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FOURTH ANNUAL REPORT
of the
AID-ARS Project

Major Cereals in Africa

G. F. Sprague

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

CURRENT STATUS

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

Regional centers were established in both East and West Africa to serve the differing ecological requirements. One center is located in Nigeria with staff located at the Institute for Agricultural Research, Ahmadu-Bello University, Zaria, Northern Nigeria and at the Federal Agricultural Experiment Station, Moor Plantation, Ibadan. The second center is located in Uganda and Kenya. At each location our staff is associated with existing research organizations and contribute to the total research effort. The objective is to extend or supplement existing research programs through inauguration of new lines of work, provision of additional staff, and the provision of limited equipment and financial support.

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

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

A.I.D. HISTORICAL AND
TECHNICAL REFERENCE
ROOM 1016 NS

Location	Name	Discipline	When Posted
Institute for Agr. Res., Zaria, Nigeria	O. J. Webster 1/	Geneticist	Sept. 1964
	S. B. King	Pathologist	April 1967
	G. T. York	Entomologist	Febr. 1966
	K. R. Stockinger	Soil Scientist	June 1966
Kaduna, Nigeria	A. Kosage 1/	Admin. Ass't.	July 1965
Federal Res. Sta. Ibadan, Nigeria	J. Craig 1/	Maize Path-Breeder	Sept. 1965
Nairobi, Kenya	-------- 2/	Cereal Processing	----------
Maize Res. Center Kitale, Kenya	S.A.Eberhart 1/	Maize Geneticist	July 1964
Serere Exp. Station Serere, Uganda	G.A.Schumaker	Soil Scientist	May 1966
	K. Starks	Entomologist	Jan. 1967
	L. V. Peters	Millet Geneticist	March 1967

1/ Now serving second tour of duty.

2/ Candidate has passed security clearance, physical examination and indoctrination pending.

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. Therefore no attempt will be made to allocate credit for each activity but rather we shall attempt to provide a measure of total progress.

Consideration is also being given to the development of closer relations among research and educational institutions. Where suitable arrangements can be made upgrading the technical competence of the local staff will be simplified and the efficiency of in-service training greatly simplified.

NIGERIA

Work in Nigeria is conducted at two centers: Institute for Agricultural Research, Zaria, with branches at Kano and Mokwa; and the Federal Research Station, Moor Plantation, Ibadan. Dr. O. J. Webster serves as the local coordinator. In this capacity he has liaison responsibilities for all consultation activities and, in addition, is responsible for maize breeding at Zaria and cooperates with the local staff on sorghum and millet breeding work. Because of the cooperative nature of the research work at the Institute for Agricultural Research, local staff at Zaria and Kano have kindly included progress reports on the improvement of sorghums and pearl millet.

Staff Consultation Activities

In addition to their research, the staff serve also as technical advisors at their respective posts, and to other agencies engaged in work for the improvement of agriculture within Nigeria and Africa. This aspect of responsibility was limited this year due to local restrictions on travel. Touring was limited to the "essential."

Inter-African travel included a brief trip by Dr. York and Mr. H. Caswell, Chairman of the Entomology Section of the Institute, to the Tarna Research Station, Maradi, Niger. Drs. York, King, and Stockinger visited the research stations in Kenya and Uganda where other project staff are posted. Tour reports have been added to the sections prepared by the staff.

Dr. Webster presented a paper entitled "Some Aspects of Sorghum Improvement in the U.S.A." before the sorghum and maize section of EUCARPIA (Association of European Plant Breeders), March 20-22, at the Mediterranean Institute for Agronomy, Montpellier, France. The proceedings of this conference are available.

A cereal conference was planned for July 5-7 at Moor Plantation, Ibadan, Staff members and other research workers from east Africa were invited to attend and be the leaders in special training courses in plant breeding methods. Since it has not been possible to have personnel from cooperating countries take advantage of the in-service training phase of the project, it was anticipated that this conference would bring to the attention of the specialists in west Africa the latest techniques for cereal improvement. Unfortunately, the conference was postponed due to unforseen circumstances. The papers and reports to be given have been printed in English and French and have been distributed to workers in west Africa. These papers will also be printed in the OAU-STRC bulletin "African Soils," volume XII, nos. 2-3 (May-December 1967).

The authors and titles of the papers were:

P. Chinwuba	-Effect of Plant Population on the Development of Yield of Maize in Western Nigeria
J. Craig	Maize Pathology
J. Craig	Maize Report for Nigeria
U. Ebong	Maize Breeding Progress Report 1965-67, Nigeria
S. Eberhart	Recurrent Selection in Sorghum
M. Jacquot	Maize in the Casamance, Senegal
J. Le Conte	Maize Report from Dahomey
H. Wiggin and A. Obajimi	Recent Status of Maize Breeding and High Lysine Maize in Western State, Nigeria
D. Andrews	Progress in Sorghum Improvement in Nigeria
H. Doggett	A Bulk Breeding Method in Sorghums
H. Doggett	Sorghum In East Africa
H. Doggett and S.Eberhart	Recurrent Selection in Sorghum
J. Le Conte	Sorghums in Dahomey Sorghum Report from Senegal
J. Nabos	Sorghum and Millet Work in Niger
B. Bhardwaj	Progress in Pearl Millet Improvement in Nigeria
S. Adeyemi	Storage Pests of Cereals (Millet-Maize-Sorghum) and Their Control in Nigeria
G. York	Insects of Cereals in West Africa.
Leroy Peters	Progress in millet improvement in East Africa

Dr. O. Webster met on two occasions as a representative from the Institute for Agricultural Research with a committee within the Ministry of Agriculture, Northern Nigeria, to discuss seed multiplication and distribution. A scheme is already operating for groundnuts and the same arrangement can be used for the cereals. Foundation seed stocks are first increased by the plant breeder on the experiment stations and then turned over to the Ministry of Agriculture for further increase at the numerous farm training centers or on other government controlled land. The weak link in the present system is the control of the seed when it gets into the hands of the farmer grower. As soon as qualified persons are available a seed inspector will be located in each state. At present the management of the seed program is another of the numerous "chores" of the Provincial Agricultural Officer.

Sorghum, Maize and Millet Breeding

O. J. Webster

Personnel: D. J. Andrews, cereal breeder posted at the Institute for Agricultural Research, Zaria, is responsible for the sorghum improvement work in Nigeria. He also is in charge of the small grain introductions and testing as well as cooperating in the millet improvement project. Dr. B. Bhardwaj, Kano, is in charge of the millet project but also supervises the sorghum work at Kano in the absence of Ayo Abifarin, who is attending Purdue University working towards a Ph.D. degree. Dr. O. Webster has assumed the responsibility of testing early sorghum varieties and hybrids along the northern border of Nigeria as well as the maize project at Zaria. Frans de Wolff was posted this year at Mokwa to do breeding and testing of maize. Mokwa is about 250 miles south of Zaria, or midway to Ibadan. Dr. Craig, maize pathologist for the project, located at Ibadan, cooperates with all the breeders in the country on maize disease problems, but also coordinates the West African maize testing program. The maize improvement program within Nigeria is coordinated by the Federal Research Station. Each year the research staff from the experiment stations meet to discuss the past year's accomplishments and to plan for future work.

According to the F.A.O. report, Supplement No. 2, "World List of Plant Breeders," there are no breeders of cereal crops in 5 of the 12 West African countries and excluding Nigeria there are 7 breeders located in the other countries but who also have responsibilities for other food crops. Because of the shortage of trained cereal breeders in the region, this project serves a very essential function in the exchange of seed of varieties and hybrids for trials as well as providing breeding stocks. This function, however, is limited by the lack of available materials for exchange.

Sorghum Regional Trials. The first regional sorghum nursery to be established under this project was in 1966. Cooperating countries in West Africa included Senegal, Upper Volta, Niger, Dahomey, Ghana, Nigeria, Cameroon Republic, and Chad. The nursery included:

	Entry	Source
1.	Ck-60 x IS 3691	India
2.	Ck-60 x IS 84	"
3.	Ck-60 x IS 3687	"
4.	MS 172 x IS 84	"
5.	MS 3675 x IS 84	"

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

Reports were submitted from all cooperators except one and after this data were tabulated and copies of the combined reports were distributed. These are available in mimeograph form. Several lessons were learned from the first attempt at regional testing.

1. Although planting is not done at most stations before June, the seed must be mailed out at least two months in advance to be certain of timely delivery.

2. Seed collection must be started six months before distribution date.

3. Since the regional stations are in different ecological zones, the entries must be sub-divided into two or three groups according to maturity. There are two main zones in which sorghums are grown. (a) The Sudan savannah represented by northern Nigeria, southern Niger, and extending across West Africa through most of Senegal. This zone has 25 to 35 inches of precipitation falling over a period of about three months. Varieties which will bloom in about 60 to 65 days from planting are required for this zone. Many of the introduced varieties and hybrids are agronomically quite acceptable in the zone but their use is limited by their undesirable grain quality for human food. White grain is desired and nearly all introductions from the U.S.A. have colored. Those from India are more acceptable since they are grown for food in that country.

(b) The Guinea savannah is south of the Sudan savannah in a rainfall belt of 35 to 50 inches falling over a period of five to six months. Zaria is located in this zone. The varieties suited for this area require from 110 to 150 days from planting to bloom. They must be planted with the first rains and bloom at the end of the rains. Such varieties are relatively low yielding with only about 10 per cent of the dry matter produced in forms of grain. Until now there have been no improved varieties developed for this zone except reselections in locally grown populations. Such selections have given significant yield increases but not enough to create a demand for seed by peasant farmers. The breeding work for this zone is discussed in Andrews' report.

Since several stations expressed an interest in the hybrids from India, additional seed was requested for the 1967 trials. The seed was delayed in the mails and did not arrive in time for distribution except in trials in northern Nigeria and Niger. Seed of only four varieties was distributed to the same stations as in 1966. These included:

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

These varieties have a range in number of days from planting to bloom of 60 to 120 and the data from each station will assist in delineating the ecological zones.

The plans for the 1968 regional nursery for the Sudan savannah region call for about 8 hybrids from the U.S.A. and India to be planted in a replicated yield trial and, in addition, about 30 items will be grown in observation rows to determine their range of adaptation. These items have been selected at Zaria from 350 included in the 1967 International Nursery. Mr. Andrews will supply seed of hybrids and parental lines for the nursery to be planted in the Guinea savannah zone. This will be the first distribution of seed sorghums from a hybridization program in this part of Africa.

Early maturing sorghum trials in northern Nigeria. The 1966 trial which was planted at five locations in northern Nigeria demonstrated the potential value of earlier maturing, short stalked varieties in this area of limited rainfall. Yields at Daura, about five miles from the Niger border, ranged between 1,500 and 4,000 pounds per acre. These trials also emphasized the losses which can occur from sorghum midge.

The potential of the crop at Tungun Tuda, 30 miles north of Sokoto, was the best of all trials but no grain was harvested due to midge.

The 1967 replicated trials were planted at Kasarawa (Sokoto), Tungun Tuda, Daura, Kano, and Zaria. The trial included:

Entry No.	Source
CSH-1 MS Ck-60 x IS 84	India
CSH-2 MS Ck-60 x IS 3691	"
MS 172 x IS 84	"
MS 2219 x IS 3691	"
MS 3675 x IS 3691-2	"
MS 172 x IS 3798	"
MS 2219 x IS 3541	"
MS 3675 x IS 1122	"
Serena	Uganda
H x 57	"
NK-300	U.S.A.
Hegari	U.S.A.
Georgia 615	U.S.A.
Local (check)	Nigeria

Stands were good in all trials and plant growth was excellent. Very good yields are expected. Half of the hybrids from India grew to a height of more than six feet and lodged before the crop was ready for harvest. Hybrids H x 57 and NK-300 will be the most productive but the grain color is brown and will probably be unacceptable as food.

Plots ranging from 1/4 to 1/2 an acre in size of hybrids NK-300 and NB 505 were planted adjacent to the replicated yield trials at Tungun Tuda and Daura. The purpose of these plots was to give the local farmers an opportunity to observe short sorghums on a field scale and also to determine if the grain from these hybrids could be sold in the local market. There is farmer interest in the short stalked sorghums which are more productive than their own. The unknown factor is whether the increase in productivity will offset the local prejudice against the grain for food. The purpose of conducting these trials with a range of materials is to establish (a) if short types will be acceptable to the local farmers, (b) what plant types will be the most productive. When the type of plant with respect to height adaptability is established then grain quality can be improved through breeding to satisfy the local demand.

The variety Hegari, from U.S.A., has given good yields on the irrigation schemes. A variety has the advantage over a hybrid in that seed can be replanted. Seed of hybrids must be obtained from special seed

production fields. The grain of Hegari will not be of the type acceptable to Nigerians, even though it is the only type used in parts of East Africa. The job of breeding high-yielding sorghums for the tropical areas would be minimized if the factor of use for human food did not have to be considered.

Progress in Sorghum Improvement in Northern Nigeria

D. J. Andrews
(Research Fellow. Institute for Agricultural Research, Ahmadu Bello University, Samaru, Zaria, Nigeria)

Improvement work on grain sorghum in Nigeria was initiated in 1956/1957 with a sample survey and selection within the principal local types. The first improved indigenous variety was released in 1960. In 1961 an accelerated programme was formulated, and the Institute of Agricultural Research, Samaru received the support of $100,000 over three years (R.F. 61062) from the Rockefeller Foundation. In 1963 a small dam with a five acre irrigation site was built by the Institute and from 1963/64 a dry season nursery has been grown enabling two breeding generations each year.

Sorghum bicolor (Moench) is the staple food crop in the Sudan Guinea Savanna zones in West Africa. The principal agronomic types existing in these ecological zones in Nigeria are shown in Stage I of the programme outlined below. These types are tall (10-20 ft) and have grain conforming to rather specific consumer requirements (large, white or yellow, endosperm vitreous, and usually without sub-coat). The main crop varieties are closely adapted to mature at the onset of the dry season by photoperiodic response. When planted at the proper time, the beginning of the wet season, they take according to variety, 90-150 days to head. The yields of these varieties are relatively low, the farmers average being around 650 lb. grain per acre.

