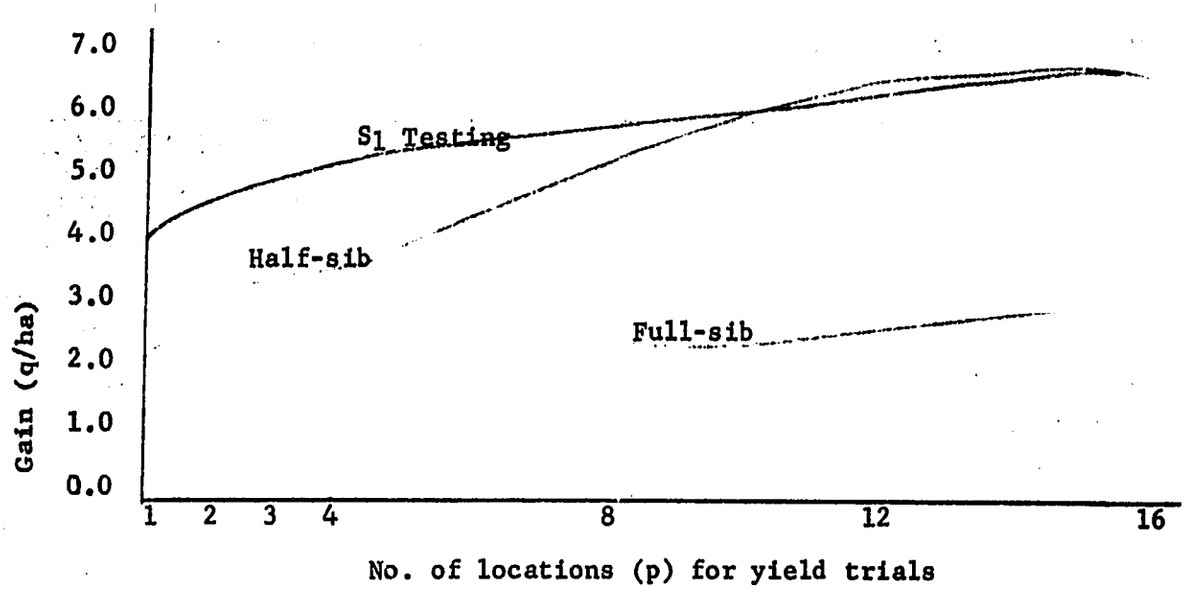


Figure 5. Expected annual gain fromselection in KCA with 3 seasons in 2 years.

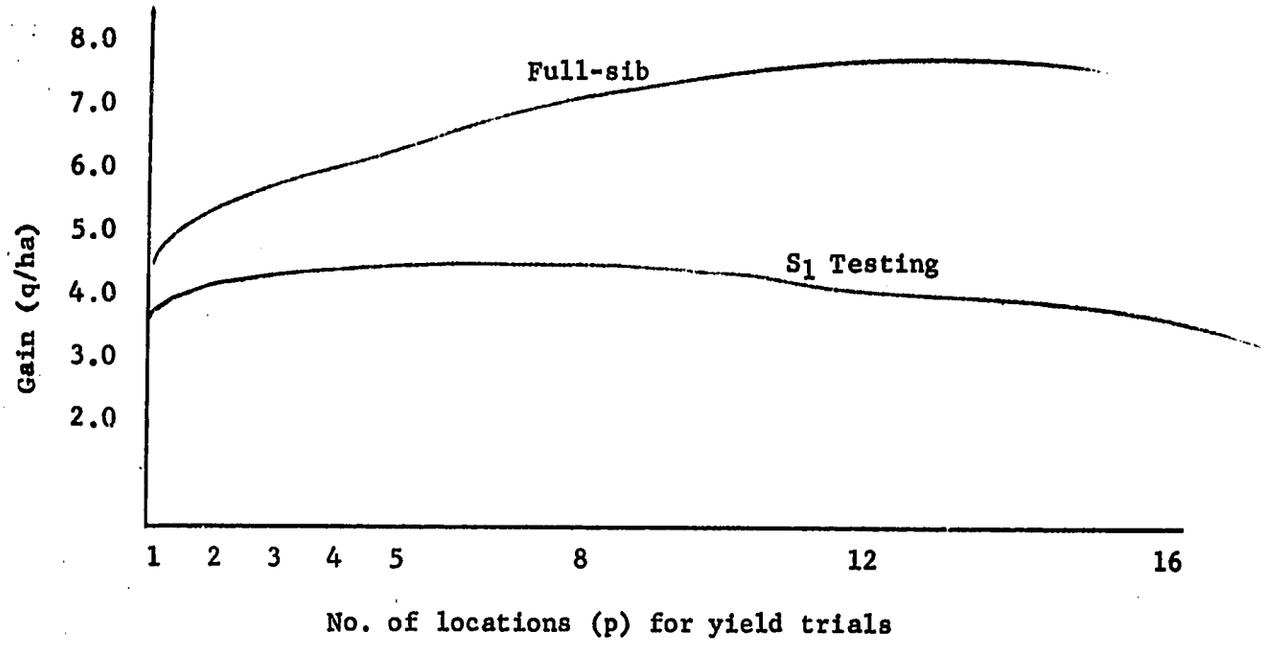


Figure 6. Expected annual gain in KCA with 2 seasons per year.

Another set of environmental conditions exist at Embu and Katumani in Kenya. At these locations there are two rainy seasons a year in which environmental conditions are very similar and the maturity of maize is short enough so that yield trials can be conducted in either season, the results analysed, and the next season's material prepared for planting. Under these conditions the differences among S_1 testing, half-sib selection, full-sib selection, and even ear-row selection are small, (table 23). However, a practical breeder would probably prefer S_1 testing because a yield trial is conducted only every third season and there is more opportunity for selection among plants in the nursery for agronomic characteristics. The ear-row selection has the advantage of requiring no hand pollinations in the nursery, but yield trials with one yield trial in isolation are required each season.

Although mass selection might be useful in obtaining improvement at small stations where qualified staff were not available to conduct more intensive methods of recurrent selection, it cannot be recommended where staff, funds and facilities permit more intensive methods of recurrent selection. Probably the most important role for mass selection is in maintaining genetically variable reserve populations. In these populations gradual improvement can be obtained, and yet the maximum genetic variability can be maintained. Such populations might be very useful in the future if the more intensive selection methods exhaust the genetic variability of the main breeding populations.

A comparison of the expected gain from selection and observed progress are given in Table 24 for some of the populations under selection. Because estimates of within plot variances were not obtained in the first years for the ear-row selection scheme, expected gain presented in this table for the ear-row selection method only includes the selection from among the half-sib families and does not take into account the additional gains expected from the mass selection among plants within a half-sib family. Observed progress in the first cycle of reciprocal recurrent selection in Kitale II and Ecuador 573 is slightly better than the improvement from the two cycles of ear-row selection. The improvement of H 611 by recurrent selection has been 8% which is somewhat less than the expected gain.

Estimates of within plot variances (s^2w) were obtained in 1965 and 1967 in KCA. When mass selection within half-sib families is included in the expected gains from selection for KCA (E7) G changes from 2.3 to 3.2. The formula to predict this expected gain is given below:-

$$\frac{(1.76)\ 1/8\ \sigma_A^2}{\sqrt{\frac{\sigma_e^2}{rp} + \frac{\sigma_{g^2e}}{p} + \sigma_g^2}} \qquad \frac{(1.76)\ 3/8\ \sigma_A^2}{\sqrt{\sigma_W^2}}$$

$$\approx 2.34 + .89 \approx 3.2$$

Although these results giving observed progress from selection are only very preliminary, they do indicate that improvement is being made by recurrent selection and that this improvement is carrying over into the hybrid variety.

RESPONSE TO VARYING ENVIRONMENTS

S. E. Eberhart

Stability parameters to measure the response of varieties to varying environments have been defined by Eberhart and Russell (Crop Sci.6:36-40 1966). In this method the mean of all varieties in a trial is used as a measure of the environmental index. The regression of each variety on the environmental index for a series of locations is a statistical measure to compare the responses of these varieties to varying environments. The stability parameters (b_ℓ) were estimated for each variety in the composite evaluation trial (724). Since there are also very different responses among varieties to altitude, the linear and quadratic response to altitude was estimated simultaneously so that the estimates of b_ℓ are adjusted for altitude. These results are presented in Table 26 and figure 7.

Several rather interesting comparisons are seen from these results. As environmental conditions improved the Hybrid 611 shows greater superiority over the parental varieties Kitale II and Ecuador 573, as indicated by the estimate of a b_ℓ of 1.25 compared to .70 and .79 for Kitale II and Ecuador 573. Similarly the new composite varieties, KCA and KCE, show a greater response to improved environments; that is, the superiority is much greater under more favorable environmental conditions than it is under poor environmental conditions. The improvement in the varieties from recurrent selection alsoseems to be greater under more favorable conditions. The expected improvement from the C2 of the ear-row selection trials is roughly equal to the improvement in one cycle of reciprocal recurrent selection. Hence, in Table 26 the average of improved populations has been computed to give a stability parameter (b_ℓ) of 1.05, whereas the original varieties

Table 24. Yields (q/ha) of original and improved varieties at 11 locations in 1966 and 1967 and at 7 locations in 1968.

Variety	1966	1967	1968	Average 1966-68	Average 1967-68	Gain 1967-68 q/ha	Gain 1967-68 %	Expected Gain q/ha	Expected Gain %
K II	50.6	39.4	54.0	48.0	46.7	-	-		
K II(R11)C1	--	43.8	55.8	--	49.8	3.1	7	--	--
K II(E1)C2	52.7	42.6	53.1	49.5	47.9	1.2	3	3.9	7.9
K II(E1)C4	--	--	60.4	--	--	-	-	7.8	15.9
Ec 573	36.7	27.8	32.1	32.2	30.0	-	-	--	--
Ec 573(R11)C1	--	39.2	57.6	--	48.4	18.4	61	--	--
Ec 573(E2)C2	45.4	40.2	42.4	42.7	41.3	11.3	38	5.8	13.1
Ec 573(E2)C4	--	--	49.4	--	--	--	-	11.6	26.3
KCA(E8L)C2	46.8	42.2	53.2	47.4	47.7	- 2.7	- 5	- 3.2	- 6.5
KCA	49.7	45.4	55.5	50.2	50.4	--	--	--	--
KCA(E3)C2	50.8	46.0	52.1	49.6	49.1	- 1.3	- 3	5.6	10.2
KCA(E3)C4	--	--	55.1	--	--	--	-	11.3	20.5
KCA(E7)C2	--	53.8	67.6	--	60.7	10.3	20	5.6	10.2
KCA(M9)C2	--	46.4	57.9	--	52.2	1.8	4	3.2	6.8
KCA(M10)C2	--	49.5	65.2	--	57.4	7.0	14	2.4	4.8
H 611	60.5	59.5	74.3	64.8	66.9	--	--	--	--
H 611(R)C1	--	66.6	76.2	--	71.4	4.5	7	7.5	13.3
L.S.D.(.05)	4.4	6.8	--	--	--	--	--	--	--

* The expected gain from selection within half-sib families has not been included.

Table 25. Estimates of $b\ell$ and predicted means from stability parameters of Kitale varieties at 1900 m in 1967.

Variety	$b\ell$	Environmental Index 25	50	75
K II	.70	25.5	43.0	60.4
K II(E1)C2	.87	20.6	42.4	64.2
K II(R11)C1	.85	22.9	44.4	65.6
K III	.92	24.1	47.2	70.2
Ec 573	.79	6.6	26.4	46.1
Ec 573(E2)C2	.98	17.6	42.0	66.4
Ec 573(R12)C1	.86	20.4	41.9	63.5
KCA(E8L)C2	.93	18.8	41.9	65.1
KCA	1.05	22.5	48.8	75.1
KCA(E3)C2	1.22	18.7	49.1	79.5
KCA(E7)C2	1.09	27.2	54.5	81.8
KCA(M9)C2	1.07	23.4	50.3	77.2
KCA(M10)C2	1.05	27.2	53.4	79.7
KCE(MC)C1	.96	27.4	51.4	75.3
KCE(MC)C2	1.03	28.5	54.3	80.1
KCE(MC)C3	1.12	28.1	56.1	84.0
H 611	1.25	33.2	64.5	95.8
H 611(R)C1	1.40	34.2	69.2	104.2
H 611B	1.40	35.8	69.8	104.8
H 613B	1.26	39.6	71.1	102.7

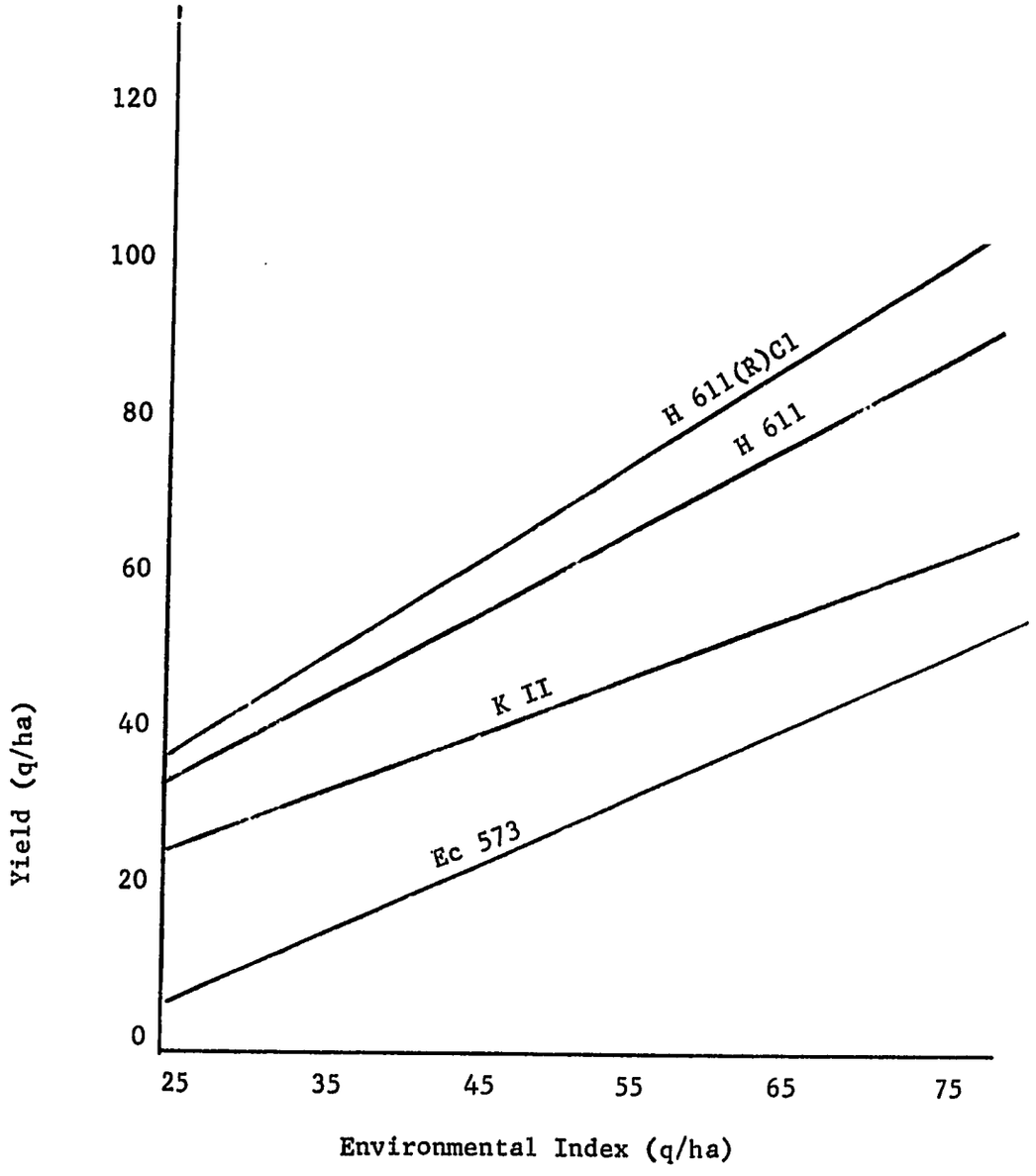


Figure 7. Predicted response of varieties to varying environments in 1967 at 1900 meters.