Except in the drier parts of the Sudan Savanna the use of even the later (70-75 days to heading) maturing USA or Indian high yielding varieties is impractical by the peasant farmer. However at Samaru good experimental crops can be obtained with such varieties and hybrids but close supervision is required.

While investigations continue on the possibility of using these "early" maturing introductions in the wetter areas, the primary need is for the development of varieties and hybrids which are as closely adapted to the rainy season as the indigenous varieties. It is to this end that the major effort of the sorghum breeding program is directed.

The production of dwarf adapted varieties is described in Stage II below, while progress in production and early testing of hybrids is detailed under Stage III. A few years have been required to develop hybrids suitable for the Guinea Savanna since both the seed parent and the pollinators have had to be bred from crosses involving

widely different parents. This is in contrast to other countries where hybrid production has recently commenced, where one or both parents of the hybrids first released are of exotic origin. The point has now been reached where varieties and hybrids of sufficient promise exist so as to require the consideration of seed production procedures.

Apart from land under Government control there are no large individual areas where uniform cropping exists. There are at present no commercial cereal seed producers.

For the multiplication and distribution of seed of a new dwarf variety the present schemes conducted by the Ministry of Agriculture and the N. A.(Native Authorities) for improved local varieties, could be expanded. Maintenance of purity in the first dwarf variety to be multiplied in an area will present little difficulty due to the obviousness of the rogues.

The production of hybrid seed presents greater problems both in the promulgation of seed laws, and the fostering of a commercial seed industry. As to methods of production there are two obvious alternatives:

a) Growing the seed crop at the normal time or
b) Planting late and giving supplementary irrigation on an irrigation scheme.

The former has the advantage in that synchronization of flowering (nicking) of the parents will be precise due to the photoperiodic response, but the crop will require adequate spatial isolation from the commercial farms. However very little wind exists at the normal time of flowering (end of September early October) and this might lead to poor pollination. Planting in August (three months late) would cause adapted varieties to flower only 3-4 weeks later than if they had been planted at the normal time.

Thus when growing the seed crop with supplimentary irrigation;

(i) Time isolation would exist.
(ii) Less time is actually required to grow the seed crop.
(iii) Good seed set could be expected due to the hamattan wind at the end October-early November.
(iv) Dry conditions would insure top quality seed.
(v) Sorghum could compete as a cash crop on irrigation schemes.

However against these advantages there are problems of establishing a crop in August, though with drainage these are not considered insurmountable.

Investigations are planned for both seed parent maintenance and hybrid seed production for 1968. Experimental plots for both have already been planted for the 1967/68 season.

The breeding programme for the improvement of sorghum grain yields in Northern Nigeria consists basically of three stages:

Stage I The identification and improvement of the best indigenous varieties.

The four principle agronomic types grown in Northern Nigeria are:

Type	Subseries	Snowden sp.	Locality (zone)
Farafara	Guineensia	S. guineense	) Northern Guinea,
Janare	"	"	) Southern Guinea) Southern Guinea) and Derived Savannas
Kaura	Caffra	S. caudatum	Central Sudan and Northern Guinea Savanna
Shambul	Caffra	S. caudatum	Eastern Sudan Savanna

Pedigree selection and yield testing have resulted in the recommendation of strains of the local varieties as shown in Table 1. Provincial yield testing is not yet complete on strains selected for the Southern Guinea and Derived Savannas but the percentage yield increases being shown in trials are of the same magnitude as have been obtained with the more northerly types.

Except on one variety of Kaura in the Sudan Savanna, pedigree selection within indigenous varieties is being discontinued and Stage I of the programme has almost been completed.

Stage II The production of adapted dwarf varieties by hybridization and selection.

The limitations of indigenous Nigerian varieties are several. At Samaru the yields of the recommended Farafara selections SFF 60 and FF BL-3-1-6, sown at 14,000 plants per acre occasionally exceed 2,000 lb. grain per acre. This weight of grain represents 1/10th of the total dry matter produced and lodging is common at this yield level. On less fertile fields the yields of the same selections may be less than 1,000 lb. grain per acre. These yields represent an increase

over the unselected local Farafara of up to 30 percent. Yields of Short Kaura (or test variety WX60) range from 1,300 to 2,700 pound grain per acre but the grain is not as popular as that of Farafara. Neither Farafara or Short Kaura are suitable for mechanical harvesting. By comparison the best USA hybrids grown at Samaru yield between 4,000 and 5,000 pound of grain per acre at populations of 50,000 plants per acre. As much as 45 percent of the final dry matter is in the grain.

However the grain of such USA hybrids or varieties is not acceptable for human consumption and the crop matures before the rains have ceased. Dwarf lines (in this context 1.5 to 2.5 metre tall) have been produced at Samaru by crossing numerous exotic varieties with the best Nigerian parents. The single most useful exotic parent has been Combine Kafir 60 (either A-or B-line (CK<u>A</u> or CK<u>B</u>) according to the cytoplasmic status required). Short Kaura (SK) has been the best Nigerian parent. The backcrosses (CKA-SK) SK have so far proved a most useful group.

During the development of dwarf lines some of the difficulties encountered have been:

a) elimination of early maturity genes;

b) the occurrence of partial male sterility where a B line has been used as a female parent;

c) combining adequate exertion of the panicle from the flag leaf with dwarf plant stature;

d) Maintenance of adequate grain quality and size (30-gm/1000)

e) susceptibility to stem-borer damage

f) " to leaf diseases

g) " to <u>Striga</u> attack

In 1966 the first yield trial was carried out, at two population levels, on 64 dwarf lines of various origins. In that year at Samaru stem-borer attack was severe and even the yields of the control, WX60, a variety tolerant to stem-borer, were low.

The yields of the 10 most productive entries in this trial are compared in Table 2. It is notable that the high yielding lines were even more productive at the higher population level.

In 1967, two series of trials containing dwarf lines have been planted.

(i) A set of 48 lines replicated twice at each of seven centres in the Northern Guinea Savanna (from 5° 20' to 11° 30'N).

(ii) A set of 80 lines replicated twice at each of five locations around Samaru.

The two series of trials contain related treatments, the seed from the second set being from the 1966/67 dry season nursery. At the time of preparing this report some 5 different strains show great promise in these trials.

Stage III The development of adapted female parents and the testing of pollinators for the production of hybrid sorghum. Much of this part is integral with Stage II.

A number of adapted female parents (cytoplasmic male steriles) have been produced from the origin CKB x Farafara, but none is entirely satisfactory. Many potential B-lines have been identified from the material produced in Stage II and backcrossing to make comparable A-lines is being carried on concurrently with the continued improvement of these B-lines.

Using the available female parents (CKB x FF derivatives) a few late maturing experimental hybrids were put into trial for the first time in 1966. Data of the best hybrid and its parents are shown in Table III.

This season (1967) a larger range of pollen parents are being tested.

Male Sterile Bulk

This project under stage II is additional to the conventional crossing and ear to row selection.

The bulk was set up in 1965 to make use of an obligatory cross pollinating system. In 1968 the male sterile selections will be sown ear to row, alternate rows being planted with their composite bulk. Thus will enable some selection to be exerted on the female parent traits which will be more affective than annual mass selection, or S_1 testing. This is because the latter would take 3 years per cycle since neither yield testing nor recombination can be satisfactorily carried out in the dry season.

The bulk was made up of 30 fertile single plant F_2 selections from a number of wide crosses made onto an adapted genetic male sterile dwarf parent discovered after irradiating Short Kaura. The use of F_2 selections was effective in preventing a preponderance of the male sterile genotypes appearing in the bulk.

Light selection pressure only was used at harvest in 1966 and the same will be applied in 1967. In subsequent cycles only about 10 percent of the male sterile plants will be retained out of a minimum population of 5,000 plants.

One of the uses of this bulk will be to produce desirable recombinations which will be taken out as single plants and selfed to homozygosity. Also the bulk was so composed that these selections might be either B or R lines in respect of cytoplasmic male sterility.

Table 1. Summary of Sorghum Variety Recommendations (February 1967)

Recommended Variety	Type	Province	Centre	Years in Trial	Yield Local variety lb/acre	Yield Recommended Variety as percentage of Local
YG5760-3-10	Kaura	Katsina	Kafinsoli	6	1287	119
	Sokoto	Sokoto	Gusau	5	1367	123
		Kano	Kano	5	1941	111
		Kano	B.Kudu/Panda	6	1712	117
		Bauchi	Azare	5	1233	106
		Bornu	Potiskum Area	6	641	119
		Bornu	Fika	3	546	135 (YG571 was test variety)
SFF 60	Farafara	Zaria	Gimi Dabosa	2	1120	124
		Bauchi	Darazo	5	827	103
		Sokoto	Tungan Fana	3	1064	103) Provisional recommendation
		Katsina	Dandawa	3	1551	) based on observation plots. 102)
		Kabba	Osara	3	502	) 134 (quality unimportant)
FF BL-3-1-6	Farafara	Niger	Zuru	4	1304	111
		Zaria	Samaru	6	1147	119
		Saradauna	Mubi	4	1133	133
		Adamawa	Hong	4	1310	117
G 59	Shambul	Sardauna	Gwoza	5	767	211
G 26-3-1	Shambul	Bornu	Maiduguri	5	1133	126
SK 5912	Kaura (short)	Zaria	Samaru	4	1236	177 (where Kaura is grown)

Table 2. Sorghum Dwarf Lines Trial 1966. Yields of the best of entries.

Line and number	At 14,500 plants per acre: Mean Yield	At 14,500 plants per acre: As % of control	At 29,000 plants per acre: Mean yield lb.grain/ac	At 29,000 plants per acre: As % of control yield at 14,500 p.p.a	% yield increase due to increase in population
Heg. - FF (25)	1052	106.5	1475	149.3	+ 40.2 %
CKA - SK (21)	800	90.2	1317	133.3	+ 47.9 %
(CKA-SK) SK (32)	756	76.5	1092	110.6	+ 44.4
" (38)	682	69.1	1048	106.1	+ 53.7
" (6)	840	85.0	1038	105.1	+ 23.6
" (51)	793	80.3	1035	104.8	+ 30.6
" (49)	1008	102.1	1032	104.4	+ 2.3
" (28)	796	80.6	921	93.2	+ 15.6
CKA - RC (30)	783	79.3	968	98.3	+ 24.0
WX 60 (control) (mean of 6)	988	100.0	800	80.9	- 19.1

Table 3. 1966 Experimental Sorghum Hybrids Trial. Data relevant to best hybrid.

Trial Entry	Mean yield lb/grain/acre	Grain as % total dry matter	Height (cm) to base of panicle
Hybrid (5069 x 5764)	2662	18.6	124
Male (5764)	1912	14.8	126
Female (5069) ≡ B Line	624	9.8	108
Control (WX 60)	846	11.8	158

Maize Breeding in Northern Nigeria

O. J. Webster

Maize is grown only as a compound crop in most of Nigeria north of the Niger-Benue Rivers. It is generally planted on the most fertile soil near the houses and is harvested when nearly mature and eaten after roasting. Relative to sorghum and millet, a small amount of dry maize is found in the markets.

Yield trials at Zaria over the past few years have demonstrated that maize yields are often double those of local sorghums. No doubt the prime reason why more maize is not grown is because of its higher fertility requirement as compared with sorghum or millet. The latter crops when planted on poor soil will usually head and produce some grain, while under the same conditions maize would fail completely. Perhaps the second reason is that maize is more sensitive to striga than are the other cereals. This possibility has not been investigated but will be studied in 1968. There is a difference in the sensitivity of different sorghum varieties to striga and a maize collection should be screened. Very little cultivated land in northern Nigeria is free from striga. In some areas neither millet nor sorghum can be grown due to this parasite. A third reason may be that maize is more susceptible to root lodging than sorghums, caused by the hurricane-like storms occurring in August and September. One of the major objectives in the maize breeding project is to develop varieties which will withstand these storms.

Since maize is not a major food crop in the north, there is not the same urgency in the development of improved varieties as there is with sorghum and millet. There is every reason to expect that this crop will increase in importance with the development of improved varieties and a better understanding of the management practices which must be followed to obtain economical returns.

The importance of management can be illustrated by the first maize trials to be planted this year on the experiment station at Kano. Maize Composite No. 2 was planted on a 1/4-acre plot which was plowed out of grass in 1965 and grown to a cover crop of cowpeas in 1966. A point of interest was that preplant fertilizer instructions were misinterpreted and one-half of the plot was given an excessively high application of super phosphate at a rate of 7.75 tons per acre, while the other half received the correct application of 2 cwt per acre. The entire plot was given a post emergence application of 2 cwt per acre of sulphate of ammonia. The first leaves of the maize emerging on the area receiving

the high phosphate treatment were "burnt," but the yield was only slightly depressed. The entire plot averaged about 4,500 pounds per acre. In contrast, a small replicated variety trial was planted on a part of the farm which had been in continuous cultivation for a number of years. The site was given a preplant application of 3 tons of organic manure and 2 cwt of super phosphate. Two cwt of sulphate of ammonia per acre was applied after emergence of the crop. The plants were yellow throughout the season and growth was poor. The crop could be considered a failure. If maize is to be grown in the Kano area, the problems of soil management must be solved. It may not be economic to grow this crop when sorghums and millet will give a good response to organic fertilizer plus a relatively small amount of commercial fertilizer.

The Institute for Agricultural Research cooperates with the Federal Department of Agricultural Research by assisting in the planning of the maize research program for Nigeria and growing the uniform Federal Maize Trial at Mokwa and Zaria. The yields from this trial in 1967 ranged between 4,500 and 5,000 pounds per acre at Zaria. The Institute also cooperated with Dr. Craig by growing the West African Trial.

The data from the 1967 trials had not been summarized by the time this report was written. A detailed report will be printed and be available. The 1966 report was distributed to all interested persons. The scope of the 1967 project was a continuation of the work started in 1965. As mentioned above, it is necessary to develop maize varieties with a high degree of resistance to root lodging if maize is to be grown for dry grain in northern Nigeria. Most of the varieties grown to date represented by Mexico-5 and NS-1 attain a plant height of 12 to 14 feet and with ears 5 to 8 feet from the ground. Such tall plants with high ear placement are vulnerable to root lodging. A better plant type is available in introductions from the maize program in Central America, and the improvement program is now largely centered around introductions from Colombia. These varieties not only have a more desirable plant type but are resistant to the maize rust, Puccinia sorghi, found in this part of Nigeria. P. polysora is more prevalent in the south.

Numerous variety hybrids have been produced by intercrossing the Colombian introductions and other exotic and local strains. Information gained from the performance of these hybrids has formed a basis for developing composites. When the seed of a group of varieties is blended and planted in an isolated plot the plants random mate, which broadens the germ plasm base of the new population or composite. After a composite is permitted to random mate for a couple of seasons it is then possible to begin selecting plants with desirable plant characteristics.

This season (1967) selection was based on plants resistant to rust, with medium ear height, and with sturdy stalks. During the dry season, 1967-68, the composites will be intercrossed and yield trials conducted in 1968 will determine what hybrid vigor there may be in these crosses. Reciprocal recurrent selection will then be started to improve the composites which may eventually be released as varieties or used as parents in varietal hybrids.

In order to introduce the brachytic gene (short plants due to reduced internode length) into two of the composites, four brachytic lines from Mississippi and Kitale Dwarf from Kenya were planted in short rows in isolated plots planted to the composites. These dwarf plants were detasseled and the ears were fertilized by pollen from the surrounding plants. Seed harvested from the brachytic rows will be planted in the irrigation site 1967-68 and the plants sibbed pollinated or selfed. Seed from these plants will again be planted in the composite blocks in 1968 and the plants again detasseled. Since there will be a range in height of plants in the detasseled rows it will be possible to select the desired types. After two or three cycles a new composite will be evolved with probable improved stalk strength.

Two high lysine lines from Dr. H. Wiggen, Western State Experiment Station, Ibadan, and one introduced from Michigan were also planted in the same blocks with the brachytics and treated in the same way. By selfing or sibbing plants in the irrigated nursery it may be possible to identify the high lysine kernels, which will again be planted in with the composites in 1968. Since maize is used mostly for human food in Nigeria, a better balance of the amino acids should greatly improve its nutritional value.

Most introductions from the maize project at Kitale, Kenya, are not suited to Zaria but do give good performance at Gembu on the Mambilla Plateau located near the Cameroons south of Yola at an elevation of 5,150 feet. Yields of 30 introductions ranged up to 4,000 pounds in the test plots in 1966. Some of the Kenya introductions also gave good yields at Mokwa in 1967 and will be incorporated into the breeding program at that station. The rains begin at Mokwa in April and continue through October. Under this environment two crops may be grown a season, the second being poorer than the first. Provision must be made, however, to dry the grain from the first crop.

Relatively few fertilizer trials have been conducted in the north with maize. In order to have a better understanding as to how to manage the research plots, a "time of application of nitrogen" study was started in 1965. In 1965 and 1966 the maize variety Mexico-5 was used. The site was given a preplant application of 3 tons of farmyard manure and 200 cwt of super phosphate in 1965 and 1966. The treatments

included (1) check (no nitrogen), (2) 30 pounds of nitrogen applied at thinning (3 weeks after planting), (3) 30 pounds of nitrogen at thinning plus 30 pounds 5 weeks later, and (4) 30 pounds of nitrogen at thinning plus 30 pounds 5 weeks later plus 30 pounds at the time of silking. In both years the largest increase came from the application of the 30 pounds at time of thinning; the second application gave a significant increase, but the 30 pounds applied at tasseling gave little or no response.

The trial planted in 1967 included the variety NS-1, similar in maturity to Mexico-5, and a variety-hybrid (C-10 x Biu Yellow). C-10 is a Colombian introduction (Cub. 325 x USA 342)-4 x Diacol V 254) and Biu Yellow, a yellow dent selection from a composite of U.S. hybrids. The variety-hybrid had not been previously tested and was used because of an ample seed supply. Prior to planting the field received an application of a mixed fertilizer 21-20-0 at a rate of 140 pounds per acre. The yields obtained were as follows:

Yield response of a maize variety (NS-1) and a variety-hybrid (C-10 x Biu Yellow) to nitrogen applied in form of nitro-chalk (22% N) at three dates. Date planted June 1. Date silk--variety August 11, hybrid July 31.

Treatment		Yield lbs/acre
A. Control	Variety	3390
	Hybrid	4683
B. 30 pounds June 15	Variety	3978
	Hybrid	4821
C. 30 pounds June 15 plus 30 pounds July 21	Variety	4871
	Hybrid	5721
D. 30 pounds June 15 plus 30 pounds July 21 plus 30 pounds August 1	Variety	4704
	Hybrid	5982

The hybrid being earlier in maturity was able to give a greater yield response to the initial fertility in the soil than the variety. The hybrid had a yield advantage over the variety of 38, 21, 17 and 27% for treatments A, B, C, and D, respectively. The yield increase

over the control for the variety was 17, 44, and 39% for treatments B, C, and D, while the increase for the hybrid was 3, 22, and 28%.

Some inbreeding is being done, but the major emphasis is to build up good adapted populations with considerable genetic variability which may be released as varieties or used to produce variety-hybrids, or synthetics.

With Frans de Wolff now located at Mokwa and devoting full time to maize breeding, the improvement work on the crop will be accelerated. The country is lacking in testing centers which are essential to making rapid progress. At present, this is best accomplished by varying the dates of planting or fertilizers at one location. This was done at Zaria in 1967 with good results.

Progress in Pearl Millet Improvement in Nigeria

Bhup D. Bhardwaj

The importance of pearl millet (Pennisetum sp.) in northern Nigeria is evident from the fact that it is second only to sorghum in acreage. In the far north millet supersedes sorghum in importance and sometimes is the only grain crop. Pearl millet is highly nutritious, exceeding some other cereals in protein content and amino acid balance. It can produce grain under adverse conditions, such as drought and heavy rain, where other cereals would fail.

Pearl millet in Nigeria falls into three types - "gero," "maiwa," and "dauro."

"Gero" millet is the most widely grown of these types over a large area in the far north. It is early sown and early maturing, taking about 90 days from sowing to harvest. Considerable morphological variability exists between "varieties." Head length varies from a few inches to over six feet; grain color, hairiness of the head (a possibly useful character for resistance to bird damage), plant height, and tillering capacity are all highly variable. One of the least variable characters is season length, there being a difference of only about ten days between the earliest and the latest of the "varieties" tested in this country.

"Maiwa" millet is generally less important than "gero," although it is found throughout the Pennisetum growing areas of northern Nigeria. It is, however, more important in the southwest of Bornu Province, in northern Katsina Province, and in the southwest part of Niger Province. "Maiwa" is freely tillering, hairy and usually red-based during active growth.

"Dauro" differs only from "maiwa" in being a transplanted crop and is glabrous. It is grown only on the Jos Plateau and in southern Zaria.

Cultural practices employed by the local farmers for the three types are different. With "gero" no preliminary cultivation is done, the crop is usually intercropped with guinea corn or cowpea at six feet intervals in furrows three feet apart. Sowing is done as early as possible after the first appreciable rain. "Maiwa" is sown later, frequently when it is too late for "gero" or on land that is too poor to support guinea corn. In some areas it is sown as a sole crop but intercropping is more usual. Sowing normally takes place in July. "Dauro" is a transplanted crop. It is generally sown broadcast in nursery beds near compounds in June or July. Plants are transplanted

when 18 - 24 inches high: one plant per stand at six inches spacing. When "dauro" is sown direct it resembles "maiwa." "Maiwa" and "dauro" can be crossed with "gero" but this does not normally take place in the field because of the different time of flowering. "Gero" is not light sensitive and will flower at any time in the year whereas "maiwa" is light sensitive and being a short-day plant it flowers only late in the year (October and November) when day lengths are short.

A number of local collections of "gero" and "maiwa" have been tested at a number of locations. As a result of these studies, several populations have been identified as having the potential for further improvement. A modified technique of mass selection from the one used in corn is being tried to improve one of the populations of "gero" (ex Bornu).

Inbreeding has been started in the selected local populations of "gero" and "maiwa" and we now have 602 S_2 and 259 S_1 lines of "gero" and "maiwa," respectively. Inbreeding has also been started in the exotic collection and 1,884 lines have been retained from the collections received from the following countries:

	No. of Lines
World collection from the Rockefeller Foundation in India	1,596
Niger Republic	48
U. S. A.	140
Senegal	100

Steps have been taken to augment "maiwa" collections this year. All the inbreds are being screened for resistance to downy mildew (*Sclerospora* sp.), smut (*Tolyposporium penicillariae*), ergot (*Claviceps* sp.), and other agronomic characters, particularly height. None of the lines seem to have resistance to downy mildew, which is the most serious disease in Nigeria, but some lines have a high degree of tolerance. Further inbreeding and screening of the material will be continued since most of the lines are still segregating for agronomic characters and disease resistance.

As soon as a number of reasonably uniform inbreds have been isolated, it is proposed to make diallel crosses between the selected inbreds. By testing these hybrids and parent inbreds with local varieties as checks, it will be possible to determine the relative importance of additive and non-additive genetic variance. This study will also give information on lines best suited for developing hybrids.

Birds cause losses of 50 to 70 percent of the crop in certain parts of northern Nigeria. Millet spikes with bristles seem to repel birds. At present we have 12 lines of "gero" having varying density and length of bristles. Another study in progress is to determine the inbreeding depression in "maiwa."

The average production of pearl millet in Nigeria (1963-64) was 538 pounds of grain per acre. The use of hybrids and better cultural practices could increase this production several fold. Research in India has recently demonstrated that excellent F_1 millet hybrids can be produced by crossing the Tifton cytoplasmic male sterile inbreds (18 and 23) with selected male lines from Indian varieties. Hybrid HB1 has recently been released for general cultivation and yields of 2,000 pounds per acre under rainfed conditions, and over 3,500 pounds per acre under irrigated conditions, have been reported. Attempts to grow these hybrids in Nigeria have met with failure because of their susceptibility to downy mildew.

Tift 23A is highly susceptible to downy mildew in Nigeria, especially when planted during the rains. For this reason it is necessary to develop female parent lines with the more tolerant Nigerian varieties. The local millets grow from 8 to 12 feet in height and a part of the crop is lost from stalk lodging. Lines for hybrids must have dwarf plants which tiller profusely. Desirable lines should be found in segregates from crosses between Tift 23A and local lines. Tift 23 can be grown satisfactorily during the dry season with irrigation, when it is possible to maintain seed of Tift 23A and also to make crosses. F_1 hybrids of Tift 23A x "gero" variety "ex Bornu" were studied for the first time in the 1967 wet season. The plants were extremely vigorous and productive, but were tall and lodged. Some F_1's had a few downy mildew plants; in others nearly all plants were diseased. F_2 progenies are being studied during the dry season. It is proposed to isolate true breeding lines which will be utilized to produce synthetics or multiline varieties for further testing.

The F_1's between Tift 23A x ex Bornu variety were all found to be male fertile showing that this variety does not possess genes for male sterility. This means it is not possible to produce even a tall female parent from Nigerian stocks by simple backcrossing as has been possible in other countries. A completely different approach is therefore being used to overcome this difficulty and will be reported after completion of F_2 studies.

Because of the difficulty in transferring male sterility easily and the complete susceptibility of Tift 23A to downy mildew, the hybrid program is not moving as rapidly as desired. This is offset, however,

by the fact that three generations can be obtained within a year as shown below:

	Planting	Harvesting	Remarks
1.	Early February	End May or early June	Dry season, sowing under irrigation
2.	Early June (immediately after harvest of (1)	End of August or September	Wet season
3.	End August, or early September (immediately after harvest of (2)	November	Part wet, part dry season. The crop grows on residual moisture.

Crosses are also to be made this season (October 1967) between "maiwa" and Tift 23 (both A & B) with a view to evaluating material for sterility genotype and also to assess the possibility of producing the hybrids and male sterile lines in this crop. Segregates from these crosses will range between both long season (due to the day length sensitivity of "maiwa") and short season (day neutral) types. It will only be possible to obtain two generations a year in breeding for types suitable to use as "maiwa," but the day neutral segregates will be of use in the "gero" program and may add to the early production of millet hybrids in Nigeria.

Plant Pathology

S. B. King

Adequate office and laboratory space has been provided for the cereals pathologist by the Botany Section. A few more items have been ordered for the laboratory in addition to those previously ordered by Dr. Futrell.

Considering the circumstances, technical assistance in cereals pathology research has been satisfactory. In addition to the permanent help available, a first year agriculture student from Ahmadu Bello University assisted in laboratory and field work from early July to mid-September. This student gained experience in certain basic laboratory techniques including isolating, culturing, and identifying plant pathogens, as well as identifying and scoring diseases in the field.

Diseases of Sorghum. Several inflorescence and foliage diseases are found on sorghum in Nigeria. Smuts generally cause a greater yield loss for farmers than other diseases; however, foliage diseases and witchweed can also cause considerable damage.

Inflorescence Diseases

Smut

All the smuts commonly reported o sorghum are found in Nigeria and are likely present throughout west Africa. Yield losses from sorghum smuts are believed to approximate 10%.

Covered smut (*Sphacelotheca sorghi*) is generally the most common of the sorghum smuts in Nigeria. This smut persists between crop seasons as seed-borne spores. Seed becomes contaminated by air-disseminated spores when smut sori rupture in the field, and especially during threshing. Under favorable conditions spores germinate and infect very young seedlings. The fungus grows systemically and ultimately smut sori develop in the inflorescence. Observations in the Samaru and Kano areas revealed that all the grains are generally not replaced by smut sori. Partial infection of the head is characteristic of race 5 of covered smut.

Covered smut can be effectively controlled by an inexpensive fungicidal treatment which requires very little extra effort on the part of the farmer. Seed treatment is practiced to a limited extent by Nigerian farmers; however, the great majority of Nigerian and probably west African farmers do not use seed treatment. A few fields

in which as many as 90% of the heads showed infection were observed in the Samaru area during 1967.