averaged 0.94. This seems to suggest that when one is comparing improved populations with original material a percentage figure might be more accurate over a wide range of conditions rather than the q/ha increase. For instance, the superiority of H 611(R)C1 over H 611 at 1900 meters is estimated to be 4.7 q/ha at an environmental index of 50, whereas the superiority is expected to be 8.4 q/ha when the environmental index is 75. However, the superiority of H 611(R)C1 is 107 and 109% respectively when environmental index is 50 and 75. The improvement in Ecuador 573, KCA, KCE, and H 611 has been great enough so that the improved varieties are superior even at an environmental index of 25. In contrast with Kitale II the improved populations tend to be somewhat lower yielding under less favorable environmental conditions and only show improvement under more favorable conditions.

Table 26. Estimates of response to varying environments (b) obtained from 11 locations in 1967.

Variety	Cycle of Selection		
	C0	C1	C2
K II(E1)	.70	--	.87
K II(R11)	.70	.85	--
Ec 573(E2)	.79	--	.98
Ec 573(R12)	.79	.86	--
KCA(E8L)	1.05	--	.93
KCA(E3)	1.05	--	1.22
KCA(E7)	1.05	--	1.09
KCA(M9)	1.05	--	1.07
KCA(M10)	1.05	--	1.05
KCE(MC)	.96	1.03	1.12
H 611(R)	1.25	1.40	
*Average	.94	1.05	

*KCA (E8L) and KCE(MC)C1 have been excluded

If recurrent selection tends to give greater improvement under more favorable environments as these results suggest, it is very important that evaluation of progress from selection be done over a range of environmental conditions. For instance, if one were to evaluate progress when the environmental conditions of the trial were extremely poor, one might conclude that no progress had been made. More important is the fact that selection for increased yield under adverse environmental conditions may not select the genotypes that will give superior performance under more favorable conditions.

These results would tend to support the policy adopted by the Maize Research Section in Kitale that environmental conditions should be made as favorable as possible, yet sufficient stress be applied by using very high plant populations to produce improved populations that are at least as good as unimproved populations under unfavorable environmental conditions. Although the plant populations and fertilizer rates chosen for the comparis of breeding methods in the maize genetics program seemed high when the project was started in 1964, subsequent work by the Maize Agronomist has shown that under the proper cultural conditions including early planting, these fertilizer rates and plant populations are only moderate. But no change ca be made for the duration of the study because plant populations and the general yield level have a very great influence on estimates of genetic parameters and expected progress from selection. However, the applied breeding program at Kitale and other breeding programs throughout Eastern Africa can make use of this information.

The results from the Kenya National Maize Variety Trial conducted in 1967 by Mr. Allan were also analysed using this method. The general response of some of the varieties to altitude are shown in figure 8. Since Ec 573 is a high altitude variety, H 611B shows more superiority at the higher elevations. H 511 seems to be very similar in response to H 622 and H 632 developed from Kenya flat white maize strains. Muratha came from the same source of material but was selected for a shorter growing season at a somewhat lower altitude. It is more susceptible to the blight and rust than the other varieties. This may account for its greater inferiority at the higher altitudes.

Another rather interesting result seems to be the greater superiority of the longer season hybrids under more favorable conditions (figure 9). There results were taken throughout Kenya in 1967 and in almost all cases there was a long enough season for the late maturing varieties to mature. In a recent report Bolton (E.A.Agric. J.(in press)) noted a similar response for the Ukiriguru Katumbili variety and H 622 as shown in figure 10. Katumbili seems to be very similar to Muratha in origin and agronomic characteristics. Like Muratha it does not seem to possess the ability to respond to improved environmental conditions to the extent of H 622 and H 632.

Very little data seems to be available on the responses of unimproved and improved varieties to fertilizer in Eastern Africa. However, it is generally realized that results obtained with unimproved varieties with rather low yield levels are not applicable to hybrid varieties grown under more favorable environmental conditions. Although considerable data was collected in Tanzania with the Katumbili variety at the 20 to 40 q/ha yield level, they have realized that a new series of trials must be conducted with the improved varieties including H 622 and Ukiriguru Composite A. The greater superiority in improved varieties under more favorable environmental conditions suggest that there will be a big interaction between varieties and fertilizers. Hence, plant population and fertilizers studies must be continually done with the improved varieties, and it is very probable that the economic levels will gradually move up with each cycle of selection if a recurrent selection is done under favorable environmental conditions.

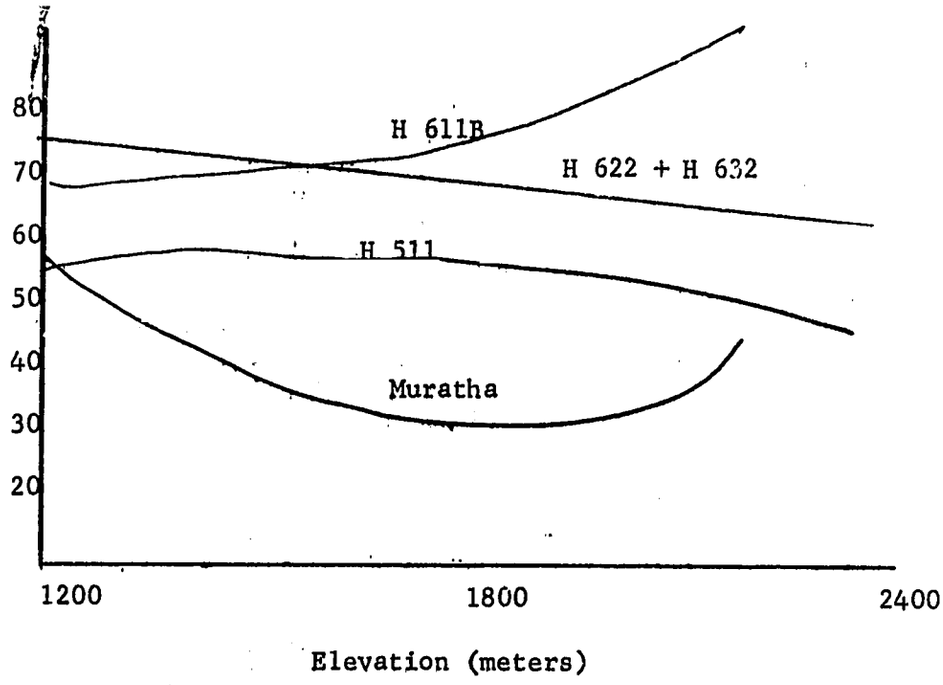


Figure 8. Response to varying elevations (Index = 67.5) from 22 locations in the NMVT in 1967

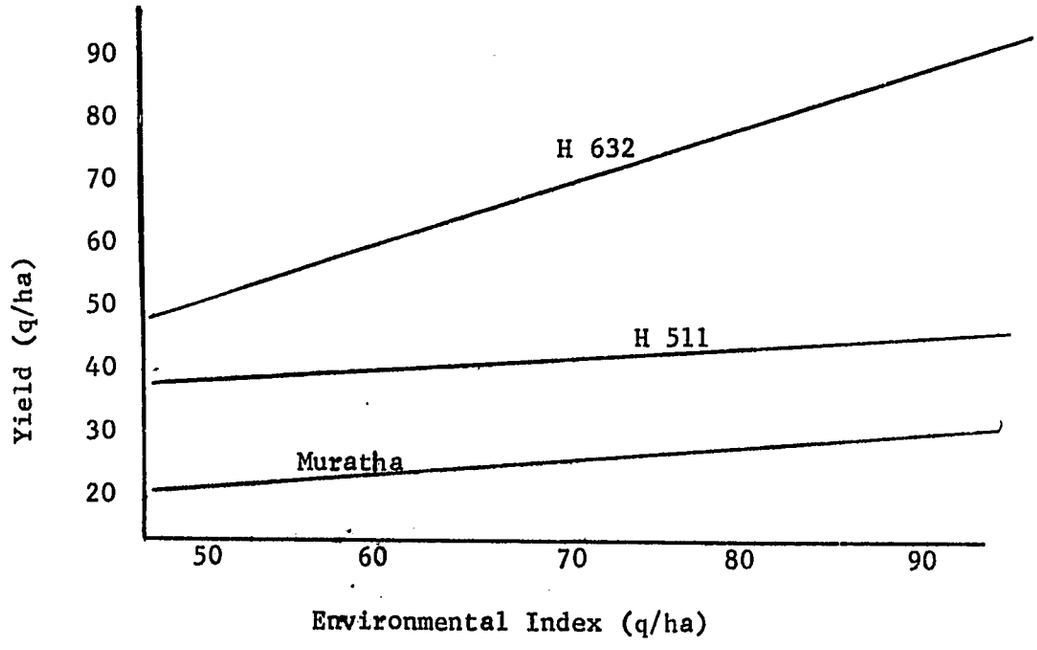


Figure 9. Response to varying environmental conditions at 1800 meters from 22 locations in the NMVT in 1967

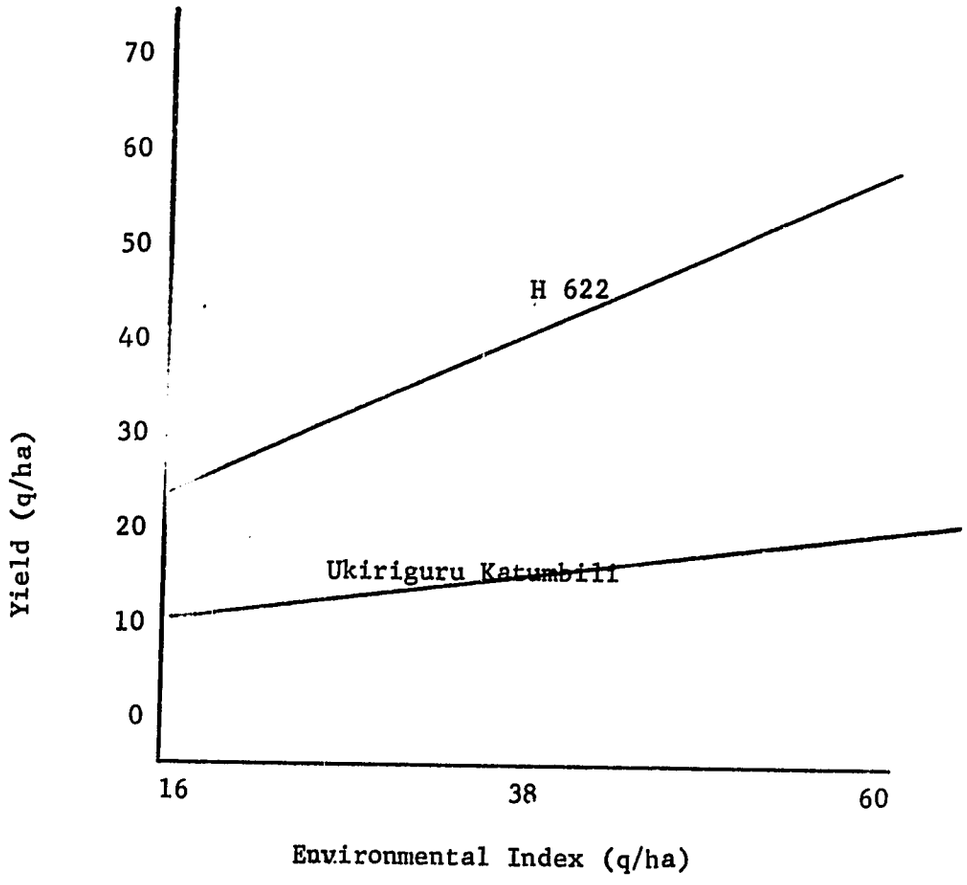


Figure 10. Response of H 622 and Katumbili to varying environmental conditions in Tanzania in 1965/66*

*A. Bolton. E.A.Agric. Jour. (In press)

MAIZE BREEDING - KITALE

F. Ogada, S. Njuguna, and C. Nyambare

The applied breeding program at Kitale was revised in 1961 with the introduction of Central American material, and preliminary work towards the formation of wider-based composite varieties was begun. The initial increase in yield obtained by the formation of these wide-based composites and the subsequent improvement by recurrent selection during the composite formation has been rather spectacular. This has been obtained even in the local composite variety, Kitale Composite B (KCB), which only includes Kenya Flat White strains of maize. Greater increases in yield were obtained from composite formation and selection in the two years 1963 and 1964 (KCB(MC)C2) than had been obtained by ten years of recurrent selection in the single Kitale Station strain, as shown in Table 27. Kitale II and Kitale III were developed from Kitale Station maize by half-sib selection.

Even though many of the varieties and races used to form Kitale Composite C (KCC) and Kitale Composite E (KCE) were much inferior in yield to the local strains when grown in Kenya, the resultant composites outyielded the improved local varieties after only two years of composite formation and selection. KCC involves Ecuador 573, Costa Rica 76, and selections from the race Cometico. KCE includes KCB, KCC, and several other Central American varieties and races.

Recurrent selection has been extremely effective in thesepopulations. All composites were carried forward under a modified method of mass selection during composite formation. Even this low level of selection (25% within an entry) has produced an increase in yield of about 5% per year, so that KCE(MC)C3 yields 95% as much as Hybrid 611. Because it was felt that KCB might not have as much genetic variation as would be desired, 25% of Ecuador 573 was added to this variety; but plant row selection was continued while the crossing to Ecuador 573 and back-crossing to Kitale Composite B were taking place to form KCB(S)CO. Intense selection was initiated in KCC in 1965 with the plant-row evaluation trial. Best entries from this trial were then selfed and a cycle of S_1 testing was conducted in 1966. Other S_1 entries were also added from KCC.

KCE was formed as a back-up population so that an improved population would be available as a source of additional breeding material if the variation in KCC was exhausted. The rapid improvement in KCE was not anticipated; but because of the high yields obtained from KCE, it was decided that intense selection in KCE should also be initiated. Hence, in 1968 S_1 testing was carried out in both KCC and KCE with the intention of merging these two populations in the variety cross as KCB x KCC and KCB gave similar yields. The applied breeding program now involves S_1 testing

Table 27. Improvement obtained by composite formation as shown by results from 11 locations in 1967.

Variety	Yield q/ha	% of Kitale II
Kitale II	39.4	100
Kitale III	45.2	115
KCB(MC)C2	51.2	130
KCC(MC)C2	50.5	128
KCE(MC)C1	50.6	128
KCE(MC)C2	54.5	138
KCE(MC)C3	56.2	143
H 611B	59.4	151
L.S.D.(.05)	4.9	

in the populations KCB and KCC-KCE. This involves a two year cycle with: (1) yield tests being conducted from April to December, (2) recombinations of selected lines from January to July, and (3) formation of S_1 lines from August to February. Yield trials of KCB are conducted in odd number years and KCC-KCE in even number years.

Commercial hybrids grown in Kenya are now Hybrid 632, which was produced by the traditional inbreeding-hybridization method and released in 1964. H 613B which is (F x G) Ec 573 (R12)C1 and H 611B (Kitale II x Ec 573 (R12)C1).

Results from 17 locations in Kenya in 1968 are shown in Table 28. The hybrids involving Ec 573 gave much higher yields at the 3 locations in Central Kenya than H 622, H 632, and H 511. At the higher plant population used this year (53,800 plants per hectare), H 511 gave yields equal to H 622 and H 632.

In Western Kenya at the lower elevations near Kakamega, H 622 and H 632 continued to outyield H 611B and H 613B. However, the new version of H 611 produced by reciprocal recurrent selection (H 611(R)C1) gave yields equal to H 622 and H 632. The performance of H 511 was relatively poorer in this area.

In the Kitale area the difference among hybrids was small but again nothing was superior to H 611(R)C1. The second cycle of reciprocal recurrent selection has been completed and the mother seed for H 611(R)C2 will be available to the Kenya Seed Company for increase in 1968 to replace H 611B.

Table 28. Performance of varieties in the 1968 N.M.V.T. from 17 locations in Kenya.

Variety	Central (Embu) (3)	Western (Kakamega) (7)	Trans Nzoia (Kitale) (7)	Weighted Mean (17)	Lodging % (4)	Bare tips per 100 plants (4)	Usable ear per 100 plants (4)	Days to Tassel (3)	Ear Height cm (4)
H 622	52.5	62.5	70.2	63.9	65	9	89	103	201
H 632	45.2	64.5	73.5	64.8	67	14	87	104	187
SR 52	62.7	63.6	76.5	68.8	49	4	87	99	179
H 611B	76.2	57.8	80.3	70.[illegible]	61	15	79	107	238
H 613B	71.6	55.3	77.9	67.5	70	22	78	104	225
H 611(R)C1	75.9	63.7	80.6	72.8	65	11	85	106	227
H 511(1966)	48.8	49.6	65.4	56.0	62	32	80	92	158
H 511(1967)	52.2	48.2	67.6	56.9	70	24	80	92	167
Muratha	29.0	42.1	46.6	41.6	66	7	71	91	152
K II	50.5	48.1	58.1	52.6	74	12	74	107	220
KCB(S)C0	63.1	44.7	66.5	56.9	68	19	68	106	228
KCC(S)C1	61.6	49.4	62.0	56.7	71	30	66	106	238
KCE(MC)C5	65.2	48.2	68.5	59.6	68	23	65	105	235

Numbers in parenthesis are numbers of locations.

MAIZE BREEDING - EMBU

B. Gichuhi

Since the development of medium maturity varieties in Kenya has only recently been begun at Embu, major emphasis is now on the development of improved breeding populations. Because of the limited genetic variability in locally available material, a major program of introducing improved material from Central and South America was undertaken. The first material was obtained from the Rockefeller Foundation through the Western Research Station at Ukiriguru near Mwanza, Tanzania. This material was evaluated in an Eastern African cooperative trial in 1965/1966 (see the 1967 Annual Report). Subsequently additional material of similar origin was obtained directly from the Rockefeller Foundation in Mexico and in Colombia. Because experience at Kitale and in other areas had indicated that when suitable material is introduced into composites, a certain amount of low yielding material does not greatly reduce the yield of the composite and any slight reduction that does occur will be more than offset by the improvement from mass selection during composite formation. Hence, these new varieties from similar ecological areas in Central and South America were added to the Embu I and Embu II without testing. Embu I now contains 110 different components and Embu II contains 74 components. These new entries were grown for the first time in the March 1968 rains and many of them, particularly in Embu I, appear to be extremely well adapted to Embu conditions.

A mixture of the variety crosses of the first 14 entries in Embu I and of the 20 entries in Embu II were grown in the Eastern African variety trial in 1967/68. As seen from the results of this trial (table 7 on page 20), the performance has been reasonably good for a medium maturity variety. These populations will be continued for three more seasons before any intense selection is initiated. At the time intense selection is begun, a separate population of each variety will be continued under 25% mass selection. The purpose will be to maintain a genetically diverse improved population in the event that the intense selection reduces the genetic variation.

Because of the unavailability of adequate isolation blocks near Embu, the improvement of H 511 is being continued at Kitale by the Maize Geneticist. The parental varieties Embu 11 and Embu 12, are being improved with two cycles of mass selection each year. One cycle is grown under natural rainfall and the other is under irrigation on land rented by the Kenya Seed Company from large scale farmers with irrigation equipment for coffee. The yields of H 632, H 511, and Muratha (the local Embu medium-maturity variety) are shown in Table 29.

Table 29. Yields (q/ha) of improved medium maturity varieties in Central and Western Kenya.

Variety	Central Kenya 1967 (5)	1968 (10)	Weighted Av. (15)	% of Muratha	Western Kenya 1967 (22)	1968 (14)	Weighted Av. (36)	% of Muratha	Days to Tassel
H 632	61.2	57.4	58.7	140	65.9	69.0	67.1	171	103
H 511	50.7	58.9	56.2	134	51.8	57.5	54.0	138	92
H 511(M)C1	--	63.4	--	(150)	--	57.9	--	--	92
Muratha	40.8	42.3	41.8	100	35.8	44.4	39.2	100	91

Spacings for trials in 1967 were 3' x 1' whereas trials in 1968 were 60 x 30 cm.

MAIZE BREEDING - Katumani

H. Mauuye

Although very great improvement has been made with the early maturing varieties at Katumani, experience with the composite varieties at Kitale suggests that the introduction of additional exotic material from Central America to give a wider genetic base would be desirable. Hence, two new synthetics have been formed; and one of them Katumani VII, will soon be ready to initiate recurrent selection. This population has been formed by combining 50% Katumani V with a panmitic population (previously formed from several Central American introductions) and the advanced generation of a variety cross (U.S.342 x Camelia) from Peru. Previous testing had suggested that a composite formed from (1) Katumani VI, (2) a synthetic developed from French inbred lines, and (3) Israeli hybrids might be superior to one that included any additional material that was tested. However, this additional material, which included crosses between a very early flint variety from Alaska and late maturing Central American material, was formed to serve as a back-up population with greater genetic variation. However, as seen in Table 30 the yield of this population (Katumani VIII-W) was equal in yield to the narrower based Katumani VIII from the more elite material.

Two additional early-maturity populations had been formed by the Maize Geneticist at Kitale. Of these populations, CBK I included 50% corn belt material and 50% crosses between the early Alaskan variety and late Central American material; whereas CBK II included Southern U.S. hybrids and varieties and a different group of Central American varieties. Although CBKI did not give very good performance at Katumani, CBK II was equal in yield to Katumani VIII or Katumani VIII-W. Consequently it was decided to merge Katumani VIII, Katumani VIII-W, and CBK II in the new Katumani VIII population.

While these new composite varieties were being formed, ear-row selection was continued in Katumani B. Although no improvement was noted in the March 1968 planting at the normal population (3' x 1'), there was some indication that Katumani B(E)C2 was somewhat superior at 2' x 1' spacing. Although really strong selection has been exercised over the past several seasons to eliminate the pale yellow kernels that appear in Katumani B, the proportion remains undesirably high. Hence, it was decid to modify the ear-row selection procedure to include alternate cycles of selfing with selection among the selfed plants with ear-row evaluation of these selfed progenies, in the hope that the pale yellow color would be eliminated.

The data from the two seasons shown in Table 30 represent the extremes in rainfall that may occur at Katumani; the October 1967 season had a rainfall period covering only 50 days, and during that time 234mm (9.2") of rain were received. Under these conditions the late maturing Local White variety and H 511 gave very low yields which were greatly inferior to the improved short-term Katumani synthetics. In contrast, during the very favorable season (March 1968 rains), H 511 outyielded the Katumani synthetics. Although the later maturing Local White variety would outyield the early unimproved variety, Taboran, under favorable conditions, improvement has been so great in the Katumani synthetic varieties that they will now equal the yield of the Local White variety even in seasons with adequate rainfall for later maturing varieties.

Under the present recommended cultural practices of early planting with phosphate fertilizer but with no nitrogen at 3' x 1' spacing, there appears to be very little difference among the Variety-cross hybrids and the improved Katumani parental varieties; i.e. the genetic potential is not limiting yields under these conditions. Because the 2' x 1' spacing did not give any great increase in yield under the favorable conditions occuring in March 1968, it is very probable that nitrogen may have been the limiting factor with the higher plant population and improved varieties. Consequently, studies are being initiated to determine whether or not the higher plant population with moderate amounts of nitrogen at planting would give progressive farmers considerably better yields under good conditions, and still give them equal yields under the most adverse conditions.

Table 30. Performance of early maturity maize varieties at 3 locations in the October 1967 and March 1968 rainy seasons.

Variety	Yields (q/ha)				Days to tassel
	October 1967	March 1968		Average	
		2' x 1'	3' x 1'		
Local White	23.5	52.3	44.1	40.0	72
Katumani V	27.8	53.4	46.2	42.5	60
Katumani VII	27.4	41.1	43.2	37.2	64
Taboran	22.4	33.3	26.8	27.5	61
Katumani VI	29.6	50.6	42.6	41.0	61
Katumani VIII	29.4	40.6	39.6	36.5	63
Katumani VIII-W	29.8	42.6	38.3	36.9	62
CBK II	--	38.3	41.2	--	67
CBK I	--	24.1	33.3	--	65
Katumani B(E)CO	--	51.0	49.0	--	61
Katumani B(E)C1	29.6	54.1	42.0	41.9	63
Katumani B(E)C2	--	56.8	42.2	--	61
Kat. V x VI	29.6	51.6	47.1	42.8	62
Kat. VII x VIII	31.2	44.7	45.9	40.6	62
H 511	21.3	62.8	59.1	47.7	65
H 632	--	45.6	51.8	--	77

The acreage of Katumani maize in Machakos, Kitui and drier areas of Meru and Embu districts increased greatly in 1967. With the help of a 'Freedom from Hunger' grant 5440 hectares (13,440 acres) were planted with new seed from the Kenya Seed Company and the Katumani Research Station. An additional acreage of 30,150 hectares (64,466 acres) were planted with seed from farm-to-farm sales for a total of 35,590 hectares (89,906 acres) compared to 2860 hectares (7065 acres) in 1966.

INCORPORATION OF QUALITATIVE GENES INTO COMPOSITE BREEDING POPULATIONS

M. N. Harrison
EAAFRO/CIMMYT Regional Coordinator

Since June 1967 the direction of Kenya's Maize Research Section has been in charge of Mr. Festus Ogada as Senior Maize Research Officer. Mr. Michael Harrison, who formerly held this post, is now employed by CIMMYT (the International Maize and Wheat Improvement Center - a joint agency of the Rockefeller and Ford Foundations). CIMMYT have seconded Mr. Harrison to EAAFRO and they have posted him to Kitale by agreement with the Kenya Government.

Mr. Harrison's new duties are twofold:-

(a) Under the direction of the Senior Maize Research Officer, to convert breeding populations to certain qualitative genes, as a contribution to Kenya's national program. This section is an account of this project.

(b) In cooperation with the EAAFRO/AID/ARS Maize Geneticist (after four and a half years Dr. Eberhart was replaced in December 1968, in this post by Dr. Penny), to establish and develop the Eastern African Regional Cooperative Maize Improvement Program. This is described in a later section of this report.

In this way both the AID/ARS Maize Geneticist and the CIMMYT Regional Coordinator are employed through EAAFRO and each has a project in Kenya's national program as well as cooperating jointly in the regional program.

As described in the previous sections, the most rapid improvement in yield in Kenya's breeding programs is going to come from recurrent selection in composite breeding populations. As well as yield, routine selection for and evaluation of other characters is, and will continue to be, part of the regular program. Nevertheless, it is considered highly desirable to incorporate single major genes for more rapid progress in improvement of certain qualitative characters. The four characters to be dealt with in this way are

(a) The opaque 2 and floury 2 genes are being used to improve protein quality.

(b) Brachytic 2, and a gene or genes with similar effect obtained from Ecuador 573, is being used to produce a strong short stalk. A major defect of the Latin American center of origin maize widely used in Kenya is its extremely tall height.

(c) Alleles of the Ht gene are being used to increase resistance to blight, Helminthosporium turcicum.

(d) Cytoplasmic male sterile is being introduced into those breeding populations which are used on the female side in hybrid seed production.