Although not as destructive as covered smut, loose smut (Sphacelotheca cruenta) and head smut (Sphacelotheca reiliana) cause a significant reduction in sorghum yields in Nigeria. Like covered smut, loose smut is also seed-borne and can be effectively controlled by seed treatment. Considerable variation was noted in the symptoms caused by loose smut with respect to time of sorus rupture. These ranged from rupture of the sorus membrane prior to emergence from the boot to delayed rupture several days after emergence. Some secondary infection reportedly occurs by floral infection of secondary tillers, but this probably does not significantly reduce yield. Head smut is essentially a soil-borne disease and is not effectively controlled by seed treatment. In addition, spores are known to survive in soil up to seven years, thus limiting the effectiveness of crop rotation as a means of control.

Long smut (Tolyposporium ehrenbergii) is found primarily in the drier areas of Nigeria from Samaru northward. Long smut is not as serious a problem as the other smuts on sorghum. Unlike the other three smuts, long smut is not systemic, but rather is a floral infecting smut.

Several inoculation techniques were tested to determine an effective method for artificially infecting sorghum with loose smut and head smut. Injecting a spore suspension into the growing point of 3 to 4 week-old plants with a syringe and hypodermic needle proved to be an effective means of inoculation and will likely be used in future investigations with these two smuts.

Further work is needed to determine for certain the identity of some of the sorghum smuts in west Africa. E. Harris has reported a smut on sorghum in Nigeria which appears to be caused by crosses between loose and covered smut. In addition to an understanding of the extent of hybridization which occurs between sorghum smuts, it would also be of value to know what races of the smuts exist in west Africa. A knowledge of this would aid breeders in developing new varieties of sorghum. Several samples of smuts have been collected from different parts of northern Nigeria which will be used in further studies.

Ergot

Sorghum ergot (Sphacelia sorghi) was not prevalent in farmers' fields in northern Nigeria this year. However, heavy infection did occur as usual at Samaru on male sterile lines. Drs. Futrell and Webster (1965) demonstrated the high susceptibility of male sterile sorghum to ergot. Floral infection occurs during the period between floral opening and fertilization. Drs. Futrell and Webster (1966)

suggested that guinea grass, Panicum maximum, growing wild in Nigeria is probably the source of primary inoculum for ergot infection.

Ergot could be a major obstacle in the development of hybrid sorghums due to the high susceptibility of male sterile lines to infection. This year ergot was first observed in mid-September and shortly thereafter all male sterile heads upon reaching the right stage of floral development became infected. Next year, plantings of male sterile sorghum will be staggered throughout the wet season to determine what effect date of planting has on the incidence of infection. Under conditions of low humidity during the dry season, ergot infection is not a problem on irrigated sorghum.

Foliar Diseases

Natural infection was used as a source of inoculum for determining reactions of 1,000 lines of the world sorghum collection to downy mildew (Sclerospora sorghi), zonate leaf spot (Gleocercospora sorghi), sooty stripe (Ramulispora sorghi), anthracnose (Colletotrichum graminicola), oval leaf spot (Ramulispora sorghicola), and rough spot (Ascochyta sorghina). Particularly good infections of sooty stripe and zonate leaf spot were observed this year. By September several lines were almost completely defoliated by these two diseases. Symptoms of sooty stripe and zonate leaf spot were not expressed on 1 and 5% of the lines, respectively. Several of those lines showing little or no sooty stripe symptoms were ones previously reported by Drs. Futrell and Webster as being resistant.

Downy mildew, anthracnose, oval leaf spot, and rough spot did not occur in epidemic proportions in the world sorghum collection this year. Each of these diseases caused severe damage in some lines; however, because of low and unevenly distributed inoculum potential, several lines which did not show symptoms were probably merely escapes. It is hoped by collecting data each season on the reaction of the world sorghum collection to various foliar pathogens that some more definite conclusions can be drawn with respect to lines having genes for resistance.

The F_3 progeny of crosses made by Dr. Futrell between Combine Kafir-60 and several downy mildew resistant lines from the world sorghum collection were planted this year. Neither the asexual nor the sexual symptoms of this disease were found in the planting. Due to the lack of a downy mildew epidemic this year, it was not possible to distinguish resistant lines from susceptible escapes. Promising lines should either be artificially inoculated with the pathogen or be exposed to natural epiphytotics before resistance can be assumed.

Sooty stripe, zonate leaf spot, and oval leaf spot were the most commonly encountered leaf diseases in experimental sorghum plantings at Samaru this year. Oval leaf spot was commonly found in farmers' fields and in some cases probably caused reductions in yield. Sooty stripe and zonate leaf spot apparently caused a very limited amount of leaf damage. Although leaf diseases are found in farmers' fields, they do not constitute as important a group of diseases from an economic standpoint as do the smuts. The relatively low incidence of foliar infection in farmers' fields in contrast to the high incidence of infection in experimental sorghum plots at Samaru can likely be attributed to: (1) the fact that locally grown sorghum has been naturally selected for resistance to the disease organisms in northern Nigeria for several years while experimental material has not had the same type of exposure, and (2) the fact that farmers' sorghum is not grown at the high plant densities common in the experimental sorghum plots. Low plant populations do not furnish as good an environment for foliar infection by plant pathogens as do high density populations which retain high humidity and free moisture on the leaf surfaces for longer periods of time.

A disease caused by a species of Cercospora, probably grey leaf spot (C. sorghi), was also observed in experimental sorghum plots and farmers' fields. This disease was first noticed during late August and, although generally not serious, became quite prevalent in some fields as crops matured.

Witchweed

Striga hermonthica was a major problem on sorghum both in experimental plots and in farmers' fields. Infestation was so intense in some fields that plants were killed prior to heading. Striga seeds reportedly remain viable in soils for up to 8 years, thus limiting the effectiveness of crop rotation as a means of control. Resistant varieties are probably the best answer to this problem. The 1,000 entries of the world collection planted in experimental plots at Samaru were scored for their reaction to Striga; however, the field did not have an even distribution of infestation and many non-parasitized entries were probably escapes. In an effort to locate resistance, parts of the world sorghum collection as well as samples of promising breeding material will be planted next year in fields which this year were heavily infested with S. hermonthica.

Diseases of Millet. Inflorescence and foliage diseases are both found on millet in Nigeria. Downy mildew is certainly the most serious disease on millet and probably causes more loss in yield than any other disease on the major cereal crops of west Africa.

Downy Mildew

Downy mildew (Sclerospora graminicola) occurs wherever millet is grown in northern Nigeria and, from the limited information available, is probably found throughout the millet growing areas of west Africa.

S. graminicola becomes systemic in the millet plant, growing with it and affecting it in various ways. Primary infection comes from germinating oospores in the soil which penetrate the roots. Heavy early infection can kill plants in the seedling stage and greatly retard the growth of others, As the fungus grows within the plant, a characteristic white bloom of sporangia and sporangiophores forms on the lower surface of infected leaves. Under suitable conditions wind-borne sporangia germinate releasing zoospores which reportedly can cause secondary infection in young leaf tissues. Secondary as well as primary tillers can become infected to the extent that heads do not emerge from the boot. At heading, the disease often gives rise to "green ear" symptoms consisting of leafy shoots wholly or partially replacing the head. It is these symptoms from which the disease receives its common name "green ear."

Since downy mildew can be manifest in so many ways and affect plant growth and development at all stages, it is difficult to assess losses in yield caused by this disease. However, it is estimated that annual losses generally range from 5 to 15% in Nigeria. Downy mildew incidence during the 1967 growing season was very severe with yield losses estimated at over 50% in some fields.

There is no known resistance to downy mildew in Nigeria. Notes were taken on the reaction of 2,506 different entries of millet to a natural epiphytotic of downy mildew at Kano during the past rainy season. Only 7% of these entries were without downy mildew symptoms. Of the 421 different entries screened at Samaru, approximately 40% did not become infected. In order to determine which, if any, of these entries actually are resistant to downy mildew, each will have to be more critically exposed to the fungus.

In the breeding work at Kano, the F_1 and F_2's of crosses between Tift 23A and "gero" selections showed marked differences in their reaction to a natural epiphytotic of downy mildew. Each plant within the F_2 and future generations is being carefully scored for both foliar and head symptoms on both primary and secondary tillers. Those showing promise for downy mildew resistance are to be exposed to more rigorous inoculation techniques. It is hoped after several generations to have downy mildew resistant plants as well as a better understanding of the etiology of this disease and the genetics of resistance.

In plantings at Kano and Samaru, Tift 23 is highly susceptible to downy mildew. Plants of this line when planted in the field almost always become heavily infected, frequently to the extent that they are killed well in advance of heading. Correspondence between Dr. Futrell and Dr. Burton (pp. 14-15, Third Annual Report of the Major Cereals Project, 1966) indicates that Sclerospora sorghi was suspected as the pathogen attacking Tift 23. Observations made during 1967 do not support this. Several samples of sporangia from Tift 23 were germinated in the laboratory and observed microscopically. All germinating sporangia germinated by forming zoospores, characteristics of S. graminicola, rather than germ tubes, characteristic of S. sorghi. No differences were observed between the downy mildew fungus found on locally grown millets and that found on Tift 23. Experiments are underway to determine whether or not S. sorghi from sorghum will infect Tift 23. Since downy mildew has not been a major problem encountered by millet breeders using Tift 23 in India, it is suspected that perhaps a different race of the fungus exists in Nigeria.

Smut

Smut (Tolyposporium penicillariae) is rather common on millet in northern Nigeria. No known source of resistance is known to this disease. T. penicillariae is reported to be a floral infecting smut, and although generally less than 5% of the florets become infected, few heads escape without at least some infection. High humidity appears to favor the establishment of this disease as evidenced by the high incidence of smutted grains found on bagged heads. At times almost 100% of the grain on bagged heads is replaced by smut sori. This poses a significant problem for the millet breeding program.

In an effort to determine whether or not earlier bagging would reduce the incidence of smut, 100 heads were bagged prior to their emergence from the boot. The incidence of smut which developed on these heads was compared with that found on 100 heads bagged after emergence of stigmas. Both treatments yielded approximately the same degree of infection. Prior to bagging sufficient inoculum must have been present on the flag leaf and sheath of the early bagged material to cause infection.

Some work at Tifton, Georgia, has recently shown that certain systemic fungicides are effective for the control of T. penicillariae in millet. The use of these fungicides as foliar sprays would not be economically practical for west African farmers, but they may have potential as a means of control of smut in the millet breeding plots at Samaru and Kano.

Ergot

Ergot (Claviceps microcephala) is fairly common on millet in northern Nigeria and in some instances causes considerable loss in yield. It is suspected that the fungus survives the dry season in the form of sclerotia. Sclerotia left in the field have been shown to germinate at about the time of millet flowering and release large numbers of wind-borne spores which infect the stigmas of millet florets. The disease starts on a few heads when the crop begins to flower, but builds up rapidly, causing almost complete infection in some late heads. Some tests have shown that ergot sclerotia, if eaten, have a toxic effect on humans and livestock. There are no varieties of millet known to be resistant to ergot.

Other Disease of Millet

Rust (Puccinia penniseti) is found on millet throughout northern Nigeria. Although it is probably not of economic importance on "gero" there are reports of rust occasionally causing severe damage to "maiwa" in Nigeria. A leaf spot caused by a Leptostroma spp. as well as a sheath rot caused by a Fusarium spp. were also observed on millet this year. Other leaf diseases occurred, but they were not satisfactorily identified during the past growing season.

Diseases of Maize. Maize was generally not severely damaged by diseases in the Samaru area. No significant root, stalk, or ear rots were observed. On the basis of host range, pustule development, and teliospore morphology, the rust which occurred on experimental plots at Samaru has been identified as common corn rust (Puccinia sorghi). Several maize lines were scored for resistance to rust. Sweet corn varieties in particular, were highly susceptible.

A virus disease believed to be maize streak was observed again this year on isolated maize plants. The disease was more prevalent on maize planted in early August than that planted in early June. Leaf blight (Helminthosporium turcicum) was also observed.

Soil Management

K. R. Stockinger

The work this year has been inhibited by the travel restriction and the frequent lengthy power outages. The facilities and cooperating personnel are excellent. No formal training programs were undertaken during the past year but during the winter and spring terms in 1968 I am scheduled to teach a course in irrigation management and a course in soil and water management related to irrigation to a group of graduate civil engineers at Ahmadu Bello University

The unsettled conditions in Nigeria during the past year resulted in most of the work being confined to the Samaru area. Two major trips were taken during the past year--one to East Africa in January, 1967 and the other to the irrigation projects around Lake Chad in November, 1967. Short trips were made to Mokwa and Kano.

The trip to East Africa was very interesting because it pointed out the similarities in the problems of East and West Africa. The questions of why the date of planting is so important and what does farmyard manure do to the soil to sustain higher yields than can be obtained with commercial fertilizers are common to both areas. The trip to Lake Chad was made to look at the problems developing under irrigation In an area near Yo in the extreme northeast corner of Nigeria some very slowly permeable clay soils are being irrigated with water which is low in total salts but is entirely made up of bicarbonate salts. Because no water passes through the profile, it has been predicted that these soils will be unproductive in about 10 years. This is probably unduly pessimistic because as the bicarbonate salts accumulate and are subjected to thorough drying at the end of the irrigation season, the calcium bicarbonates would precipitate as carbonates, reducing the effective concentration of the salt by two thirds. Use of ammonium sulfate fertilizer would neutralize the sodium carbonate remaining and should add to the period in which these remain productive. Chiseling and return of crop residues will also help. The permeable soils with good drainage should remain productive for many years with good management practices. Rice does very well in the area but is very sensitive to sodic soils. Wheat, the principal irrigated crop in the area, is much more tolerant. At Azare in a region of sandy soils, extreme variability in an experimental area was noted. Addition of farmyard manure brought the fertility of the poor areas up to that of the better soils while commercial fertilizers were ineffective.

A brief description of the work underway on evapo-transpiration and soil fertility follows.

Evapo-transpiration

Does lack of water limit yields during the rainy season? Should we conserve all of our rains or do we have a surplus disposal problem? How much water should we apply to irrigate a crop? These are just a few of the questions whose answer depends on a knowledge of evapo-transpiration.