The opaque 2 gene for high lysine quantity is by far the most important contribution of this program. The main storage protein of maize endosperm is zein which is deficient in both lysine and trytophan. Opaque 2 throws a blockage in the final stage of the chain of metabolic changes to reduce the proportion of zein thus increasing the percentages of lysine and tryptophan. These two latter amino-acids happen to be the two amino-acids most needed to improve human nutrition. In countries where maize is used mainly for livestock feeding, some feeding manufacturers and a few farmers add synthetic lysine to the ration at moderate extra cost. Though big efforts are being made with opaque 2 in these countries, the value of high lysine maize is no greater than this extra cost (though cheap tryptophan is not yet available). The importance of high lysine maize is far greater in Eastern Africa where maize is a staple food crop for millions of people. It is unrealistic to expect the peasant housewife to go to the shop to buy lysine to add to the family cooking pot. Instead our policy is to convert all improved hybrids and varieties to high lysine. The hybrids sell on their higher yields and we will have no need to attempt the difficult job of convincing the housewives about biological feeding value, amino-acids, lysine, opaque 2, gene etc. etc. The people will get the benefit of better protein nutrition whether they know about it or not. It has been worked out that one pound of high lysine maize satisfies all human protein requirements and this is the level of maize consumption in Kenya (9 million people annually consume 15 million bags of 200 lbs. each). The importance of this for human welfare cannot be overemphasized.

In a convential inbreeding and hybridisation maize breeding program, all the inbred lines have to be converted to a recessive qualitative gene, such as opaque 2, by standard back-crossing technique. There are two serious snags to this. When new lines are developed with better performance, it is necessary to convert all such lines to opaque 2 before they can be used. This involves several years delay and a considerable part of the breeding effort is taken up with making such conversions, seriously to the detriment of themain program if staff and funds are limiting. Converting composite breeding populations is a bigger job (though not longer) because sufficient numbers must be back-crossed to maintain the full genetic variability of the composites (otherwise future progress by recurrent selection for yield will be reduced). However, once done there is never any need to make any conversions in future. Whatever comes out of the future breeding program - improved composites, composite crosses, or inbreds extracted for conventional hybrids - all are genetically pure for high lysine and can be used immediately. The second snag

when inbred lines are converted to major genes is that some of the inbred lines may have unfavorable modifier complexes. Whatever the modifier complex present it cannot readily be greatly changed and it is just too bad if it is unfavorable. Converting a composite to a major gene means that future recurrent selection will automatically sort out the best modifier complex for the major genes.

The intention is to convert composites to each gene separately, check out yield and other characters, and then merge together selected conversions.

Other countries elsewhere are already turning towards recurrent selection in composites. If the conversion of such composites is successful in East Africa, the methods developed (with such modifications as may be needed), can be applied to other countries.

Conversions to high lysine were started at Kitale in the Kenya national program in 1966 by Mr. Festus Ogada and continued by Mr. Simeon Njuguna. This work, and conversions to other qualitative genes, now taken over by the EAAFRO/CIMMYT Regional Coordinator, has been expanded for the Kenya program to include early maturity Katumani and medium maturity Embu, as well as late maturity Kitale breeding populations. It has also been expanded for Tanzania and Zambia composites and is now a facility offered to any maize breeders in the East African region. This development and expansion means that more junior staff and funds will be required. The intention is that CIMMYT will be negotiating, through EAAFRO, with the Kenya Government to give this extra needed support.

The conversion of the Embu medium maturity H 511 will be the first high lysine maize commercially available in East Africa, and one of the first in the world. Normally several back-crossing generations are needed. However, we have obtained opaque 2 on Corn Belt material from Purdue, Indiana, (where its importance was first recognized), and on Eto from CIMMYT, Colombia. Eto x Corn Belt crosses are about equal in yield to local maize at Embu. Opaque 2 is being introduced on one side of H 511 from Corn Belt maize and on the other side from Eto. Both parents of H 511 are composites under recurrent selection improvement. Evaluation will begin at the first backcross stage and it may not be necessary to go beyond that (though this will be done separately also). The first high lysine H 511 trials are scheduled for the second rains in 1969 and, if successful, first commercial lots could be out in 1970 or 1971. A word of caution is necessary. The opaque 2 gene causes a small reduction in yield and, if this is too great for H 511, selection in the composite parents will have to continue until the yield is raised sufficiently.

In the Kitale program we have started converting Composite B (used as female) to high lysine, brachytic 2, dwarf, blight resistance and male sterility. We have started converting Composites C and E (used as male) to the same genes but to fertility restorer. Two generations

a year are being achieved, using the irrigation nursery and the drier, but more back-crossing generations are needed and it will obviously be much longer before a commercial product can be released. However, the important point is that eventually all the populations, including those developed using the methods from the maize quantitative genetics program, will have qualitative genes incorporated into them.

MAIZE AGRONOMY - Kitale, Kenya

A. Y. Allan and B. S. Masianga

The maize agronomy section has continued with its program of investigating the most important factors which affect maize yields, finding out the optimum levels of these important factors, and studying how the various factors interact with each other, as the interactions frequently have very profound modifying influences on the responses to the main factors. The final object of the program, and the most important one, is to integrate all this information so that a simple package of improved practices can be worked out and put across via the extension staff to farmers.

Main Factors

(a) Investigations have continued into the "time of planting" phenomenon: in many tropical countries it has been found that maize planted at the start of the rains gives higher yields than maize planted later. In areas with rather short rainfall seasons this decline is obviously caused to a great extent by deficits of moisture at the end of the later planted crops' growing period. However, in other areas with long rainfall seasons, water deficits do not occur even in very late planted maize, and yet similar declines are caused by late planting. In the long rainfall season areas of Western Kenya these declines have been as much as 70-80 kg/ha for every day's delay in planting after the onset of the rains.

Experiments at Kitale in 1968 have shown that varying levels of soil moisture during the first 5 weeks after planting have a very big effect on early growth and later yields. In particular, excessive moisture during this period severely retards growth, and these retarded plants give lower grain yields. It appears that the maize plant is very sensitive to excessive soil moisture or its counterpart, poor soil aeration, during the first few weeks of growth. During this stage the plant puts out its radicle and seminal roots, which grow downwards below the seed. If the soil there is poorly aerated, these roots cannot escape suffering from such conditions. When the nodal roots start emerging from the "crown", which is above the seed, the plant becomes less susceptible to the adverse effects of poor aeration because these later roots can grow upwards towards better aerated conditions in a wet soil. (Conversely in a drier soil they tend to grow downwards, towards the moisture).

These characteristics of the maize plant must be considered in relation to the climatic and soil conditions at the beginning of the growing season. There are great differences between these conditions in temperate areas and in the tropics. In temperate areas with alternating winters and summers, the soil is generally wet, cold and poorly aerated just before planting time, and gradually becomes drier, warmer and better aerated. In the tropics, with alternating dry and wet seasons, the soil is dry, warm and well aerated at the beginning of the rainy season, and then gradually becomes wetter, colder and more poorly aerated. Maize, of course, originated in a tropical environment and hence evolved to suit tropical conditions.

Under tropical conditions maize planted at the start of the rains is put into moist, well-aerated, warm soil, and grows through this critical stage under the most favorable conditions. Maize planted later is put into wet poorly-aerated, colder soil, and therefore experiences unfavorable conditions during this critical stage of growth; this causes a severe growth check from which the plant never fully recovers.

In the long rainfall season areas of Kenya the decline in yields due to late planting is due to the poor soil aeration in the early stages of growth of late planted maize. In the short rainfall season areas late planted maize can suffer from this effect as well as suffering from water deficits later in the season, and therefore receives a double check; the first caused by excesses, and the second by deficiencies of soil moisture.

(b) Responses to fertilizers are being studied in a continuing program of NPK fertilizer trials which have been extended to nearly 50 locations in the Trans Nzoia and Uasin Gishu districts of Western Kenya. It is being found that as husbandry levels and the genetic potentials of the new hybrids rise, better and better responses to fertilizers are being obtained. In a series of 9 NPK trials in 1967 in the Trans Nzoia district, the application of 56 kg P_2O_5 and 116 kg N per ha increased yields from 52.9 to 82.5 q/ha (84.1 to 131.2 bu/acre). This yield increase of 29.6 q/ha represented a profit of 170% from the use of these fertilizers at the prices then current.

(c) The effects of different plant populations are being followed up in a series of population trials incorporating three types of maize with different maturity lengths. It was found that the very tall, large, late-maturing Kitale H 613B (which takes about 110 days to reach tasseling at 1900m altitude) reached its optimum yield at populations of around 44-49,000 plants/ha. Above this population lodging and barrenness increased rapidly. In contrast, the early maturing, short type, Katumani Composite B (which tassels in about 75 days at the same altitude) had not reached its optimum yield even at populations of 100,000 plants per hectare. In the 1968 trials the Katumani type is being grown at populations up to 200,000 plants per ha. The third type of maize is H 511 which is intermediate between the other 2 types. These trials are in Western Kenya, where rainfall is rarely a limiting factor.

(d) In a series of weed competition trials in 1967 it was found that complete weed control by either hand or chemical methods increased yields by 50% compared with no weeding. At one of the 5 locations of these trials no weeding resulted in a complete crop loss. In Kenya, where labour is inexpensive and abundant, the cost of hand weeding is quite low and the only chemical which at present can compete on an economic basis is 2,4-D, which gave very satisfactory weed control in these trials under suitable conditions. Other herbicides of the triazine type gave equally good results, but are too expensive at the moment to be economically competitive in Kenya.

Interactions Between Factors

Most of the field experiments in the agronomy program are of a factorial nature, and this has enabled information to be obtained on the interactions between the most important factors. This information is of tremendous value in interpreting the results of many other experiments, and it is also knowledge which is essential to extension workers and maize growers in this country in their efforts to increase yields. Some examples of important interactions are presented.

(a) Interactions between time of planting and response to nitrogen topdressings are shown in Table 31.

(b) The response to nitrogen topdressing is also influenced by the plant population. For example, it was found in 3 trials in 1967 that 112 kg per ha of N increased yields by 14.8 q/ha at populations of 27,000 plants per ha, whereas the same rate of N increased yields by 20.9 q/ha at a population of 54,000 plants per ha.

(c) The hybrids which have been released by the maize breeders have a potential for much higher yields than the former local maize, but this higher potential can only be realised if the crop is grown properly, as there are big interactions between genotype and cultural conditions. As examples of this, the interactions between genotype and two other factors, namely time of planting and plant populations, are shown in Table 32 which summarises these data from 11 multifactorial trials carried out in Western Kenya in 1966 and 1967.

(d) The final part of the maize agronomy program is concerned with the integration of the information which has been obtained from these investigations into a recommended "package". This function is an extremely important aspect of our efforts, and we think it is essential that there should be a proper understanding of the relative importance of the various factors affecting yields and of how they interact, otherwise efforts to improve yields may be misdirected and may end in failure.

Table 31. Effects of time of planting on response to 158 kg N per ha.

Year	No. of experiments	Time of planting	Yield, q/ha without N	Yield, q/ha with N	Yield increase q/ha
1965	2	Start of rains	59.0	74.7	15.7
		21 days later	52.2	60.5	8.3
		42 days later	37.7	36.5	--
		63 days later	20.6	19.3	--
1966	4	Start of rains	56.3	80.7	24.4
		21 days later	49.8	63.0	13.2
		42 days later	48.0	48.9	0.9
		63 days later	33.9	35.2	1.3
1967	2	Start of rains	59.0	92.6	33.6
		28 days later	43.5	65.9	22.4

Table 32. Interactions between genotype and (a) time of planting and (b) plant populations.

Treatments	Yields in quintals per hectare: Local variety	Hybrid 613	Differences
Planted 4 weeks late	27.6	40.6	13.0
Planted at start of rains	48.2	68.2	20.0
Differences	20.6	27.6	--
20,000 plants/ha	33.6	47.8	14.2
40,000 plant/ha	42.2	60.8	18.6
Differences	4.6	13.0	--

We now have plenty of information to enable us to put forward a "package" of improved practices which can multiply local maize yields by a factor of at least three, and possibly six. The way in which hybrid seed, fertilizers, and improved cultural practices must be combined for maximum effect is shown in Table 33 which illustrates how some combinations of these inputs do not produce much improvement compared with the correct combination.

Table 33. Combining factors in different ways.

	Yields in quintals per hectare		
	No fertilizers Local variety	Fertilizers H 613	Differences
Planted 4 weeks late 20,000 plants per ha Weeded once, late	20.2	28.0	7.8
Planted at start of rains 40,000 plants per ha Clean weeded	53.8	85.0	31.2
Differences	33.6	57.0	--

The fertilizer rates were 56 kg/ha of P_2O_5 at planting and 80 kg/ha of N topdressing at knee height in these trials.

Under Kenya conditions the use of fertilizers and hybrid seed with the poor cultural practices is barely profitable, whereas the same inputs of hybrid seed and fertilizers give a very attractive profit margin under the good conditions. Similarly the extra hard work which is involved in adopting these improved cultural practices is more profitable when the crop is grown with hybrid seed and fertilizers. The complete "package" in these trials increased yields from 20.2 q/ha (which is above the national yield level) to 85 q/ha.

These results, incidentally, show why the impact of fertilizers is often disappointing in peasant agriculture. If fertilizers are used under poor conditions they will have little, if any, effect on yields, and peasants seeing this and not realising that other factors are limiting the responses to fertilizers, will jump to the conclusion that fertilizers are not profitable investments. By adopting the "package" approach, we are trying to ensure that all the factors are at a high level, so that there is the best chance of obtaining all the beneficial effects of the positive interactions between these factors.

MAIZE AGRONOMY - Embu

T. W. Gathechah

When the Embu medium maturity was started in 1965, it was realized and recognized by the Maize Research Section that there would be a great need for an agronomy program to go along with the work on breeding suitable maize for Central Kenya. This recognition followed the experience we had from the work done in Kitale for Western Kenya where it had been shown that it was invaluable for agronomy work to go side by side with breeding work. In Central Kenya with a different set of conditions and problems which were not yet too well known, particularly with regards to maize growing, there was an even greater need for this work to be started.

Although some agronomy work had been done in the past with maize in Central Kenya, we had no clear information on the various factors influencing maize yields because the experiments and trials in the past years were ad hoc and results tended to be erratic and without any consistency over years.

In 1966 when the first maize agronomist for the Embu program started work, he started with several trials designed to investigate the various agronomic factors influencing maize yields. These experiments were designed on the same lines as similar trials run in Western Kenya.

A husbandry trial aimed at evaluating six major factors affecting maize yields was laid down at four locations in Central Kenya in 1966 and 1967. These factors were tested at two levels, i.e. bad husbandry as practised by the local farmers and good husbandry according to research recommendations. The results shown in table 34 which follows, are given with economic considerations assuming the maize price at $4.35/q ($1.10/bu).

Time of Planting

As can be seen in the table early planting increases the yield of maize appreciably and costs no extra money.

Further work has been carried out at Embu to appraise this important husbandry practice. Delaying planting of maize after the onset of rains decreases the yields drastically, as would be seen in figure 11. This decrease is evident both under poor rainfall conditions (1965 with 510 mm of rain) and under adequate rainfall (1967 with 1151 mm).

Plant Populations

Trials evaluating H 511 and Muratha at different plant populations show that H 511 outyields Muratha at higher plant populations quite considerably. Figure 12 presents data obtained from six locations scattered

Table 34. Factors affecting maize yields at 4 locations in Central Kenya and their economic consideration

Factor	Level	Yield q/ha	Increased Yield q/ha	Cost Difference	Increased Return $	Profit per ha $
Time of planting	Dry planting Vs. 2 weeks late	45.7 24.9	20.3	Nil	90.48	90.48
Plant population	35,860 Vs.17,930	39.5 31.4	8.1	2.79	35.24	32.45
Type of maize	Hybrid 511 Vs.Muratha	55.9 47.0	8.9	4.17	38.72	34.55
Standard of weeding	Clean weeding one late weeding	36.8 34.1	2.7	6.96	11.75	4.79
Single super phosphate	280 kg/ha 0	38.3 32.3	6.0	11.14	26.10	14.96
Nitrogen A.S.N.	280 kg/ha 0	35.6 35.0	.6	27.86	2.61	- 25.25

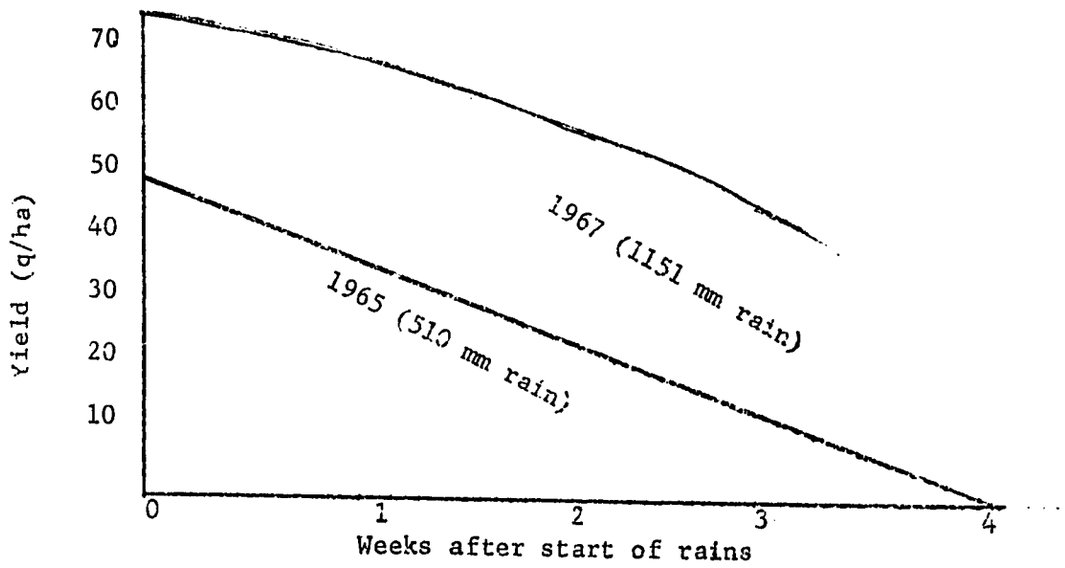


Figure 11. Effect of time of planting on yields of Muratha at Embu.

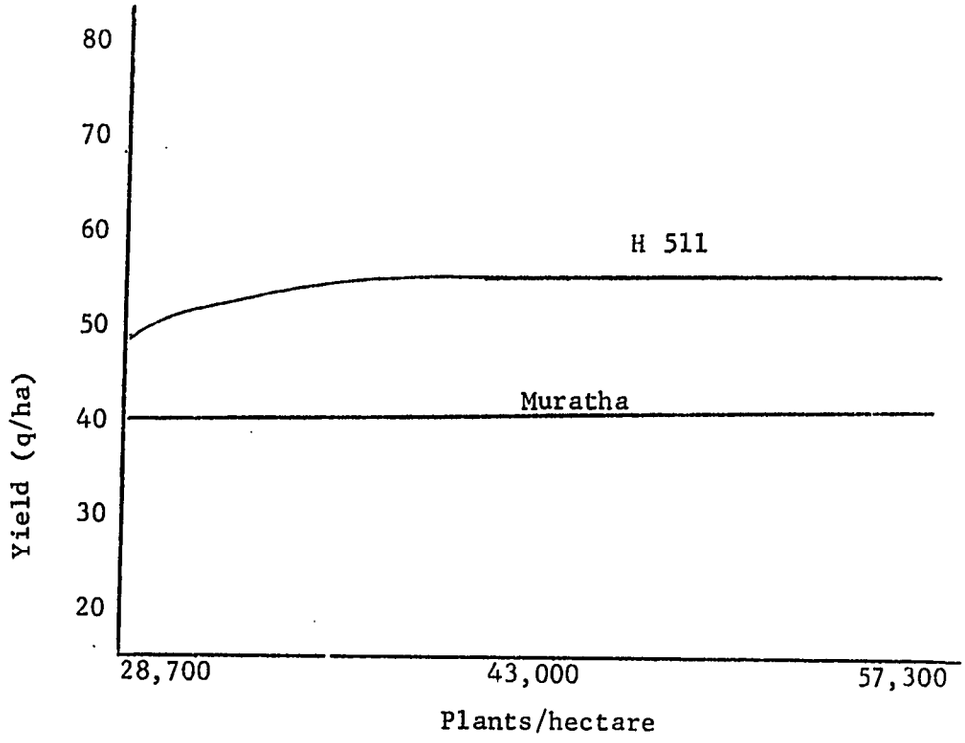


Figure 12. Response of Muratha and H 511 to increasing plant populations at 6 locations in Central Province in 1967.

all over Kenya in the Coffee Zone. Spacing was uniform between the rows (76.5 cm) and varied within the row. The within the row spacings were 22.9, 30.5, and 45.7 cm, giving 57,300, 43,000, and 28,700 plants per hectare respectively. 280 kg/ha of single supers were used.

This trial combined factorially different rates of phosphate, nitrogen and spacing. Large responses were obtained from plant populations, but only slight responses from phosphate. Nitrogen gave no significant response and farmers may not need to use it unless their fields are too poor after many years cultivation.

From these trials we have come to the conclusion that the right spacing of H 511 should be 2' x 1'. This will give us about 53,800 plants per hectare.

SEED PRODUCTION, CERTIFICATION AND DISTRIBUTION

G. Ravagnan and J. Wahungu: Ministry of Agriculture
V. Verburght and E.J.R. Hazeldon: Kenya Seed Company

One of the most important aspects of maize improvement is the seed production and distribution. The research to produce improved varieties and the information on how to obtain maximum yield from these improved varieties is of little practical use unless the farmer can obtain adequate quantities of high quality seed at a reasonable cost. The Kenya Seed Company of Kitale, Kenya, has done an excellent job in this field.

A committee of agricultural research staff members and Kenya Seed Company representatives screen the applications of farmers who wish to produce hybrid seed. The better farmers are selected and given contracts for specified acreages. The Kenya Seed Company agrees to buy all hybrid seed produced on these acreages at $12.39/q ($3.16/bu). This seed production is done under certification standards equal to or above those of the International Crop Improvement Association, and inspections are carried out by government inspectors. The Kenya Seed Company also maintains an advisory service to help the farmers to meet these high standards. Seed from certified fields is shelled on the farm and delivered to the Kenya Seed Company as shelled grain. The Kenya Seed Company then cleans; grades and treats the seed with a seed dressing and packages it in appropriate sized bags. For the small scale farmer the seed is packed in a 10 kg package which is sufficient to plant approximately 1/3 of a hectare. Because this seed will be hand planted, it is normally ungraded. The large scale farmer who machine plants can buy medium flat and large flat graded seed in a 50 kg bag. The distributing agents for Kenya Seed Company are the Kenya Farmers' Association and Dalgety's. These companies handle fertilizer as well and make contracts with small shopkeepers scattered throughout the small farming areas so that both seed and fertilizer are available at reasonable distances from most small scale farmers. In Tanzania the distribution is done through the Tanzania Farmers' Association and in Ethiopia through the Ethiopian Building Supplies and Technical Company (S.C). As seen from Table 35 there has been a large annual increase in hectares of hybrid maize grown from 1964 until 1967. These estimates are obtained assuming 22.4 kg/ha of seed as this was the recommended rate until information was obtained by Agronomy Research which indicated that higher plant populations will give greater increases in yield. However, most farmers still do not reach the new recommended rates, and this figure provides a reasonable estimate of the actual acreages grown.

The seed available was limited in 1966 by the drought in the preceding year. Hence, all farmers who would have planted hybrid were not able to do so because of lack of seed. The large scale farmers switched to hybrid seed as soon as adequate quantities were available in 1967. Small scale farmers were a bit slower in taking up the hybrid seed, but increasing acreages have been grown every year. The reduction in acreage in 1968 over 1967 for the large scale farmers was due to the drop in the price of maize from $5.81/q to $4.34/q when delivered to a Maize and Produce Marketing Center. This would be a drop from $1.48/bu to the current price of $1.11/bu. Despite the drop in prices the small scale farmers have increased their acreages somewhat, although the expansion is probably not as great as it would have been if the price had remained high. Because of the transportation costs and local county council cesses on maize sold. these small scale farmers may get as low as $3.25/q ($.83/bu) as the farm price.

Table 36 shows the hectares of hybrid maize grown in other Eastern African countries. Although these amounts are still extremely limited, it does show that the Kenya Seed Company is making an effort to distribute hybrid seed in these other countries. However, until a more vigorous extension program is mounted in these countries the expansion will not be very great.

Table 35. Hectares of maize hybrids grown in Kenya

Year	Large scale farms (ha)	Small scale farms (ha)	Total (ha)	Total (acres)
1963	156	4	160	400
1964	11,400	700	12,100	29,900
1965	22,200	8,100	30,300	74,800
1966	25,500	15,300	40,800	100,600
1967	55,500	46,700	102,200	252,400
1968	40,600	52,300	92,900	229,300

Estimated from sale of hybrid seed assuming 22.4 kg of seed are used per hectare.

Table 36. Hectares of maize hybrid from Kenya grown in other Eastern African countries.

Year	Tanzania	Uganda	Ethiopia
1964	4	8	--
1965	2150	25	--
1966	50	12	--
1967	100	20	160
1968	6050	270	270

Because of the drought in Kenya in 1965 and the subsequent shortage of seed, export of hybrid seed was severely restricted from October 1965 to January 1967.

Estimated from sale of hybrid seed assuming 22.4 kg of seed are used to plant a hectare.

The details of hybrid seed production are given in Table 37. Because of the severe shortages of hybrid seed from the low production in 1965, production was tripled in 1966. This produced such a large carry-over that it has been necessary to restrict the acreages grown in 1967 and 1968.

As ownership of the large scale farms is shifting from European to Kenyan ownership these new Kenya farmers are encouraged to get into the hybrid seed production. They have accomplished this in a very satisfactory manner as indicated by the fact that around 40% of the seed producers were Kenyan in 1967 and 1968.

Table 37. Hybrid seed production in Kenya

	Certification		Av. Yield (q/ha)		No. of Growers	
Year	Hectares	Seed (q)	Total	Seed rows	European	Kenyan
			Late Maturity			
1963	116	2,677	23.0	30.7	26	0
1964	202	7,308	36.2	48.2	29	0
1965	426	9,581	22.5	30.0	38	1
1966	1,240	40,225	32.4	43.2	69	9
1967	686	22,422	32.7	43.6	33	24
1968	466	(15,682)	(33.7)	(44.9)	29	17
			Medium Maturity			
1966	24	254	10.6	16.0	2	0
1967	15	270	18.0	24.0	1	0
1968	34	(610)	(17.0)	(24.0)	1	0

1968 production is estimated

EXTENSION

S. A. Eberhart and M. N. Harrison

The rapid increase in the acreage of hybrid maize grown by the small scale farmer shown in table 35 on page 119 reflects the activities of the Extension Service in Kenya. The aim of the Extension Service has been to have a one acre demonstration plot with the package deal where everything is done correctly within walking distance of every small scale farmer in Kenya. Leading farmers in each area are selected. If these farmers agree to buy hybrid seed, insecticide and fertilizer, and to carry out the recommended practices on the one acre plot, the agricultural instructors advise him at all stages to see that everything is done correctly. A fertilizer company provided the fertilizer at a reduced cost for some of the early demonstrations; but more recently there has been no subsidy whatsoever for these demonstration plots. The surrounding farmers are invited in for a field day to see how the land was prepared, planted and fertilized. Then at harvest time they are asked to come again and observe the results of this demonstration plot. The increase in yield from this package deal is so great in comparison with maize in surrounding farms that the local farmers cannot help but be impressed by the results obtained.

The acreage in small scale farms increased very rapidly until 1968. This reduced rate of expansion of hybrid maize in the small scale farms can partly be attributed to the drop in price and probably also partly to the fact that most of the progressive farmers have already adopted hybrid maize. In order to obtain further expansion the extension service will need to mount a new intensive program to show farmers that maize production is still very profitable when the recommended practices are used.

F.A.O. is launching an extensive drive in Kenya to encourage the use of fertilizers in 1969. The cooperative project between the Ministry of Agriculture and F.A.O. is being planned to see that other parts of the package program are also carried out so that these demonstrations are conducted in such a way as to show the farmer how he can get the maximum benefit from fertilizer.

MARKETING AND UTILIZATION

M. N. Harrison

If maize improvement is to be achieved in the developing countries, marketing and utilization cannot be neglected. Even though a farmer has improved maize varieties available, knows how to grow these varieties to give maximum yields, and can obtain the other imports such as fertilizer and insecticide easily, he will have no incentive to produce a good crop of maize unless he can market it at the time the crop is harvested for a fair price.

Very great progress has been made in Kenya in breeding and agronomy research, in seed production and in extension. But marketing and utilization may halt this progress unless immediate steps are taken to remedy the situation. As seen in Table 38, in the past Kenya has periodically gone through periods of maize surplus (large exports) and periods of deficits (large imports). The purchase of 325,600 tons by the Maize and Produce Board in 1967/68 greatly exceeded any previous purchase. This production and the average yields per hectare shown in Table 39 suggest that henceforth Kenya will have an annual production of maize greatly exceeding the amount required for human consumption. This increased production is coming not only from the large scale farming areas where the acreage is planted almost entirely with hybrid seed and the average yields have increased from 13.3 q/ha in the 1958-63 period to 28.2 q/ha in 1967; but also this increased production is occuring in the small scale farming areas. Even though the average yields have doubled in the large scale farming areas, the agronomy research and further genetic improvement in the hybrid varieties suggest that even greater increases in yield could be made with better farming practices.