Because of the frequent rains during the wet season, determination of evapo-transpiration by soil moisture measurements is inaccurate. This left only the use of meteorological measurements (temperature, rainfall, windspeed, humidity, and total short wave radiation) to estimate the evapo-transpiration. An independent check under African conditions as to the accuracy of the various formulas using the type of data available is necessary.

Much of the past year was devoted to the installation of a weighing hydraulic lysimeter to provide a direct measurement of evapo-transpiration. The lysimeter was made as large as possible (12'x12'x14') so that adequate populations of row crops could be grown. The depth was limited by the presence of a water table at the 4-foot depth at the end of the rainy season.

The basic components of the lysimeter were kept as simple as possible to facilitate construction and maintenance at the end of a long supply line. The inner container was made of 12 gauge sheet metal reinforced with angle iron on the sides and bottom. The outer walls were made of concrete blocks and the floor was a 6-inch thick slab of concrete. The inner container rests on four 6-inch diameter, nylon reinforced butyl rubber irrigation tubes filled with air-free water. The tubes were filled with sufficient water to be about 2½ inches thick when the tank filled with soil was resting on them. The tubes were connected to a manifold which was in turn connected to a manometer in an air conditioned room about 150 feet from the lysimeter site. A combination mercury-water manometer is used so that the 26 lb. per sq. in. pressure could be measured in a room and still maintain its sensitivity. The manifold and connecting tubing were kept at a 4-foot depth to minimize temperature fluctuations. The room is air conditioned so that the manometer is maintained at a constant temperature. A grid of perforated copper pipe wrapped in nylon cloth was laid in the bottom of the inner tank to provide drainage. These tubes are connected to a vacuum pump with a calibrated receiving tank so that excess water can be removed and measured.

The installation was completed in June and functioned very well. Calibration by addition of weights to the tank showed a change of 1.6 mm for each .001 of one inch of water. However, heavy rains set in shortly afterwards and considerable trouble was experienced with water

leaking into the outer pit of the lysimeter. It was also noted that the calibration changed and sensitivity was reduced. Finally, in August an especially heavy series of rains resulted in the water table rising and the outer masonry being pushed in against the sides of the inner tank. It was necessary to excavate and replace the side walls of the outer pit. The new walls were reinforced and buttressed so that they should not move. The tank was jacked up, the mud which had washed in was cleaned out, and the sodium silicate solution, which had been used as a self-sealing liquid in the rubber tubes in case of leaks, was replaced with air-free water. It was found that the sodium silicate was plugging the manifold, causing sluggish responses to changes in weight.

The lysimeter was in operation again in late September and has been working satisfactorily ever since. Its sensitivity has increased to 2.2 mm per .01 inch of water or 8.7 mm per 1 mm of water change in the lysimeter. If the temperature of the room with the manometer is maintained at a constant temperature $\pm 1^{\circ}$ C the daily fluctuations are about 2mm.

The site is to be sprinkler irrigated during the dry season to get some estimate of evapo-transpiration during this period. Although the oasis effect is large, the irrigation projects in Nigeria have relatively small contiguous irrigated acreages separated by dry open areas and would also have oasis effect. A crop of wheat will be grown since wheat is the principal irrigated winter crop in northern Nigeria.

The average daily evapo-transpiration for the period June 15 to August 15 was 0.17 inches per day for the days when good records were obtained. At the end of the rainy season (early October) the evaporation from wet bare soil was 0.22 inches per day showing that the evaporation rate goes up as soon as the rains quit.

A Troxler neutron probe and scaler were received at the start of the rainy season and are being used to check evapo-transpiration measurements and also to study the moisture extraction pattern of the various crops. It is also being used to determine how much soil moisture the different crops and natural vegetation remove from the soil during the dry season.

Soil Fertility

Soil fertility work on sorghums is being adequately handled by the Agronomy Section of the Institute for Agricultural Research. In addition to extensive work throughout northern Nigeria on local sorghums, they are studying the relations of stand density on light and yield of a tall local variety and a short American hybrid at high fertility levels. As soon as a high yielding variety or hybrid is developed for Nigeria, additional work will be needed to determine the economic levels of fertilizer application.

As is mentioned in the section on maize breeding, information on the soil fertility requirement is limited. In 1966 a maize fertility experiment near Samaru showed that maize responds to both nitrogen and phosphorus but low yields made the experiment of doubtful significance.

In 1967 a nitrogen, phosphorus, and variety experiment was set up on the Institute farm with 4 nitrogen levels, 3 phosphorus levels, and 3 varieties. The experiment was planted late, June 17, and experienced considerable stand reduction on plots near the bush due to bush fowl. Plant height observation and visual observation showed a large phosphorus response but little or no effect from nitrogen. The maize in the phosphorus plots was severely stunted with only a few plants forming ears. On the other plots, plants with striped leaves were observed scattered throughout the field. These leaf symptoms looked very similar to zinc deficiency symptoms shown in the literature. Leaf samples were taken from all plots to be analyzed for nitrogen, phosphorus, and zinc.

Seed yields showed a very large phosphorus response varying from 10 to 3,700 pounds per acre. Nitrogen with phosphorus increased yields by 60% while without phosphorus it had no effect. There was an appreciable yield increase at 35 pounds phosphorus as compared to the 17.5 pound rate. The best combination was 35 pounds of P and 80 pounds of N, giving a mean yield of 2,302 pounds per acre.

The response of the three varieties used in the experiment was quite disappointing. The differences between NS-1, Samaru Synthetic, and Bomo Local were not significant and there was no variety x fertilizer interaction. This may have been due to the two week delay in planting reducing the yield potential of the varieties and masking the variety differences. The experiment was designed to measure the interactions but not variety difference, so a 20% yield reduction with Bomo Local is not large enough to be significant.

Considerable evidence has accumulated that minor element deficiencies are an important problem and should be investigated further.

In addition to the striped leaf zinc deficiency symptoms observed in the above experiments, similar symptoms were noted at Kano and in other maize plantings at Samaru. The maize variety trial at Kano had the most severe symptoms and the yields from these plots were very low. Similar symptoms were also observed in sorghum but not nearly as severe or as widespread. At Samaru one spray application of all minor elements one month after planting by Mr. Heathcote, the soil chemist, has produced an 80 percent increase in seed cotton yields. No visual symptoms were noted on the check plots and there was no vegetative response to the minor elements apparent to the eye. The biggest effect was on the first picking, indicating that a soil application or more sprays might have been even more effective. These observations and results indicate that further work should be done to determine which minor elements are deficient and how widespread the problem is.

The problems of how to manage tropical soils under continuous cultivation become more and more important as population pressure increases the amount of land continuously cultivated. Some of the answers as to the effects of continuous cultivation under different fertilizer levels and applications of farmyard manure are available in the long term DNPK (Dung, Nitrogen, Phosphorus, and Potassium) experiments being carried out at Samaru, at Kano in the north, and Yandev in the southern part of northern Nigeria since 1950.

At Samaru and Kano there is little or no response to nitrogen fertilizer while dung gives a very large response. Since the nitrogen source used in this experiment is ammonium sulfate, it was felt that the lack of response to chemical nitrogen may be due to the acidifying effect of this fertilizer. 1 The pH of the nitrogen treated plots is as low as 3.8 in 0.01 M calcium chloride solution while the dung plots range as high as 5.6. It was decided to lime the plots to a uniform pH to eliminate the pH effect of the treatments. Because the soils are so poorly buffered, the buffer curve of the soils from each plot was determined and the amount of lime required to bring the pH of the soil in 0.01 M calcium chloride was calculated. The lime requirement ranged from 100 to 950 pounds per acre. Soils at the same pH required differing amounts of lime due to soil variability and organic matter content. Exchangeable aluminum was also determined and correlated very well with the buffer curve lime requirement. It tended to be less with some plots having only a trace of exchangeable aluminum. Plots which received manure applications had a definitely lower exchangeable aluminum content, showing that the primary effect of manure on pH is by forming organic complexes with aluminum. The phosphorus had a similar but much smaller effect on the aluminum indicating that the aluminum is being precipitated as aluminum phosphate. This would tend to make phosphorus less effective as a fertilizer and may explain why phosphorus does not give a larger yield increase. The results indicate

that these experiments may primarily be measuring the effect of the treatments on the soil pH and exchangeable aluminum rather than their nutritional effects.

The experiment at Samaru was located in a poorly drained area with a very high water table at the end of the rainy season. In 1966 the water table was at or near the soil surface for nearly a month. This effect was general over the plot area but did result in reducing the yield level of the whole area. The combined reducing conditions and low pH might also increase the solubility of manganese to toxic levels. High levels of manganese were noted in the plant material from this experiment. Tile drains were installed in the experimental area. The tile system was designed and staked by K. R. Stockinger and installed by hand labor by the Agronomy Section. Although it was a comparatively dry year in 1967, the tiles flowed for about 24 hours after each of several heavy rains indicating a very rapid drawdown for the system,

Cotton is the test crop used in the experiment and the crop looks much better this year. The nitrogen plots are definitely greener than the comparable no-nitrogen plots. There is considerable more vegetative growth on the check plots this year. The plots have not been picked as yet, so yield results are not available.

At another location at Samaru a liming trial by Mr. Heathcote shows a large increase in yield with cotton. Calcium sulphate was added to some of the treatments. Liming more than doubled the yield of cotton while the use of ammonium sulphate reduced yields even further. Since a neutral source of calcium gave no increase in yield, the effect was probably due to the toxicity of aluminum. Past work on liming had not taken into account the poorly buffered nature of the soils and failed because of the excessive rates used.

The DNPK experiment at Kano should be investigated to determine its need for lime and treated as needed because it also gave no response to nitrogen. Soils at various locations should be checked as to their need for liming and additional trials should be set out, especially with other crops such as sorghum and maize.

Eliminating the adverse effect of pH from the experiments will make it possible to evaluate the nutrient effects of the dung and the fertilizers and to see if it is possible to sustain good yields under continuous cultuvation. The experiments should be evaluated periodically to see that side-effects of the treatments are not masking the objectives of the experiments. Changes in treatment should be made only after careful consideration of the effect the change will have on the objective of the experiment.

Date of Planting

The importance of planting most crops as soon as possible after the beginning of the rainy season has been observed at Samaru, at Mokwa, and at Kitale, Kenya, and many other areas of tropical Africa. At Samaru sweet corn planted the last half of July grows very slowly, remains short and stunted, is yellow, and yields only a few nubbins while earlier plantings produce normal plants. Adequate nitrogen and phosphorus were supplied, so fertility is not a problem. At Kitale, Kenya, a trial with maize showed a larger increase in yield by planting as early as possible than from variety, stand or fertilizers. At Mokwa any delay in date of planting reduces yield markedly. Similar effects are noted with other crops such as local sorghum, cotton, and groundnuts.

It is important to know why date of planting has this effect on plant performance so that agronomic practices can be adjusted to compensate for this effect. Explanations as to why date of planting is so critical are not satisfactory. With a photoperiodic crop such as the local sorghum the changing lengths of day may be the explanation for the importance of date of planting but it does not explain non-photoperiodic crops. Light intensity is reduced from about 500 to 350 langleys per day but this is still at a greater level than growth chambers and winter greenhouses which give a satisfactory growth. Leaching of nitrogen liberated by microbes with the moisture from the first rains has been advanced as the probable cause but nitrogen fertilizer added to the crop does not overcome this effect. Aeration may be a problem with the large amount of rain coming during this period but the effect is observed on coarse-textured, well drained soils as well as fine-textured soils. Later crops may of course be attacked by diseases and insects which have built up after the start of the rains but attacks severe enough to cause such large reductions in growth and yield are not usually reported.

Soil temperatures decline during the rainy season and reach a minimum from mid-July through September. The minimum daily temperature at 4-inch depth is in the range of 70° to 75° F while the maximum ranges from 75° to 85° F during this period. In May at the beginning of the rains the minimum at this depth varies from 80° to 90° F and the maximum from 90° to 110° F. Since the soil temperature of the date of planting decreases as the yield decreases, it was felt that this may be a factor in the effect of date of planting on yield. It was thought that the germination temperature may be the critical factor on subsequent growth, so two trials were attempted. One was carried out in December using maize and sorghum and the other in August with just maize. In the December trial, seed was germinated under controlled conditions at 65°, 75° and 85° F, planted in moist soil, and immediately irrigated. The cold soil prevented the sorghum from

emerging and no effect was observed on maize. Because the soil was kept damp and a cool, very dry wind blew over the plots, the soil temperature never got warmer than about 70° F for several weeks and may account for the lack of response. A smiliar trial in August with maize germinated at 95°F compared to that germinated in the soil gave similar results. Although neither test was entirely satisfactory, it was decided that perhaps a longer period of warmer soil temperature was needed to reach any conclusion on the importance of soil temperature on the growth of maize seedlings and its relationship to date of planting. An attempt will be made to heat the soil in the field to a set temperature using soil heating cables with a temperature control device at the seed level. This could be installed in different dates of planting in the field and its effect on plant growth measured.

Entomology

G. T. York

As pointed out in the Third Annual Report of 1966, two separate and quite distinct types of pest control for cereals are involved in West Africa. One pertains to the protection of valuable experimental plantings, while the other deals with low yielding local varieties that cannot be economically treated with insecticides. In due time there should be a mutual benefit from these studies.

To elaborate somewhat more on this, the use of insecticides on experimental plots may be far in excess of that which would be economically feasible on a commercial crop. This is justifiable from the standpoint of obtaining valuable research data. At the same time new chemicals as well as different formulations, methods of application and proper timing of applications are being evaluated to determine the cheapest and most effective method of control. This in turn should lead to practical control methods as the production of cereals develops to higher levels of efficiency.

On the other hand, since the present local varieties are so low yielding that any expenditure of money for pest control could not be recovered from the meager increase in yield, other methods of control are needed. Possibilities along these lines include such factors as resistant varieties, improved farming practices, and the disposal of crop residues. Resistant varieties hold considerable promise but often require years in development and refinement. Once they are properly defined they can be transferred to improved varieties by the plant breeders. Thus any discoveries or developments along this line could have far reaching effects on the future development of cereals not only in West Africa but throughout the World.