The climate in most of Kenya's major crop producing areas is very well suited to high yields of maize. Although alternate crops have been surveyed there is no other crop under consideration that has the potential of maize. Hence, it seems imperative that Kenya considers exploiting this crop more fully.

Although the individual farmer does not receive much more for his crop than farmers in other areas, the Maize and Produce Board must export this maize at a loss because of the excessive handling and storage charges between the maize producing areas and the ships in Mombasa. A recent study has suggested the current cost of $2.31/q for moving maize from the Kitale area to ships for export could be reduced by $.90 with an efficient bulk handling system. If some of the farmers' costs (duty on farm trucks, the cost of fertilizer and diesel fuel, etc.) could be reduced, the farmer could produce maize at a profit even with a somewhat lower price than the current $4.34 per quintal. Such an internal price should encourage utilization of maize for industrial uses and also greatly expand the use in the livestock industry. Under such a system the excess maize could still be exported without a great loss to the Treasury or to the Maize and Produce Board while these latter uses are building up.

Table 38. Maize handled by the Maize and Produce Board annually (metric tons)

Year	Hybrid maize grown (ha)	Purchases (tons)	Export (tons)	Import (tons)
1959/60		150,825	9,132	--
1960/61		144,200	228	17,035
1961/62		149,375	9,168	64,817
1962/63		203,000	87,071	--
1963/64	160	97,550	53,182	--
1964/65	12,100	106,400	---	13,598
1965/66	30,300	134,025	---	191,884
1966/67	40,800	228,050	63,122	--
1967/68	102,200	325,600	271,435	--
1968/69(est)	(92,900)	(318,000)	(218,000)	--

EAST AFRICAN MAIZE VARIETY TRIALS

S. A. Eberhart and M. N. Harrison

In order to obtain information on available maize varieties and to determine their responses to the varying environmental conditions, an Eastern African Variety Trial was initiated in 1967. This was not begun early enough for the stations in the Southern Hemisphere that plant in November and December; but trials were grown at 21 locations in Ehtiopia, Uganda and Kenya as seen in Table 40. Even though there are a wide range of environmental conditions in these areas, it was surprising to see that H 632 and SR 52 did well at all sites below 1900 meters. They outyielded the local varieties by 138 to 167%. H 613B did reasonably well below 1900 m; and was the best yielding variety above 1900 m. The seasons at all of these sites were much too long for the early maturing Katumani variety and even for H 511.

Table 39. Source of maize purchased by Maize and Produce Board.

Year	Large local farms				Small local farms		Total
	Hectare grown		Av.Yield	Product-	Hectare grown	Product-	Product-
	Hybrid	Total	q/ha	ion(tons)	Hybrid	ion(tons)	ion(tons)
1958/59		60,000	13.50	81,000		85,625	166,625
1959/60		54,475	12.98	70,700		81,125	150,825
1960/61		57,625	13.86	79,900		64,300	144,200
1961/62		64,075	12.04	77,150		72,225	149,375
1962/63		64,459	15.74	101,450		101,550	203,000
1963/64	156	45,300	11.68	52,900	4	44,650	97,550
1964/65	11,400	30,225	19.01	57,450	700	48,950	106,400
1965/66	22,200	38,850	13.52	52,525	8,100	81,500	134,025
1966/67	25,500	57,500	21.52	123,750	15,300	104,300	228,050
1967/68	55,500	57,600	28.25	162,725	46,700	162,875	325,600
1968/69	40,600	(42,000)	(28.25)	(114,700)	52,300		

Table 40. Yields (q/ha) from the Eastern African Variety Trial in 1967.*

Variety	Ethiopia (3)		Uganda (8)		Central Kenya (3)		Western Kenya (3) (1200-1500m)		Western Kenya (4) (1800-2100m		Weighted Average
	Mean	% of Local	Mean	% of Local	Mean	% of Local	Mean	% of Local	Mean	% of Local	
H 632	79.1	167	44.1	152	68.4	150	68.8	138	52.3	127	57.7
SR 52	73.2	154	46.8	161	69.1	152	72.2	144	40.0	97	56.0
H 613B	69.2	146	35.2	121	65.6	144	67.5	135	61.5	150	54.0
H 511	52.3	110	35.2	121	63.3	139	46.3	93	43.1	105	44.8
LH 11	37.9	80	40.0	134	51.5	113	44.0	88	19.1	46	37.9
SV 28	37.7	79	37.5	129	47.6	105	40.2	80	23.4	57	36.7
Local syn.	50.5	106	33.1	114	49.9	110	50.0	100	41.1	100	41.9
Local	47.5	100	29.1	100	45.5	100	--	-	--	-	--
Katumani	42.2	89	31.0	107	38.5	85	38.2	76	25.1	85	33.6
L.S.D. .05	14.8	-	4.5	-	12.0	-	20.8	0	14.2	-	--

* Recommended hybrids are underlined. SR 52 is not available in East Africa.

The 1967/68 trial was expanded to include the new improved composite varieties that were being developed for intense selection by the various breeding programs. The following entries were included in the 1967/68 Eastern African Variety Trial.

Variety	Abbreviation	Maturity	Source
Hybrid 632	H 632	Med:late	Kenya
Hybrid SR 52	SR 52	Med;late	Zambia
Hybrid 613B	H 613B	Late	Kenya
Hybrid 511	H 511	Medium	Kenya
Hybrid LH 11	LH 11	Med:late	Malawi
Zambia Composite A	ZCA	Med:late	Zambia
Ukiriguru Composite A	UCA	Late	Tanzania
Kitale Composite E	KCE	Late	Kenya
Ilonga Composite	ICR	Med:late	Tanzania
SV 28		Med:late	Malawi
Askari Composite		Med:late	Malawi
White Starr		Medium	Uganda
Jimma (Jimma)		Late	Ethiopia
Jimma (Alemaya)		Late	Ethiopia
Embu I		Medium	Kenya
Embu II		Medium	Kenya
Katumani V X VI		Early	Kenya
Katumani B		Early	Kenya
Local		--	--

Seed for 42 of these trials was sent out to various locations in Eastern Africa and two trials were also sent to Western Africa. Results currently available are shown in Table 41. H 632 has done reasonably well in Zambia and very well in Malawi, just as SR 52 has given high yields in Tanzania, Uganda, Kenya and Ethiopia. The new composite varieties are also giving good performance, especially ZCA, UCA, and KCE. The ICR also gave reasonably good yields at lower altitudes in Tanzania and Uganda. However, it is very difficult for it and the other medium maturity varieties, Embu I and Embu II, to compete with the later maturing varieties. Embu I has outyielded Embu II at all locations. The early-maturity Katumani varieties have been the lowest yielding entries at all location.

Table 41. Yields (q/ha) currently available from the E.A. variety trial in 1968.

Variety	Zambia (2) q/ha	Zambia (2) % of Local	Malawi (2) q/ha	Malawi (2) % of Local	Nigeria (1) q/ha	Nigeria (1) % of Local
1 H 632	37.1	119	57.1	202	37.5	133
6 SR 52	45.7	147	54.5	193	39.7	140
2 H 613B	35.9	115	54.2	192	34.4	122
3 H 511	35.2	113	47.4	167	29.2	103
5 LH 11	34.3	110	52.7	186	--	-
8 ZCA	39.5	127	49.9	176	21.6	76
13 UCA	33.8	109	49.5	175	22.7	80
14 KCE	29.7	95	51.7	183	14.6	52
10 ICR	35.9	115	41.8	148	22.4	79
7 SV 28	--	-	--	-	--	-
7 Askari	29.1	94	37.7	133	26.9	95
9 White Star	28.6	92	35.6	126	27.2	96
5 Jimma (J)	--	-	--	-	25.7	91
15 Jimma (A)	--	-	--	-	23.5	83
11 Embu I	31.7	102	39.6	140	39.2	139
12 Embu II	28.4	91	36.7	130	22.9	81
4 Katumani VXVI	26.0	83	31.6	112	19.0	67
15 Katumani B	28.1	90	38.6	136	--	-
Local	31.2	100	28.2	100	28.3	100

Table 41 (cont'd.)

Variety	Tanzania							
	Coastal & Central(6)		Western(5)		Uganda (2)		Kenya (5)	
	q/ha	% of Local	q/ha	% of Local	q/ha	% of Local	q/ha	% of Local
1 H 632	50.9	146	53.9	141	79.0	190	68.0	148
6 SR 52	--	-	--	-	79.5	191	59.8	130
2 H 613B	47.5	136	51.4	135	66.6	160	75.9	165
3 H 511	39.0	112	41.2	108	73.2	176	53.8	117
5 LH 11	44.7	128	37.9	99	70.3	169	--	-
8 ZCA	39.0	112	36.6	96	80.3	193	49.5	108
13 UCA	40.7	117	47.6	125	57.2	138	57.8	126
14 KCE	41.5	119	42.5	112	59.5	143	61.2	133
10 ICR	45.8	131	37.1	97	65.2	157	37.0	80
7 SV 28	45.7	131	39.2	103	--	-	--	-
7 Askari	--	-	--	-	64.5	155	35.4	77
9 White Star	35.7	102	29.5	77	59.1	142	31.0	67
5 Jimma (J)	--	-	--	-	--	-	37.5	82
15 Jimma (A)	--	-	--	-	66.7	160	41.0	89
11 Embu I	43.1	123	37.0	97	71.8	173	45.3	98
12 Embu II	35.8	103	32.3	85	66.0	159	39.7	86
4 Katumani VxVI	22.7	65	24.4	64	55.5	133	20.8	45
15 Katumani B	23.5	67	25.7	67	--	-	--	-
Local	34.9	100	38.1	100	41.6	100	46.0	100

REGIONAL COOPERATION

M. N. Harrison and S. A. Eberhart

Since maize is one of the most important food crops throughout Eastern Africa, emphasis is placed on the coordination of maize research in Eastern Africa and in the stimulation of the exchange of ideas and materials among maize workers. Workshop conferences were held in 1965 and 1967 in Kenya and Uganda for this purpose; and a third workshop conference is being planned for March 1969 to be held in Zambia and Malawi.

Visits have been made to Uganda, Tanzania, Malawi, Zambia, and the Congo (Kinshasa) by the Regional Coordinator and/or the Maize Geneticist in 1968. From the information obtained on these visits and other correspondence, a brief summary of the maize work in other countries is added to this report.

MALAWI

The Malawi Maize Breeding Program which has been running continuously for more than sixteen years, has been under the direction of Mr. Gordon Selley for the past four years. The selected synthetic varieties and the inbred lines from the hybrid breeding program are being combined into a Malawi Composite variety. Exotic introductions from Central America are also being evaluated in order to form a second diverse composite variety to give good crossing value with the local Malawi Composite. As soon as these basic breeding populations have been thoroughly recombined, intense recurrent selection will be initiated.

Meanwhile seed of two synthetic varieties, SV 28 and Askari, are being increased and distributed to Malawi farmers. Several conventional hybrids have been developed and LH 11 has been selected for release. It has also given good performance at the lower elevations in the Eastern African Variety Trial. However, at present there are no facilities for commercial seed production to provide adequate supplies of this seed to Malawi farmers.

Although SR 52, H 632, and H 613B have done well in Malawi in the 1967/68 Eastern African Variety Trial, the local method of food preparation strongly favors the flinty varieties.

ZAMBIA

The maize breeding program in Zambia is under the direction of Mr. John Abington. A traditional maize breeding program had been conducted previously by the three countries of the Central African Federation with

headquarters in Salisbury, Rhodesia. Upon the breakup of the Federation the inbred lines were distributed among the three countries. Of the hybrids available from this program the single cross, SR 52, has given outstanding performance throughout Zambia under all conditions. A Zambia Seed Growers' Association was formed; so that this hybrid is now available in adequate quantities, and the Zambian Seed Growers' Association are looking for an export market.

Because the cost of single cross seed is somewhat greater than three-way crosses, an attempt has been made to screen other inbred lines for a potential pollen parent with SR 52 as the seed parent. Two such lines have been found, 63 J 96 and 63 J 347. Adequate seed of these two hybrids have been produced for local trials and also for the 1968/69 Eastern African Variety Trial.

Because of the greater potential for future progress from the Comprehensive Breeding System over the traditional inbreeding and hybridization method, traditional inbreeding is being phased out and major emphasis is being switched to the formation of composite varieties and recurrent selection. From previous top-cross evaluation trials the better inbred lines obtained after the breakup of the Federation were composited to form Zambia Composite A. This variety was randomly-mated four cycles without selection utilizing the Kafue irrigation scheme. Selection was considered as the method for recurrent selection. But cold winter temperatures cause slow growth and make this system rather difficult to use. Hence, S_1 testing has been selected as a method of population improvement, and the first cycle of selfing will be done in the 1968/69 nursery to initiate yield trials in 1969/70.

Central American accessions have been obtained from the Kenya Maize Research Section and from the Rockefeller Foundation in Mexico. Of this material the Bahio mixture and the Cometic race have given very good performance. One cycle of the S_1 testing has already been completed in the Bahio mixture. The best material from these exotic accessions will be combined to form a second main breeding population.

Details of the breeding program and the extensive agronomic research conducted by Zambia can be obtained from the Annual Report of the Research Branch, 1967. Findings from these research investigations seem to be very similar to those in Kenya. Time of planting, plant populations and fertilizer rates are extremely important with interactions among all these factors. The results from Lundazi give an example of the results obtained showing the interaction with the unimproved variety and the hybrid SR 52. Figure 13 shows the response to nitrogen with yields of SR 52 increasing from 52.6 to 100.6 q/ha. As shown in Figure 14 response to increasing plant populations is also greater for SR 52 than for the variety Namulenga.