Another point not previously mentioned but of vital concern is the potential of various insect pests under different growing conditions. Some work along this line has been done in anticipation of various planting dates of improved varieties for more efficient production

The major emphasis of the entomological work was on the three major insect groups mentioned in last year's report, namely shoot flies, stem boreres, and the sorghum midge. In addition, work was started on termites, in cooperation with Dr. Stockinger, soil scientist of this project. These different problems are discussed separately.

Termites

K. R. Stockinger and G. T. York

The main purpose of the preliminary work with termites was two-fold, first, to obtain information on the amount of crop residue consumed by termites and second, to obtain information on stem borer survival in stems subjected to termite feeding. Another entomological problem pertained to stem borer survival in stems laid on the ground, which subjected them to higher temperatures than the usual practice of putting the stalks in upright piles.

Three experiments were undertaken. The first was at Kano where six plots 50 x 50 feet were treated with approximately five pounds actual dieldrin per acre on November 4 and six plots were left as checks. This was on land that had been well disked and had a loose, dry surface. There was good soil moisture three to four inches down. On November 23 two stakes of local soft wood were driven into the ground near the center of each plot for determining termite activity. At the same time samples of CO_2 production were tkane as a preliminary check on testing this method for determining termite acticity. It was later decided that this method was not satisfactory for this type of analysis and no further work was done along this line.

On March 13, 1967, the stakes were examined for termite feeding. In all six of the treated plots there was no feeding on the stake, thus showing complete suppression of termite activity under this heavy dosage of dieldrin. In the untreated plots all showed termit activity. No further work was done on this experiment.

The second experiment to be discussed was on 32 plots previously used in fertility trials. A crop of sorghum had been grown and harvested. Clean culture by hand weeding had been practiced, hence only the sorghum stover remained. As is the usual practice in northern Nigeria, the soil was not tilled in any way toward the end of the rainy season and the soil surface became brick-like.

On December 17, 1966, the stalks were collected and weighed, each plot being handled separately. The weights varied from a low of 39 pounds to a high of 142 pounds. The total weight was 2,711 pounds. During the following two days these weighed stalks were spread as uniformly as possible on the particular plots where they were grown.

Cursory examinations from January through April indicated some termite activity. This was evident from the earthen tunnels that were constructed over and around parts of the plants. It was somewhat surprising to find that most of this activity, or more precisely the removal of the plant material which would serve as food, was largely concentrated on the leaves. It would seem that the amount of earth required to enclose these parts would hardly justify the return. Nevertheless, most of the food material removed was the leaves.

On May 12, 1967, the stalks were collected from the gound and re-weighed. These varied from a minimum of 34 pounds to a maximum of 103 pounds, and a total weight of 2,329 pounds. The total loss was 382 pounds, which amounted to 14.1 percent. On the basis of individual plots the reductions varied from zero in one case to 34 percent. There was no apparent pattern regarding reduction of stover on plots of different initial amounts.

The second experiment was somewhat more elaborate and conducted under quite different conditions. This was a randomized plot experiment with four replicates involving two chemicals at two rates of application for varying degrees of termite control, and two rates of stover application. Also the soil surface was cultivated at the end of the rainy season.

The plots were 40 x 42 feet or approximately 0.04 of an acre. This was the maximum size that could be used on the land that was available. This land during the rainy season had been in miscellaneous sorghum and corn plots. At the end of the rainy season it was rotary mowed to break up what stalks were present and then disked.

Insecticide treatments consisted of three and six pounds of actual DDT per acre and one and two pounds of actual dieldrin per acre. These were applied by hand sprayers on December 9, 1966. On the following day all plots were disked once to mix the insecticide into the upper layer of soil. From December 12 through 16 sorghum stalks were hauled from an adjacent field, weighed and placed on the plots. These were applied at rates of 5,000 and 10,000 pounds per acre. Stalks were laid on the ground, and were spread as uniformly as possible.

Wooden stakes of local soft wood one inch by one inch, two feet long were used to mark the plots. On February 22 alternate rows of these stakes were examined for termite activity. This varied from no feeding on 13 of the stakes to almost complete destruction of two of the 42 stakes. At the same time a cursory examination of the stalks on the plots failed to show any feeding.

On March 9 the first feeding on leaves of the stover was noted.

The first examination of all plots for recording termite activity was made on May 9, 1967. This was shortly after the first early rains of the season, but a week or two prior to the normal planting season. The second examination was made on June 5, which was after considerable rainfall which resulted in a heavy growth of native grass and weeds on the plots. The examination consisted of going over the plots and recording the number and size of the termite feeding areas. Since the weighted figures, that is the number of feeding areas times the size, gave no appreciable difference from the numbers alone, only the total feeding areas will be considered. Also, since the examinations of the two dates were fairly comparable, only the totals of the two dates are given in the following table.

Termite feeding on sorghum stover following insecticide treatments of the soil

Plot Treatments	Insecticide Treatments			
	DDT		Dieldrin	
	number of feeding areas	percent of feeding areas	number of feeding areas	percent of feeding areas
Check	128	55	83	84
Light application #1	64	27	10	10
Heavy application #2	43	18	6	6

#1 Light application of DDT was 3 pounds of actual insecticide per acre, and dieldrin 1 pound actual insecticide per acre.

#2 Heavy application of DDT was 6 pounds of actual insecticide per acre, and dieldrin 2 pounds actual insecticide per acre.

From the table it may be noted that there was a considerable difference in the check plots of DDT and dieldrin. This can only be attributed to variations in the termite population since the plots were selected at random and were bordered by both DDT and dieldrin plots. The four replicates showed an even higher amount of variation. The two rates of DDT showed reduced rates of feeding as the dosage increased. Since DDT is not considered particularly good for termite control, this was the condition that was anticipated. Hence for future work where varying degrees of control are desired, the dosages are now quite well established.

Dieldrin on the other hand is a good insecticide for termite control and at both levels reduced the population to a very low figure. And, although no special notation was made at the time of examinations, most of this feeding could have been along the edges of the plots. At any rate, for future work larger plots should be used and only the central portion used for evaluating results.

The amount of feeding done by termites in this experiment was much less than in the other one and it was considered impractical to re-weigh the stalks. A part or all of the reduced feeding could have been due to the loose soil surface.

These preliminary experiments showed quite clearly that termites consume only a small portion of the sorghum stover when it is spread over the ground. Thus most of the crop residue can be incorporated into the soil at the beginning of the rainy season to improve the soil structure.

Unfortunately, the stem borer population in the stalks was so low that no information could be obtained on the effect of exposure to sunlight. Likewise, with this low population there was no information on borers being destroyed by termites; but with most of the termite feeding on the leaves there seems little likelihood of the borers being destroyed in the stems.

Observations following the completion of the experiments brought out two points of interest. In the experiment where the stover was weighed before and after termite activity, after the final weighing the stalks were left in the field in bundles of 10 to 30 pounds. Termite activity in these bundles was quite intense and might well account for a much higher destruction of plant material than when it is spread over the ground. In the other experiment following incorporation of the stalks into the soil, this decomposed plant residue could be found throughout the growing season, indicating very little consumption during this period.

Shoot Flies

The work on shoot flies this season has been a cooperative project invovling Mr. John C. Deeming, Curator of the Insect Collection of the Institute for Agricultural Research, who handled the taxonomic work, and Mr. Richard Langdon, a graduate student who was working with resistant varieties and will use his data for thesis material. My work has been the rearing of shoot flies and field observations on prevalence and damage.

In the 1966 report the work on shoot fly was given under the title "The Shoot Fly *Atherigona varia* ssp. *soccata* Rond." More extensive work this season has shown that several species are involved, thus complicating the studies on resistance and control.

The species found up to the present time are:

Family Muscidae

1. Delia arambourgi Signy n. comb. (Hylemyia)
2. Atherigona varia soccata Rondani
3. Atherigona lineata ugandae van Ender
4. Atherigona sp.? (probably new sp.)

Family Chloropidae

5. Scoliophthalmus micantipennis Duda
6. " trapezoides Buker
7. " sp. (new sp near femoralis Buker)
8. Anatrichus erinaceus
9. Oscinella sp.

The first five are the most abundant.

In addition to the above mentioned species of shoot flies, a small beetle Buphonella metallica Jac. was found causing damage that was not distinguishable from the true shoot fly. The larvae bore into the central shoot of the seedling plant and cause the same damage as shoot flies. The only reference thus far found relates to another species, Buphonella murina Gerst, causing serious damage to maize in Northern Rhodesia (Wilson, K. L., Life history and control of the maize rootworm Buphonella murina Gerst, Bull. Fed. Minist. Agric. Rhod. No. 2169, Salisbury, S. Rhod., 1963). It was stated that the small larvae enter the subterranean part of the stem, but it had never been observed attacking the roots, hence the common name "maize rootworm" was a misnomer.

At Samaru only a few specimens have been recorded so it is not a serious pest at the present time.

In order to obtain additional information on sorghum pests throughout the growing season, plantings of the hybrid variety NK 300 were made on four different dates. These were June 2, July 12, August 5, and October 3. Regular monthly plantings could not be followed due to heavy rains and wet soil.

Seedlings of the June 2 planting emerged on June 5. On June 10 shoot fly injury was first noted. This was only five days after emergence of the seedlings. Plants attacked at this early stage were generally killed. As is usual with plantings this early in the season, the infestation was quite light and plants were not noticeably attacked at a later date.

The second planting was made on July 12. On July 15 a few seedlings were showing above ground and by July 17 all seedlings had emerged. As in the first planting, shoot fly damage was noted five days following the emergence of seedlings. The infestation was much more severe than in the first planting. No attempt was made to determine the per cent of plants infested since the seeding rate had been quite heavy (20 to 30 plants per linear foot of row) to compensate for possible loss of plants due to "bush fowl" digging out seeds and seedlings. Under normal planting rates there would undoubtedly have been virtually 100 percent infestation, since it was not uncommon to find five or ten plants per linear foot infested.

Most sorghum seedlings, if they can develop for 10 days to two weeks before being attacked by shoot fly, will develop tillers. Under light shoot fly infestations these tillers will develop and produce a crop. However, under heavy infestations these tillers are also killed. Production of additional tillers follows but these also are infested and killed. This results in a dwarfed, rosetted plant which does not produce seed. Under heavy infestations this causes a marked reduction of yield or complete crop failure. An example of this rosetting effect can be seen in the photograph showing a normal plant about to head compared to rosetted plants on either side.

The planting of August 5 was also heavily attacked by shoot flies. As in the two previous cases, shoot fly attack was noted five days after seedling emergence. Tillers continued to be infested, resulting in many resetted plants. Due to the initial heavy rate of seeding, followed by hand thinning, plus the fact that a number of the tillers escape infestation, a reasonable crop was produced.

The last planting of October 3 was near the end of the rainy season. Normally a few inches of rainfall would be expected, but this year there was only 0.13 of an inch precipitation in October and nothing in November. Seeds germinated well and seedlings made a good growth with moisture already in the soil. There was no initial infestation by shoot flies as in the previous plantings. However, at the end of two weeks some shoot fly damage was evidenced. The infestation increased causing serious damage with the customary rosetting of plants.

This work has shown quite clearly that in the Samaru area any planting of sorghum after the initial planting season at the beginning of the rainy season is subject to heavy infestation by shoot flies. The damage caused by such an infestation would materially reduce the yield and could even cause a complete crop failure. Solutions to the problem of mid-season planting are the development of highly resistant varieties or chemical methods of control.

Normal sorghum plant in "boot" stage and on either side dwarfed, rosetted plants resulting from continuous attack by shoot flies.

Stem Borers

The most destructive stem borer to sorghum and corn in northern Nigeria is the noctuid Busseola fusca (Fuller). In addition, three species of Sesamia are present but they cause relatively little damage in comparison to Busseola. In millet the only stem borer of importance is Coniesta ignefusalis (Hmps.). This species is reported as attacking sorghum but has not been noted in this host during the past two years. In fact, during the 1967 season it was extremely scarce in millet in the Samaru area.

Indigenous varieties of sorghum are quite thick stemmed and grow 10 to 20 feet high. They are able to withstand several borers in the stem with no apparent detrimental effect on the yield. With the low yield generally obtained by local farmers, any expenditure for borer control would not be economically feasible. However, on short, small stemmed, high yielding varieties, chemical control would appear to be quite logical and economical.

Habits of the young larvae of Busseola facilitate control procedures. Soon after hatching the young larvae migrate to the whorl or "funnel" of the plant where they feed for several weeks. Insecticides applied during this migration period or shortly after can be quite effective. On the other hand, if treatments are delayed until the young larvae bore into the tightly rolled leaves of the whorl the insecticides cannot be effective since they cannot reach the borers. The main problem then becomes a matter of properttiming with the most efficient insecticide, but proper timing cannot be accomplished by casual observations of the plants. By the time plant injury is noted most of the small larvae have penetrated into the tightly rolled leaves of the whorl and cannot be killed by chemicals.

In order to obtain information on moth emergence and numbers, which will in turn be followed by egg laying and subsequent larval degelopment, light traps have been installed in the Samaru area. These are the "black" light traps used in survey work in the United States.

Considerable difficulty has been experienced in operating these traps. When they were operated on a storage battery with inverter the tubes would only last a few to a maximum of 14 nights. A 150 ohm resistor was put in the circuit and the first tube tested operated slightly over 700 hours. However, subsequent tests did not materially increase the life of the tube over that of operating without the resistor. Operation onthe local electric power source of 220 volts with a transformer to reduce to 110 volts was quite satisfactory from the standpoint of tube life. Under continuous operationttubes lasted

four to six months. The main disadvantages were that the power source was unreliable, being off on occasions as much as four days, and also the fact that electricity was not always available in a location where it would be desirable to have a trap.