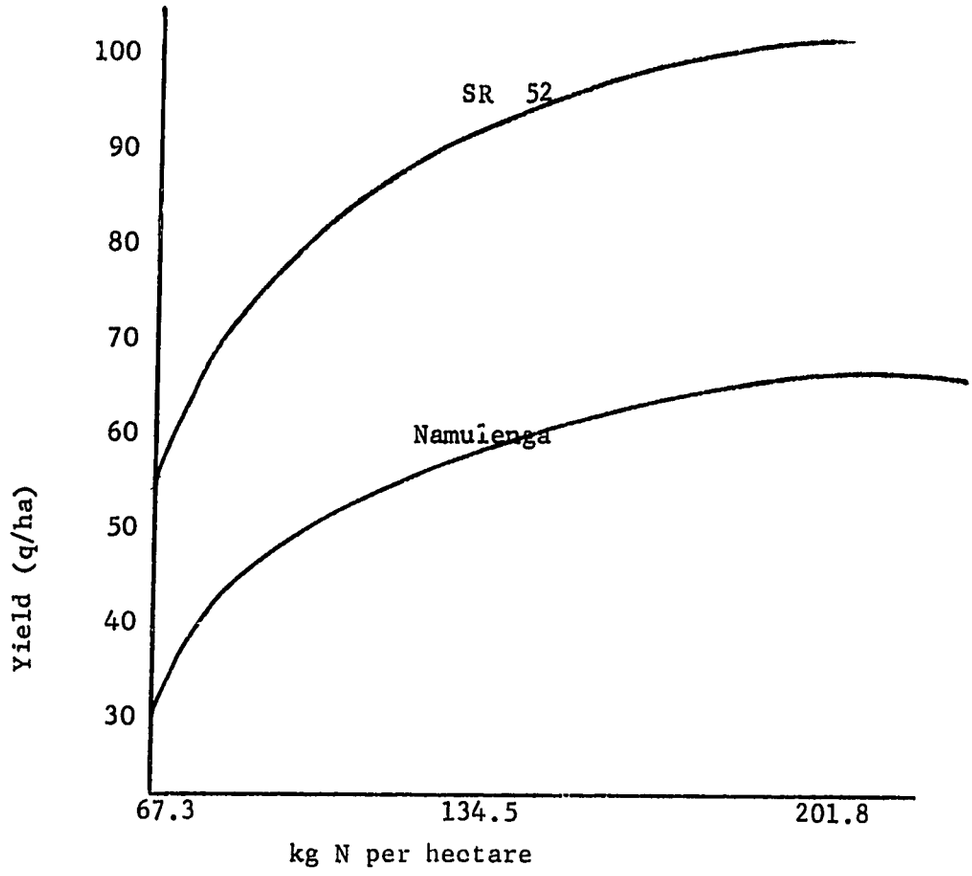


Figure 13. Response of varieties to N at Lundazi, Zambia in 1966/67

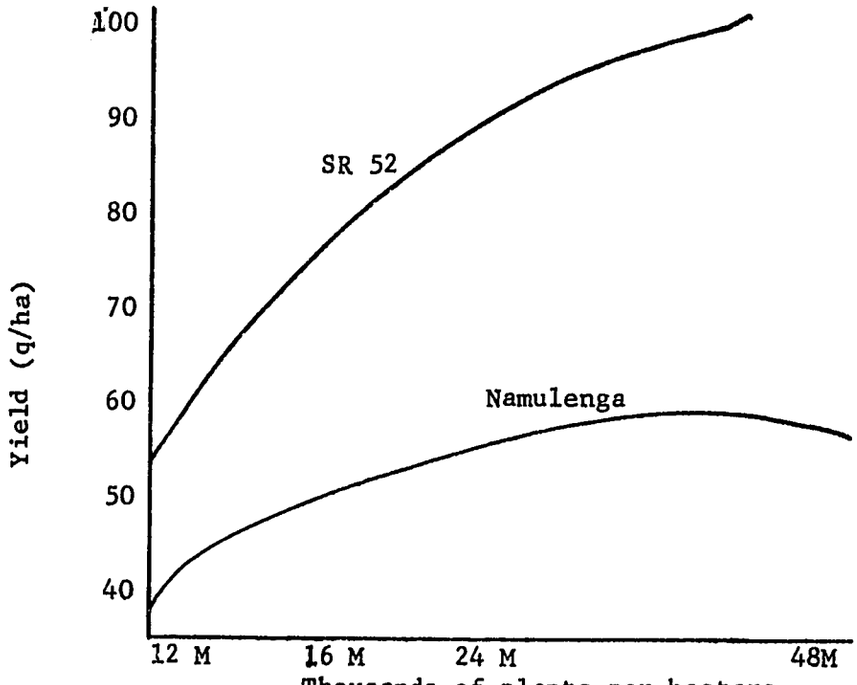


Figure 14. Response of varieties to plant population at Lundazi, Zambia in 1966/67

These yields are obtained with 168 q/ha of N. Namulenga only increased from 16.6 to 58.7 q/ha, whereas SR 52 increased from 23.4 to 101 q/ha. This was a factorial trial with four rates of nitrogen, and without nitrogen there was no response to increased plant population. Similarly, at the low plant populations there was very little response to nitrogen; but at the high plant populations there was a very great response.

On large scale farms that apply phosphorus fertilizers annually; phosphorus responses with maize have only been moderate; but very good responses to nitrogen have been obtained using as much as 160 or 170 q/ha of N. Sulphur responses have also been obtained with Magoye reporting yields of 32.7 without Sulphur compared with 45.1 q/ha with the application of 10 lbs. elemental sulphur per acre as flowers of sulphur.

CONGO (KINSHASA)

Although in early years the Republic of the Congo had been self sufficient in maize, one of the most important food crops, 74,000 tons had to be imported in 1967. The European Common Market has agreed to initiate a program for improving the peasant agriculture in the Congo with two projects. USAID/CONGO has agreed to provide assistance to the Institut Nationale Pour Les Etudes Agronomique De Congo (INEAC) so that seed of superior varieties of food crops and cultural recommendations can be made available. One pilot project will be at Likasi in Katanga Province at 1200 meters with approximately 1400 mm rainfall in a single growing season during mid-November to April. The food crops will include maize, peanuts, beans and manioc.

The INEAC Stations to serve this project are Kipopo and Keyberg near Lubumbashi. The ecological conditions are similar to those found in Zambia, Malawi and Tanzania and many of the varieties and research findings on these Eastern African areas should be applicable. The second project will be in the Gandajika Territory in Kasai Province. The food crops will again be maize, peanuts, beans and manioc, but the cash crop will be cotton. The elevation of this area is about 700 meters with two growing seasons per year. 1400 mm of rain are received in the two growing seasons, September-December and February-May. The ecological conditions of this area are more similar to other West African countries and the varieties and the findings from the USAID Cereal Improvement Programs centered in Nigeria should be useful.

At the present time INEAC has no facilities for maize breeding work near Lubumbashi. Hence, it seems that the most desirable procedure will be to make use of breeding work from the other Eastern African countries. Seed of 2 of the Eastern African Variety Trials have been delivered to Mr. Couvreur, Regional Director, INEAC, at Kipopo for the 1968-69 growing

seasons. Additional quantities of H 632, SR 52, and ZCA have been sent to Mr. Couvreur to use in his more extensive variety trials. An agronomy program will also be initiated to study optimum plant population and fertilizer requirements for these improved varieties.

At the INEAC Research Station at Gandajika Mr. P. Scohier is in charge of the research on food crops. The maize breeding program has been under way on the Station for many years and two synthetic varieties, G.P.S.2 and G.P.S.4, have been released. Seed of the two Eastern African Variety Trials were delivered for the September 1968 planting, and arrangements are being made for seed of the Western African Trial to be delivered in time for the February 1969 planting season. Agronomic research will also be conducted here to determine plant population and fertilizer requirements for the new G.P.S.4 variety.

A suitable area with irrigation permits three crops season a year at Gandajika with mass selection. It would be impossible to obtain more than two seasons with any other breeding method. Hence, under these conditions mass selection should be an extremely efficient breeding method and should produce considerable further improvement in the G.P.S.4 variety.

TANZANIA

Maize Research in Tanzania is under the direction of Mr. A. Bolton at the Western Research Center, Ukiriguru, near Mwanza. The Comprehensive Breeding System has been in use at Ukiriguru for several years and one cycle of full-sib selection in UCA has been completed. Selected entries from KCE which were expected to be better suited to the lower elevations found in Tanzania were sent to Ukiriguru in 1965 to form this Composite. As seen in the results from the 1967/68 Eastern African Variety Trial in Table 41, the performance of UCA has been extremely good.

Additional Central American entries were selected from the 1965/66 Eastern African Cooperative Trials to form UCB. Seven of the entries which were white were used to form UCB-W. This population has now been random-mated for four seasons with mass selection during Composite formation, and full-sib families were made this year at Kitale. Although irrigation facilities are being extended at Ukiriguru to provide adequate nurseries space in time for the next dry season, the space was not available this season to form the full-sib families for both UCA and UCB-W. Hence, the Maize Geneticist at Kitale was able to make these crosses during the regular rainy season. Additional entries were included in UCB, and this has also been undergoing random-mating in Tanzania with mass selection during composite formation, and this wider base composite will serve as the "back-up" composite for UCB-W.

Extensive agronomy trials involving three varieties (H622, H 511, and Katumani B), three plant populations, and three levels of fertilizers were conducted throughout Tanzania in 1967/68 and these results should be available from the Tanzania 1968 Annual Report.

The Comprehensive Breeding System is also being used at Ilonga. Mr. D. Haswell is in charge of the Maize Breeding work at the Central Research Station, Ilonga near Kilosa.

Several composites and synthetics had been formed by Dr. Turner from the local Katumbili variety and introductions from Central America provided by Dr. Wellhausen of the Rockefeller Foundation. As seen from the results of EAVT and also from Table 41 Ilonga Composite (ICR) has given greatly increased yields over the local farmers' maize and the Katumbili variety. Full-sib selection has been begun in this variety as well. UCB-W has been obtained from Mr. Bolton and full-sib selection will also be initiated in this variety.

Because of the high yields obtained from H 622 and H 632, the extension service at Ismani, Jnombe and Mwanza have begun demonstration plots showing what can be obtained with the "package-deal" of the hybrid variety and improved cultural practices. The Kenya Seed Company has made arrangements with the Tanzania Farmers' Association (TFA) to distribute hybrid maize seed to these and other areas in Tanzania in an effort to increase maize production in Tanzania. However, a much more vigorous extension program will be required before there is any great effect in Tanzania. The Tanzania Wattle Company at Njombe have also shown an interest in hybrid seed production and in 1967/68 they grew a small pilot production field to obtain information on the problems associated with seed production. Seed of Kitale II (R11)C2 and Ec 573 (R12)C2 have been sent to the Tanzania Wattle Company for increase in case they decide to go into seed production in the near future.

UGANDA

McMaster has shown that nowhere in Uganda does maize occupy more than 20% of the total acreage of food crops. The F.A.O. census, in round figures shows there is about 100,000 acres grown in pure stand, another 100,000 acres in mixed stands predominantly maize, and some 400,000 acres in mixed stands predominantly other crops. One reason for this is that the hot, humid conditions with two rainfall seasons a year present difficult storage problems, so that bananas (plantains), cassava and sweet potatoes are greatly favored. The most important cereal is finger millet (Eleusine), whose small seeds dry easily and are too tiny for many storage pest to enter. Another reason is that they are common insect pests of cotton and maize (this applies equally to sorghum), so that maize expansion has been officially discouraged at times. Yet a further reason is that difficult soil/water relationships in many areas limit the possibilities for maize.

Hansford, has, however, shown a growth in maize acreage from 17,500 acres only during the 1916-1919 period. 40 q/ha, a yield greatly exceeding most food crops, was obtained as a mean of 8 locations in Uganda in the 1967 Eastern African Cooperative Maize Variety Trials. In 1968, the Namulonge

Cotton Research Station and the Kabanyolo University Farm have obtained field yields of up to 60 q/ha, mainly be attention to correct agronomic practices, especially early planting. In most parts a patch of maize is grown for eating green and for roasting ears but there is probably a great potential as a grain crop in the western higher parts of the country with well drained loam soils and in the better rainfall parts of the north that have a monomodial rainfall distribution.

For many years there has been a maize breeding program at Kawanda and the Soil Chemistry Section have carried out many fertilizer and other agronomy trials on maize. This has led to release by the Uganda Department of Agriculture of the improved varieties, Western Queen and White Star. Mr. Musisi, the Maize Breeder, spent some weeks at Kitale studying our methods, and four visits to Kawanda by the CIMMYT Regional Coordinator have been made over the last four years to see what help and support can be given. Seed production plans have been discussed with the leaders of the seeds organisation being set up with British Ministry of Overseas Development funds.

Mr. Musisi is now forming a Kawanda Composite that includes his best Uganda material, best material extracted from information given by his locations in the Eastern African Cooperative Trial, together with other selected material from the regional program. Kawanda Composite A was designed to meet the urgent need of the new seeds organisation to have something to bulk that was superior to any open-pollinated varieties so far available in Uganda. The components were also selected, so that the Kawanda Composite will be complimentary to the two Embu Composites, and future best hybrid crosses in some parts of the Eastern African region may come from crosses between Kawanda Composite and one or other of the Embu Composites.

Combinations of better cultural practices and improved varieties could alter the status of maize in many parts of Uganda. Introduction of high lysine opaque 2 maize could be of very great benefit because Uganda is the country that has more Kwashiorko than any other Eastern African Country.

SUMMARY

Sorghum-West Africa

Sorghum regional trials were conducted in 9 countries in 1966. Data indicated that 2 or more separate regional trials are required; the subdivision being based on amount of rainfall and duration of the rainy season as well as day length response. In 1968, regional trials of Guinea Savanna zone maturity were grown in 10 countries. Thirty-nine varieties were provided for 15 observation nurseries in the Sudan Savanna zone.

New dwarf sorghum varieties have been developed and are currently in the evaluation phase. Standard types for the area grow to a height of 12 feet or more whereas the dwarfs range from 4 to 8 feet in height. Yields from these new types are substantially greater than those from local strains.

The best of the new lines are being evaluated as potential parents in the production of superior hybrids. One of these new hybrids has been designated Samaru Hybrid No. 1

Extensive agronomic experiments will be required to establish the optimum planting rates and fertilization program for these new dwarf types. The best combination of practices thus far tested has given yields approximately 4 times greater than local varieties grown under conventional practices.

Striga (*Striga hermonthica*) is a serious weed throughout the sorghum growing area. In some fields infestations are so heavy as to result in complete crop failures. Observations suggest that differences in tolerance may exist. Critical data are difficult to obtain, however, due to the general ununiformity of infestation. Attempts to overcome this limitation are being made through the identification and use of fields possessing extremely heavy infestations.

Smuts (*Spacelotheca sorghi*, *S. cruenta*, *S. reiliana* and *Tolyposporium ehrenberjii*) are the most important group of diseases affecting sorghum. Studies currently underway suggest that biological races other than those occurring in the United States may be involved. Sources of resistance to the loose and covered smuts are available and are being incorporated into breeding stocks. These two smuts can also be controlled by appropriate fungicides but due to lack of chemicals and experience seed treatment is not a common practice. Satisfactory inoculation techniques have not yet been developed for either head smut or long smut.