Two traps were operated on the electric supply (when it was available) throughout most of the year. One was on the experiment farm and the other in the residential area. Collections during the dry season were to obtain information on Sesamia and also to secure miscellaneous material for the insect collection. On June 7 two Busseola were recorded, which were the first for the season. No additional specimens were taken until July 9, but the traps had not been operated for five days prior to this due to power failure. From two to seven Busseola per day were then recorded for the following eight days in the trap on the farm. Numbers from the trap in the residential area were lower but showed the same trend. For six days following this there were no specimens taken. On July 25 Busseola were again taken and continued in relatively small numbers until August 12. For the following two weeks numbers were very low. Activity picked up again on August 27 and, aside from power failures of two to four days duration, it seems quite safe to say that the heaviest flight of the season was between August 29 and September 16. The highest number obtained from the field trap was 24 on September 12. The residential trap had a maximum catch of seven on the same date. Following this major flight, Busseola continued to be taken in numbers from one to five through October 10. For the following ten days only one specimen was taken and it was more or less decided this was the end of moth activity. However, moths were again taken on October 23 and continued in relatively low numbers until November 11. With no further recoveries up to November 21, it is presumed that all Busseola larvae have gone into diapause and there will be no further activity until next season.

The number of specimens taken in the residential trap was always lower than in the field trap. However, with the exception of the late flight of October 23 to November 11, when no specimens were obtained, the flight pattern was the same for the two traps.

In addition to the two traps operated on the electric current, one trap was run on storage batteries from July 2 to September 13. This was on the Nigerian Tobacco Company farm approximately three miles west of the Institute for Agricultural Research. Considerable sorghum was grown there under mechanized farming and it seemed desirable to have information relative to stem borer activity.

Flight activity recorded from this trap was virtually the same as for the other two traps, with the catch slightly higher than that of the trap on the experimental farm.

The flight pattern of the millet borer Coniesta ignefusalis was also quite clearly defined. This again followed the same pattern in all three traps for the first two flights. There was no early flight which in turn resulted in practically borer-free millet early in the season. The first major movement was in late July and early August, followed by a second and larger flight in early September. This second flight was at the same time as the second flight of Busseola. Rather surprisingly, a third period of activity in late September and early October was noted in the residential trap which was not detectable in the experimental farm trap.

The number of Sesamia taken in the traps was very low through the entire growing season, with a slight increase in the experimental farm trap in early November.

The results obtained from the operation of the traps this year showed quite clearly that this type of "black" light is satisfactory for determining flight activity of stem borer moths. The period of initial infestation, as well as subsequent major flights, can be accurately determined and control measures applied at the proper time.

Experimental chemical control measures against stem borers were very limited because it was impossible to get the insecticides.

Five pounds of five percent Azodrin granules were donated by Shell Company of Nigeria, Ltd. This was arranged by Shell International Chemical Company, Limited, of London after it was found impossible to send liquid Azodrin from the United States. Preliminary tests with this material gave a kill of 90 percent. There was no phylotoxicity. Locally available formulations of DDT and carbaryl cause considerable burning of plant tissue.

Another insecticide, five per cent Thiodan granules was received too late for tests this year but will be used next season.

From the date of planting studies this year the early, intermediate and late plantings were all subject to stem borer attack. Only the very late planting of October 3 was free of stem borers. The degree of infestation this year was about the same for the three planting dates. This, however, could conceivably be quite variable from year to year depending on the number of moths present. At any rate, there remains the probability that stem borer control would be essential for any planting date throughout the growing season.

The Sorghum Midge Contarinia sorghicola (Coquillet)

General observations of the sorghum midge were made on the date of planting experiment. Information on abundance was secured by counting the number of midges on 25 heads at approximately 10:30 a.m. each work day.

Midges were first observed on the second planting on September 9. The counts were quite low, less than one midge per head until September 26 when they increased to slightly over two per head. This increase was undoubtedly the result of theemergence of the first generation since only 14 to 21 days are required for the completion of a life cycle. Numbers then increased to slightly over four per head byOctober 8 and remained there for a week. As the second planting was becoming too mature at this date to serve as a favorable host, the counting was shifted to the third planting. Counts then rose to about ten per head and remained at this high peak for another week. For the following two weks counts dropped to six or eight per head. By November 13 the counts had dropped to less than one per head and remained at this low level to November 23.

The first planting of June 2 matured prior to any infestation of sorghum midge. The second planting of July 12 was just flowering when the first midges were observed in the field. Total damage from the original and subsequent infestation was estimated at 50 per cent. The third planting of August 5 received the heaviest infestation with counts of around ten midges per head. Crop loss here was estimated at 80 per cent. This was so severe that it was not considered worthwhile to harvest the crop. The fourth planting of October 3 was very poor due to lack of moisture. Although a few plants started to flower by November 23, it is doubtful if they would be attacked to any extent by the very low population at this late date.

The presence of sorghum plants in a suitable stage for infestation, such as the two plantings of July 13 and August 5, undoubtedly accounted for the large increase in the midge population. Likewise the experimental plantings at the Institute with a wide range in maturity dates created the same serious problem. On the other hand, local farmers' crops, which all mature at the end of the rainy season, suffer very little from midge damage.

From the information obtained this year it seems quite likely that two crops of sorghum could be raised without serious injury from the sorghum midge. The first should be planted early so that it matures before the midge is present. This of course creates the problem of harvest during the rainy season. The second crop should be planted so that it will mature at the end of the rainy season. For the protection

of the second crop against midge there should be no intermediate plantings to serve as host plants. The problem of shoot flies on the second planting would be serious and needs further work to develop proper control procedures.

Miscellaneous

A trip was made to the Katsina area with Mr. G. H. Caswell on August 22-25 to observe and check on the larvae of Janomima mesundulata. This is a lepidoperous larva of the family Lasiocampidae that breeds on native plants and when partly grown migrates to fields of millet and sorghum. It can completely ruin large areas since it migrates at the time when these crops are quite small.

The Native Authority made available insecticides and application equipment for control measures. Farmers report infestations and cooperate in applying insecticides. Results from the procedure were quite satisfactory in 1967. However, additional studies should be made to determine if there are other and more effective ways of controlling this pest.

Storage pests problems are being studied by Mr. G. H. Caswell, Head of the Entomology Section of the Institute for Agricultural Research. He receives periodic samples of cereals and legumes from various markets and determines the amount of damage throughout the year. He reports relatively light damage to millet and sorghum but cowpeas may suffer 75 per cent loss by storage pests. Additional protection against these pests could mean a large saving in food products.

Summary

Termites destroyed only 14 percent of the crop residue left on the land during the dry season, thus leaving 85 per cent that could be incorporated into the soil.

Eight additional species of "shoot flies" were found in the Samaru area in 1967. Damage was relatively light for early plantings but severe thereafter.

Stem borers caused damage on all except very late plantings.

The sorghum midge developed to very damaging populations when a continuation of host material was available, but caused negligible damage to local sorghum that matured over a relatively short period at the end of the rainy season.

Maize Program
Moor Plantation, Ibadan, Nigeria

J. Craig

This program is concerned with maize improvement for the tropical lowland areas of West Africa. Attention is being given to the development of composite populations which may be useful throughout West Africa, the detection and evaluation of types possessing resistance to the major diseases of the area, the establishment of regional uniform tests and training.

Maize Composites

Composite populations are being developed which have a broad genetic base and possess an acceptable level of disease resistance. This material will be available to the maize breeder of West Africa for the development of synthetics or hybrids adapted to their specific conditions.

Two composites have been established and are undergoing selection in the program at Ibadan. Yielding ability and resistance to lodging and diseases receive major attention in the selection program. The opaque-2 gene is being incorporated in both of these composites.

Disease Resistance

Diseases constitute one of the important production hazards of maize. Over 800 strains from the maize collection and breeding materials were screened for resistance to rust and blight.

Leaf rust, caused by Puccinia polysora is one of the major diseases of the lowland tropics and often causes severe losses. Several inbred lines have been developed which possess resistance to the local races of this rust. Identification of the Nigerian races of this rust has been undertaken through use of differentials known to possess resistance to one or more of the previously described races. Tests completed thus far suggest that the races of importance in Nigeria are previously unreported. Resistance to these new races is being introduced into the composites and has been supplied to workers in Kenya, Dahomey and Jamaica.

Southern leaf blight, incited by Cochliobolus heterostrophus, causes losses of leaf tissue and yield reductions. In an extensive search for sources of resistance a strain was found which possess a new type of resistance. The resistant type is characterized by the formation of

chlorotic lesions, much reduced in size, and which permit a very much reduced sporulation. Inheritance studies indicate this type of resistance is simply inherited. Resistance to both leaf blight and rust are being introduced into the breeding composites.

Root lodging is severe in some seasons. A special program was initiated in 1966 to determine the effectivenss of mass selection in increasing root strength. Two cycles of selection for root strength, measured as pounds required to pull have been completed. Root strength has been increased by 34 percent. This same technique may be valuable in the improvement of the breeding populations now under development.

Even in areas of high rainfall, drought can be an important factor because of droughty periods and poor root development. Fifty-two selections were tested for resistance to wilting under conditions of moisture stress. The 5 most resistant lines have been recombined to form a new composite. If the progeny retain resistance to drought-stress recurrent selection studies will be initiated.

Maize Disease Survey

A survey was conducted to determine the severity of maize rust and Southern maize leaf blight in Western Nigeria in the early season of 1967. Maize rust (causal agent Puccinia polysora) and Southern maize leaf blight (causal agent Cochliobolus heterostrophus) are important causes of reduction in maize yields in Nigeria. Studies conducted at Moor Plantation have shown that epiphytotics of rust or blight can reduce yields of Lagos White maize by 44% and 22% respectively (1,2).

Maize fields bordering the highways leading from Ibadan to Oyo, from Ibadan to Akure and from Ibadan to Agege via Illaro were observed for rust and blight in July. Observations were made at intervals of 10 miles along each highway. Fifty maize plants were scored for rust and blight damage at each observation site. The results of the survey are shown in Table 1.

The results shown in Table 1, indicate that damage from rust and blight were relatively low in the Ibadan to Oyo area. Rust was more

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[1] Craig, J. 1966. Effects of maize rust on yields of two maize varieties. Federal Department of Agricultural Research, Nigeria. Memorandum No. 102.

[2] Eijnatten, C. L. M. van. 1962. Yield reduction in maize due to leaf blight caused by Cochliobolus heterostrophus at Ibadan. Federal Department of Agricultural Research, Nigeria. Memorandum No. 36.

damaging than blight in the Ibadan to Akure area. Maize plantings in the Ibadan to Agege area exhibited moderate to severe damage from both maize light and maize rust.

The reduction in maize yields resulting from the observed disease incidence is not known. It appears probable that losses in yield would be appreciably higher in the Ibadan to Akure and Ibadan to Agege areas than in the Ibadan to Oyo area.

Table 1. Incidence of maize rust and Southern maize leaf blight in Western Nigeria, July 1967.

Route	Rust Score*	Blight score*
Ibadan - Oyo[1]	2.5	2.
Ibadan - Akure[2]	3.4	2.9
Ibadan - Agege[3]	3.4	3.4
Mean Score[4]	3.1	2.76

1.- 3 sampling sites. 2 - 12 sampling sites. 3 - 11 sampling sites.
4 - Mean of all sampling sites.

* Scores of 2-3 indicate light to moderate damage; scores of 3-4 indicate moderate to heavy damage.

Uniform Regional Trials

Uniform regional trials were initiated in 1967. Eight countries, Cameroon Republic, Dahomey, Ivory Coast, Liberia, Nigeria, Senegal, Sierre Leone, and Upper Volta participated. The nine items in the test were supplied by Dahomey, Nigeria, Senegal and Upper Volta. Only the results from the test in Nigeria are available for this report and are presented in Tables 2 and 3.

The experimental design was a randomized complete block with 9 treatments and 4 replications. Plot size was two 25 foot rows of each maize entry. The rows were 3 feet apart with stands spaced one foot apart in the row. Maize was planted at the rate of 2 seeds per stand and thinned to one plant per stand two weeks after planting.

Maize was planted April 21; 4-12-12 fertilizer was applied at the rate of 450 pounds per acre 18 days after planting. A second application of fertilizer 400 pounds 16-4-0 per acre, was made 7 weeks after planting. Rainfall during growing season was much lower than usual and the maize plants often exhibited symptoms of moisture stress.

Maize entries were observed for number of days to tasseling, damage from maize rust and Southern maize leaf blight, root lodging, stalk breakage and yield.

Table 2. Yields of 9 maize entries in West African uniform maize trial at Moor Plantation, early season 1967.

Entry	Origin	Yield *
Composite Jaune D'Ina	Dahomey	3448 lbs. A
Massayomba	Upper Volta	3250 lbs. AB
NS 5	Nigeria	3127 lbs. AB
NS 1	Nigeria	3052 lbs. ABC
NS 4	Nigeria	3003 lbs. BC
Addiobla mais blanc	Upper Volta	2681 lbs. CD
Darsalam	Upper Volta	2442 lbs. D
ZM 10	Senegal	1460 lbs. E
Jaune flint de Saria	Upper Volta	1039 lbs. F

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

Table 3. Observation on maturity time, standability and disease resistance of 9 maize entries in West African uniform maize trial Moor Plantation, early season 1967.

Maize Entry	Origin	Anthesis Time[1]	Harvest Time[2]	Stalk Breakage[3]	Root Lodging[4]	Rust[5]	Blight[6]
Composite Jaune D'Ina	Dahomey	48	83	17.5 BC	2.8	3.6	2.4
Massayomba	Upper Volta	48	95	14.5 C	4.8	2.8	2.3
Aldiobla mais Blanc	Upper Volta	48	95	21.7 BC	1.6	3.7	2.2
Darsalam	Upper Volta	45	83	11.2 C	3.5	3.4	2.5
Jaune flint de Saria	Upper Volta	39	77	12.2 C	5.7	4	3
ZM 10	Senegal	47	95	46. A	0.6	3.5	2.5
NS 1	Nigeria	56	116	28. BC	2.9	3.	2.2
NS 4	Nigeria	54	104	20.8 B	0	3.1	2.1
NS 5	Nigeria	53	95	28.6 B	0	3.	1.6

1 Number of days from planting to pollen shed. of 50% of plants

2 Days from planting to harvest

3 Percent of plants showing stalk breakage. Entries having an alphabetical letter in common are <u>not</u> significantly different at the 5% level. Entries <u>not</u> having an alphabetical letter in common <u>are</u> significantly different at the 5% level.