The sugary phase of Ergot (Sphacelia sorghi) may present a serious obstacle to the commercial production of hybrid seed. The cytoplasmic sterile female strains are quite susceptible to this disease. The problem can be partially avoided by delayed plantings of seed fields. This practice, however, may require the availability of supplemental irrigation.

Several foliar diseases may cause serious losses under certain conditions These are now not commonly serious in farmers' fields. If more intensive production practices are adopted some or all of these diseases will increase in importance. Sources of resistance are being sought through screening of the World Sorghum collection.

The shoot flies, the stem borers and midge represent the three major groups of insects attacking sorghum. Problems of control, either by chemicals or the development of resistant types, is more complicated than was originally visualized.

Thirty species of shoot flies have been identified thus far. Of the chemicals tried, endosulfan (Thiodan) appears to offer some promise but this same chemical appears to be very effective in control of stem borers (Busseola fusca).

Sorghum varieties from other areas, reputed to be resistant, were evaluated for resistance to midge at Samaru in 1968. Differences in resistance were noted but no varieties were found possessing a high level of resistance.

A hydraulic weighing lysimeter was used to study soil-water-plant relations in sorghum. During most of the growing season water is not a limiting factor for growth. Adapted varieties, however, flower toward the end of the rainy season and grain development must be realized on stored moisture reserves. Adequate water balance data for this period are not available. Extensive studies involving varying population and fertility levels will be required to provide a sound basis for agronomic recommendations.

Millet

The major objective is to develop lines or hybrids possessing increased productivity combined with satisfactory levels of resistance to lodging, downy mildew and smut.

Breeding work is developing along two somewhat different lines: mass selection and the formation of composites based on S_2 line performance. To date these two methods appear to be giving comparable improvements in (Table 8), yield. Top-crosses of S_1 lines from the mass selection series offer promise of substantial increases in yield combined with acceptable resistance to downy mildew.

The commercial production of hybrid millet will be dependent upon the isolation of a downy mildew resistant cytoplasmic male sterile seed parent. Tift 23A currently used in the production of experimental hybrids is highly susceptible to this disease. Crosses have been made between this strain and the more tolerant Nigerian and exotic types. Selection in segregating progenies appears to offer great promise that satisfactory A and B types can be developed. Both 'gero' and 'maiwa' types of millet are variable for fertility restoration genes so types suitable for hybrid seed production can be isolated.

Preliminary trials of hybrids have been very encouraging and more extensive trials will be conducted in 1969.

Downy mildew (Sclerospora graminicola) is the most serious disease of millet in Nigeria and probably in all of West Africa. Some strains from the World millet collection have been disease free for 2 seasons at both Kano and Samaru.

The sugary phase of ergot (Sphacelia; Claviceps micriephala) is serious on breeding material and, as with sorghum, poses a problem for commercial hybrid seed production. Types possessing a satisfactory level of resistance are not yet available.

Smut (Tolyposporium penicillariae) is common throughout Nigeria. This disease poses a serious barrier to breeding progress as bagged heads tend to be heavily infected. This situation is not consistent with the assumption that infection is floral. Work is continuing on satisfactory control measures either through chemicals or the identification of resistant types.

Maize - Zaria

Experimental yields of maize in the Zaria and Maliwa areas are greater than yields obtained with sorghum. In spite of this fact maize is not an important food crop of the area. Several factors may be involved; susceptibility to root lodging and striga (Striga hermonthica), low fertility levels and sensitivity to a shortage or unbalance of nutrients and the local preference for sorghum and millet as foods.

The breeding programs at Zaria and Mokwa are based on the development of suitable composites and the utilization of these in various recurrent selection schemes. The composites have been planned to provide genetic diversity within each and a heterotic response in crosses among them.

The programs are at an early stage of development but preliminary results are very encouraging.

The response of maize to the application of various nutrients is providing some interesting information. In tests at Samaru, nitrogen gave a 50% yield increase and trace elements 25% increase. Molybdenum is the trace element most commonly involved.

Comparable tests at Kano indicated a nitrogen response of 580% and potassium response of 140 percent.

Although pH values are often low, lime does not appear to be needed. Its main function appears to be in increasing the availability of molybdenum.

The widely differing responses in different areas indicates that much more work is necessary to provide background information for the development of suitable recommendations.

Maize - Ibadan

Regional maize trials were initiated in 1967 with 8 countries participating. These trials were continued in 1968. Interest in this activity appears to be increasing and Gambia and Ghana have expressed an interest in participating in the 1969 trials. Large differences in yield have been observed.

A cooperative program of composite development was initiated at the Maize Breeders Conference held at Moor Plantation, Ibadan, Nigeria February 5 through 7, 1968. After formation these composites will be distributed to all countries interested to serve as a basis for local breeding operations. The genes for protein quality (opaque 2), polysora rust resistance and H. maydis resistance will be incorporated into these composites.

Two races of Puccinia polysora have been identified. These appear to be different from the races previously identified in the United States. Sources of resistance are available. Studies on the inheritance of resistance are underway.

A strain of maize has been identified which possess resistance to Helminthosporium maydis, one of the important foliar diseases. This resistance and resistance to polysora rust has been combined into a single strain. Seed of this type has been distributed to 10 countries. If these types of resistance provide adequate protection throughout West Africa it will greatly simplify the disease resistance problems.

Training

In-service training has not developed as rapidly or as extensively as could be wished. Two students from Ahmadu Bello University received training in Plant Pathology during the summer of 1968. Two research officers of the Federal Department of Agricultural Research, Moor Plantation, Ibadan, Nigeria have been assigned to the maize program and are receiving training in maize breeding and pathology.

East Africa

The Major Cereals Project is concerned with 4 cereals in East Africa: orghum, bulrush millet (Pennisetum), finger millet (Eleusine) and maize. elative yield data are limited and critical data difficult to obtain. hus the economic and ecological limits for each cannot be sharply drawn.

Sorghum

The development of suitable sorghum hybrids has been hampered by the lack of adapted cytoplasmic male sterile types. The U.S. developed parents are poorly adapted and susceptible to insect attack. In a series of comparable hybrids two new parents, 2DMS 1 and 2 DMS 7 were superior to standard U.S. parents by 30 percent. These hybrids could be used for commercial production if an adequate extension program could be mounted.

A system of population improvement has been initiated utilizing the genic male sterile, ms_3. Several populations have been established: (1) a restorer population based on 40 varieties, (2) a genetically similar population composed of non-restorer types, (3) a restorer population based on 100 varieties and (4) a comparable population based on non-restorers. Each population is further subdivided into coarse and quality grain types. Improvements within these populations resulting from recurrent selection procedures could be quickly used in the production of commercial hybrids.

A new composite is being formed based on recent introductions from Ethiopia. No selection has been practised as yet within this material.

Selection studies are underway to concentrate factors for resistance to the shoot fly. Advanced generations of crosses between either Serena and Namatare and lines possessing good yield or quality characteristics have been screened for the recovery type of resistance. The apparently resistant segregates have been crossed with the genic male sterile, ms_3, to form a new random mating composite. This population will be subjected to further screening under conditions of heavy infestation.

Chemical control of shoot fly does not offer great promise. Eighty to 90 percent control has been achieved through the use of 'endosulfan' but this level of control required 4 to 6 applications at 3-day intervals. Two organophosphate systemic insecticides gave promise of effective single treatment control but these have undesirable mammalian toxicities.

Sever experimental insecticides give promise of control of the pink stalk borer (Chilo sp). Chemical control, however, is not well suited to subsistence agriculture due to cost of materials and the necessity for timely applications.

Sorghums respond markedly to increased N and P_2O_5 fertilization. These potential gains however, are not realized under conditions of heavy stalk borer attack.

Further work is required to establish the interactions among dates of planting, fertilizer rates and population densities.

Finger Millet

Over 300 varieties of finger millet have been screened and 52 varieties retained on the basis of yield, disease resistance and other desirable characters. Twelve of these have been included in District Variety trial centers. Yields of over 50 quintals per hectare (4460 pounds/acre) have been obtained under proper fertilization and management.

Blast, Piricularia oryzae is one of the most serious diseases. The line, Serere 359 is highly resistant and this resistance is being transferred to the five highest yielding varieties.

A gene pool is being established based on the 597 entries from the World collection. Neither genetic nor cytoplasmic sterility is known for this crop and intercrossing is being accomplished through hot water emasculations.

Extensive fertilizer trials have been conducted. The economic optimum level of fertilization is 70 pounds N and 67 pounds phosphate per acre. On the basis of present fertilizer costs and grain value the net return is approximately 280 shillings per acre. Further trials involving varying planting rates and fertilizer applications are required.

Bulrush Millet

The World Collection of bulrush millet is being crossed on to the cytoplasmic sterile, Tift 23A to identify the 2 groups: restorer and non-restorer. Preliminary data indicate that the majority of the items comprising the collection carry the restorer gene in either the homozygous or heterozygous condition. Few completely lack the restoration ability.

Two separate recurrent selection schemes are being initiated as part of a long-range breeding program. The first is based on the restorer vs. non-restorer classification and may lead rapidly to the production of acceptable commercial hybrids. The second scheme is aimed at population improvement based on S_1 testing. This should be a very efficient system as one complete selection cycle can be completed each calendar year. Improvements under this scheme would be utilized directly as an improved variety or superior isolates could be used for hybrid production.

The sterile strain, Tift 23A, is not well adapted to East African conditions. A new sterile, Serere 102 is now available and others are in the process of development.

Improved types of sorghum and finger millets are now available. A reasonable body of experimental data are available indicating desirable agronomic practices. Further improvements will be achieved in both materials and practices. However, the current status appears to be quite adequate to justify mounting a comprehensive extension effort along the lines used so effectively in the Kitale maize program.

Cereal Processing Technology

Work in this field was initiated in July 1968. A laboratory has been established, equipment installed and certain preliminary results obtained. The main effort, thus far, has been devoted to an assessment of the over-all problem, and the establishment of cooperative relations which will be required in the evaluation of new procedures or products.

Preliminary data have been obtained on a rice polishing machine to debran sorghum. Marked varietal differences were apparent. Varieties lacking tests color produced an acceptable product which would have many of the characteristics of rice. In addition to other potential benefits this new laboratory will be of great value to the sorghum breeders in the delineation of desirable grain characteristics.

Maize

The cooperative maize program in Kenya is predicted on the assumption that 5 major factors are essential for sustained increases in productivity. These are; (1) Breeding research to develop superior varieties, (2) Agronomi research to establish the cultural practices required to obtain maximum economic returns, (3) the development of adequate seed production and distribution facilities, (4) an effective extension program to ensure wide-spread adoption of improved practices and (5) price and marked structures which favor the adoption of new techniques. Item 5 normally receives little attention under conditions of scarcity but assumes primary importance as the most pressing food demands are satisfied.

The maize program in Kenya has achieved World prominence in the development of simple breeding procedures adapted to the needs of developing countries and in the demonstration of the practical utility of such methods.

Several recurrent selection methods are being evaluated for relative efficiency in population improvement; such populations to be used in the production of commercial varietal hybrids.

Expected and realized gains for the several systems are in reasonable agreement. The improvements achieved in the base populations are retained in the varietal hybrids. Responses tend to be greater under favorable than

unfavorable or limiting environments.

Maize breeding is underway at 3 locations: Kitale, Embu and Katumani. These represent the three main ecological zones where maize is grown. Maturity requirements differ for each zone. Composites have been developed for each zone and recurrent selection practiced for varietal improvement. The improvements achieved average approximately 5 percent per cycle. As each cycle of improvement is evaluated, if progress is satisfactory, the new parental stocks are increased and used for seed production.

Opaque$_2$, floury$_2$, brachytic$_2$ and the gene Ht for resistance to Helminthosporium turcicum are being introduced into all composites. Opaque$_2$ and floury$_2$ give improved protein quality. This is of great importance as the bulk of the maize is used for human food. The late and medium maturity materials are excessively tall. The use of brachytic$_2$ will lead to reduced plant and ear height. Leaf blight occurs regularly at the higher elevations and may become more serious with increases in planting rates and level of fertilization.

Agronomic trials have been conducted in each maturity zone to establish the relative importance of: (1) time of planting, (2) improved or local varieties, (3) population level (4) weed control and (5) level of N and P_2O_5 fertilization. Such tests are continuing giving greater emphasis to population densities and levels of fertilization. In a series of 9 trials in 1967 (Trans Nzoia district) the application of 56 kg P_2O_5 and 116 kg N gave a yield increase of 29.6 q/ha. This represents a very profitable return at the prices then current.

In the original extension package the recommended plant populations were double those in general use. Further studies have indicated that additional yield responses can be obtained by still further increases in planting rate. Under favorable conditions early types, such as Katumani composite B had not reached its optimum yield at populations of 100,000 plants per hectare.

The agronomic factors mentioned above exhibit marked interactions. Nitrogen response is greatest with early planting and is essentially absent with late planting. The magnitude of nitrogen response is markedly influenced by population level, type of maize and level of weed control. The main effects and interactions must be continuously evaluated with each new hybrid or composite to ensure that the package recommendations provided to the Extension staff are soundly based.

An extension program based on demonstrations involving the complete package have been highly effective. The utilization of hybrid maize on the European farms reached 100 percent very rapidly. The use of hybrids by the small scale farmers increased rapidly up to 1968 then showed somewhat due to reductions in price. Even with current prices maize production can be profitable if the recommended practices are followed.

All of the hybrid seed is produced under contract for the Kenya Seed Company. They provide an advisory service but official field inspections are carried out by government inspectors. Certification standards are equal to or above those of the International Crop Improvement Association. Initially all contracted seed was grown on European owned farms. In the last 2 years nearly half of the seed acreage has been grown by Kenya farmers.

The East Africa Maize Variety Trials were initiated in 1967. In addition to the East Africa Community other participating countries include Ethiopia, Malawi, Zambia and the Republic of the Congo. Regional cooperation has been developed which has a much broader basis than regional trials This involves the development and exchange of composite populations and advice and counsel on breeding procedures.

The East Africa Cereal Workers Conferences held in 1965 and 1967 have served to develop and strengthen this regional cooperation. At the 1967 meeting the workers requested that such meetings be held each year with some system of rotation among potential host countries. Meetings are tentatively scheduled for March-April of 1969 in Malawi and Zambia.

This project has been most fortunate in the cooperation extended the scientific and administrative staff at each of the host centers, by EAAFRO, the AID Missions and by the Government officials concerned. This cooperation and support has simplified working relations and greatly increased the effectiveness of the funds and effort expended.