4 Percent of plants showing root lodging; no significant differences among entries.

5 2-3 = light to moderate damage from maize rust, 3-4 = moderate to heavy damage from maize rust.

6 1-2 = light damage from Southern maize leaf blight, 2-3 = moderage damage from Southern maize leaf blight.

Tests of this sort should be helpful in establishing zones of adoption and should lead to an increasing exchange of both seed and research information.

Training

Two graduate students from the University of Ibadan were given three months specialized training in maize pathology research. The Nigerian Federal Department of Agricultural Research has assigned one research officer to this project for training.

Maize Improvement Kitale, Kenya

S.A. Eberhart, F. Ogada, M. N. Harrison, A. Y. Allan,
S. Njuguna, G. Ravagnon, T. Gatheca, B. Gichui, H. Mauuye

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 Agricultural and Forestry Research Organisation.

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. Ravagnon; Asst. Maize Geneticist, C. Ndegwa; Asst. Maize Breeder, C. Nyambare; 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. Gatheca and Asst. Maize Breeder is B. Gichui. The drier areas of 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. The Asst. Maize Breeder is H. Mauuye.

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

Quantitative Genetic studies have suggested that although the inbreeding - hybridization method of maize breeding produces large yield increases initially, long term improvement is not as great as

from recurrent selection. Several methods of recurrent selection have been proposed in order to improve the breeding populations from which superior inbred lines can be extracted for new hybrids. Maize geneticists in the United States, Colombia and Mexico have shown that such recurrent selection procedures are effective in population improvement.

With these recent advances in maize genetics, the development of an efficient breeding system was an important preliminary step in the U. S. AID/ARS cereal improvement program in Africa. A comprehensive breeding system has been developed by the Maize Research Section and published (Eberhart, S.A., M.N.Harrison, and F.Ogada, Der Zuchter 37:129-174. 1967). The three phases of this system are: (1) Formation of two high yielding composite varieties with large amounts of genetic variation from local selections and adapted accessions. (2) An effective program of recurrent selection in each composite for continuous improvement and (3) the production of a commercial variety as the advanced generation of the variety cross (an open-pollinated variety) and/or a variety cross hybrid. The choice of a variety or hybrid depends on facilities available for seed production and distribution. Inbreds can be extracted at any stage for conventional type hybrids, and the recurrent selection will have made a very large initial improvement in the source populations. But it is not logical to do so while the progress per year is greater for recurrent selection than for inbreeding and hybridization.

Because this system has produced greatly improved varieties and hybrids in Kenya, assistance is now being given to breeders in other Eastern and Western African countries by the Maize Geneticist and by the CIMMYT Regional Coordinator to enable them to modify their breeding programs to increase the effectiveness of their work.

Composite Formation - Kitale

A study of the history of maize in East Africa early in the Kenya maize breeding program indicated that only a small proportion of the available germ plasm from the center of origin of maize was being used. The varieties that had been introduced were unadapted varieties from lowland areas. Although the field selection by local farmers and by the experiment stations followed by the more intensive selection by the Maize Research Section had produced reasonably good results (Kitale Synthetics II and III); the desirability of testing introductions from the highland areas of Central America was apparent.

An extensive evaluation program of such introductions was begun following a visit to Latin America by Mr. Harrison in 1959. The accessions were screened in top crosses to Kitale Synthetic II and the variety crosses of three of them (Ecuador 573, Costa Rica 7, and Cometico) were outstanding. Selections from these three introduced varieties were combined to form Kitale Composite C. Three other composites were also formed; Kitale Composite B was formed with the

best selections developed from the local collections, Kitale Composite D included all entries in Composites B and C, and Composite E included all entries in D as well as a very large range of 16 center of origin races which had other desirable agronomic characteristics but which were lower in yields when testcrossed to Kitale II. A method of composite formation was developed by Mr. Harrison in which the entries were kept as separate entry rows, so that mild mass selection could be done each cycle within entries, yet full mixing is not delayed because maize is a cross-pollinating variety.

Even though all Central American accessions were lower yielding than Kitale II, the formation of composites and the mild mass selection during composite formation has produced composite varieties that are all superior in yield to Kitale II. Ecuador 573 was one of the higher yielding Central American varieties but as shown in Table 4 , the yield was only 72% of Kitale II. The composite involving the largest number of varieties, Kitale Composite E, has shown the greatest improvement in yield and is now approaching H611 in yield. Because of the divergence of the material forming this highest yielding composite, genetic variation is expected to be greater so that future progress should also be at a better rate. Previously breeders have been reluctant to make such broadly based composites and have been concentrating more within individual varieties or variety crosses. The demonstration that such composites have a great potential is an important contribution to maize breeding.

Maize Genetics - Kitale

After the superior composite varieties have been formed with adequate genetic variation, recurrent selection must be initiated to obtain further improvement. Although many methods of recurrent selection have been proposed and information has been obtained showing that progress can be made, information comparing the relative efficiencies of these methods is limited. Hence, the primary objective of the maize genetic section was to adapt these methods for maximum efficiency in developing countries and then to compare the relative progress actually obtained from the various methods. Since the Composites were still in the process of formation when this program was begun in 1964, Kitale II, Ecuador 573 and the advanced generation of this variety cross were selected as the breeding populations in which to study these recurrent selection methods. Figure 1 shows the outline of the program and the various recurrent selection procedures under comparison.

Although several more cycles will be required to compare observed progress from the various methods, statistical genetic information is now available so that progress from selection can be predicted to give some preliminary comparisons. This information can also be used to modify recurrent selection procedures to give greater efficiency.

Table 4. Mean yields of Kenya Composite varieties from 10 locations in 1966 and 8 locations in 1967

Variety	Yield (q/ha) 1966	1967	Mean	% of Kitale II
Kitale II	50.9	46.1	48.5	100
Ec. 573	38.7	31.0	34.9	72
Kitale Composite A	51.2	52.1	51.7	107
Kitale Composite B	54.1	59.3	56.7	117
Kitale Composite C	53.5	54.4	54.0	111
Kitale Composite E C_0	--	54.8	--	-
Kitale Composite E C_1	57.5	60.3	58.9	121
Kitale Composite E C_2	--	60.7	--	-
H 611	62.7	67.5	65.1	134

The formulas for predicting gain from selection have been published recently (Sprague, G. F. 1966. Quantitative genetics in plant improvement. Plant Breeding. Ch. 8 pp 315-354. Uni. Press, Ames, Iowa). The generalised formulas is as follows:

$$G = \frac{k\,(x)\ \sigma A^2}{y\sqrt{\frac{\sigma e^2}{rp} + \frac{\sigma ge^2}{p} + \sigma g^2}}$$

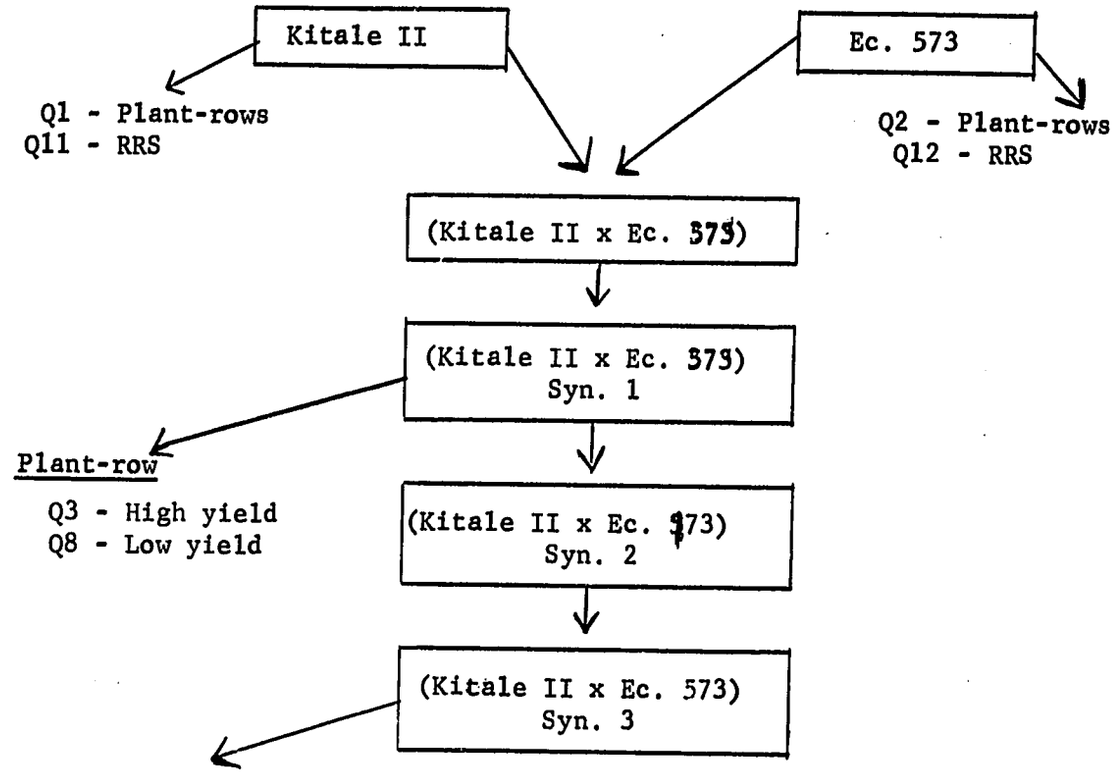
The four main ways of increasing gain from selection are evident from the formula:

1. Increase the additive genetic variance (σA^2) of the population under selection.

2. Increase the selection intensity (k).

3. Use the most efficient method of recurrent selection. The method affects x, y, σg^2, and σge^2, where x is the proportion of additive variance among families, y is the number of years per cycle, σg^2 is the genetic variance among families, and σge^2 is the genotype x environmental variation.

4. Reduce the phenotype variance by increasing the number of plants per plot (n), replications (r) and locations (p).



Q9 - 2% selection intensity
Q10 - 10% selection intensity

Plant-Row

No selection of male plants (49 ear-rows)
Q4 - 9,680 plants per acre
Q5 - 19,360 plants per acre

Selection of male plants and 19,360 plants per acre

Q6 - 49 ear-rows
Q7 - 100 ear-rows

S_1 Testing

Q13 - S_1 Testing and recombination of selected S_1 lines

Test-cross evaluation and recombination of selected S_1 lines

Q14 - High-yield tester
Q15 - Low yield tester
Q16 - Inbred line tester

Full-sib selection

Q18 - Recombination of remnant seed of selected lines

Figure 1. - An outline of the Maize Genetics Program

Table 5. Expected gain from selection expressed as percent of the mean per year*

Variety	Design			Selection method					
	n	r	p	Mass	Plant row	Half-sib	Full-sib	S_1	RRS
3 seasons/2 years	22	2	4	-	5.4	10.8	-	-	-
Kitale II	22	2	4	-	5.4	10.8	-	-	-
Ec.573	22	2	4	-	9.1	18.2	-	-	-
Kitale II x Ec.573	22	2	4	-	-	-	-	-	7
Kitale Comp. A	22	2	4	4.6	5.2	10.5	7.5	11.8	-
" "	15	2	4	4.6	-	10.0	7.4	11.6	-
" "	15	1	8	4.6	-	10.2	7.6	12.0	-
" "	30	1	8	4.6	-	11.0	7.9	12.3	-
" " (5%)	15	1	8	4.6	-	11.4	8.9	14.1	-
2 seasons/year									
Kitale Comp. A non similar seasons	15	1	8	4.6	-	10.2	15.2	12.0	
similar seasons	15	1	8	9.3	-	12.8	15.2	16.0	

* Selection intensity for mass selection is 2% and 10% for all other methods except as indicated otherwise.

The comparison of expected gain from selection in Table 4 illustrates these principles. With 3 seasons in 2 years, half-sib selection is more effective than full-sib selection but with 2 non-similar seasons a year full-sib is considerably more effective than half-sib selection. S_1 testing appears very promising with 3 seasons in 2 years as we have at Kitale. This method also permits a higher selection intensity for agronomic traits during the selfing phase of the cycle. Increasing the selection intensity from 10% to 5% gives greater expected gain but this must be balanced against the increased costs of the larger number of entries required to prevent loss of genetic variation due to finite population size. The use of high plant populations in yield trials also appears to increase the expected gain from selection. The extra gain from selection resulting from increased numbers of replications and locations (r x p) is shown in principle in figure 2. The increased gain when r x p exceeds 8 is probably not worth the extra cost for Kitale Composite A. Two replications at 4 locations give nearly as much gain as 1 replication at 8 locations and the costs are much less.

Observed progress is compared with predicted progress in table 6 and figure 3. Results from 8 locations are available in the 1967 and 10 locations in 1966. Observed progress in the recently introduced variety, Ec. 573, has been greater than predicted, whereas progress has been somewhat less than predicted in Kitale II and Kitale Composite A. Improvement by reciprocal recurrent selection (RRS) is similar to predicted improvement. But the improved combining ability of Ec. 573 (12) C_1 is not shown in the hybrid (F x G) x Ec. 573 (12) C_1.

Maize Breeding - Kitale

The development of Kitale Synthetics II and Kitale III from the local Kenya Flat White varieties and the production of the conventional three way and double cross hybrids 632 and 622 had made available improved varieties for use by the commercial farmers early in the breeding program. The good crossing value of Kenya varieties and Central American varieties was utilized immediately by the production of the variety cross hybrid 611. Further improvement was realized from the cross (F x G) x Ec. 573 - H 613 B. The performance of these varieties is shown in Table 7. It has been very difficult in recent years to find local farmers strains to use in the comparison of progress. The 7% superiority of Kitale II over local strains shown in early trials has been used in this table.

With the rapid progress expected from the Comprehensive Breeding System further work by traditional inbreeding and hybridization methods cannot be justified in Kenya. It takes 8 to 10 years to develop inbred lines, make the possible double cross combinations and evaluate these new hybrids. The improvement over the variety cross from which these

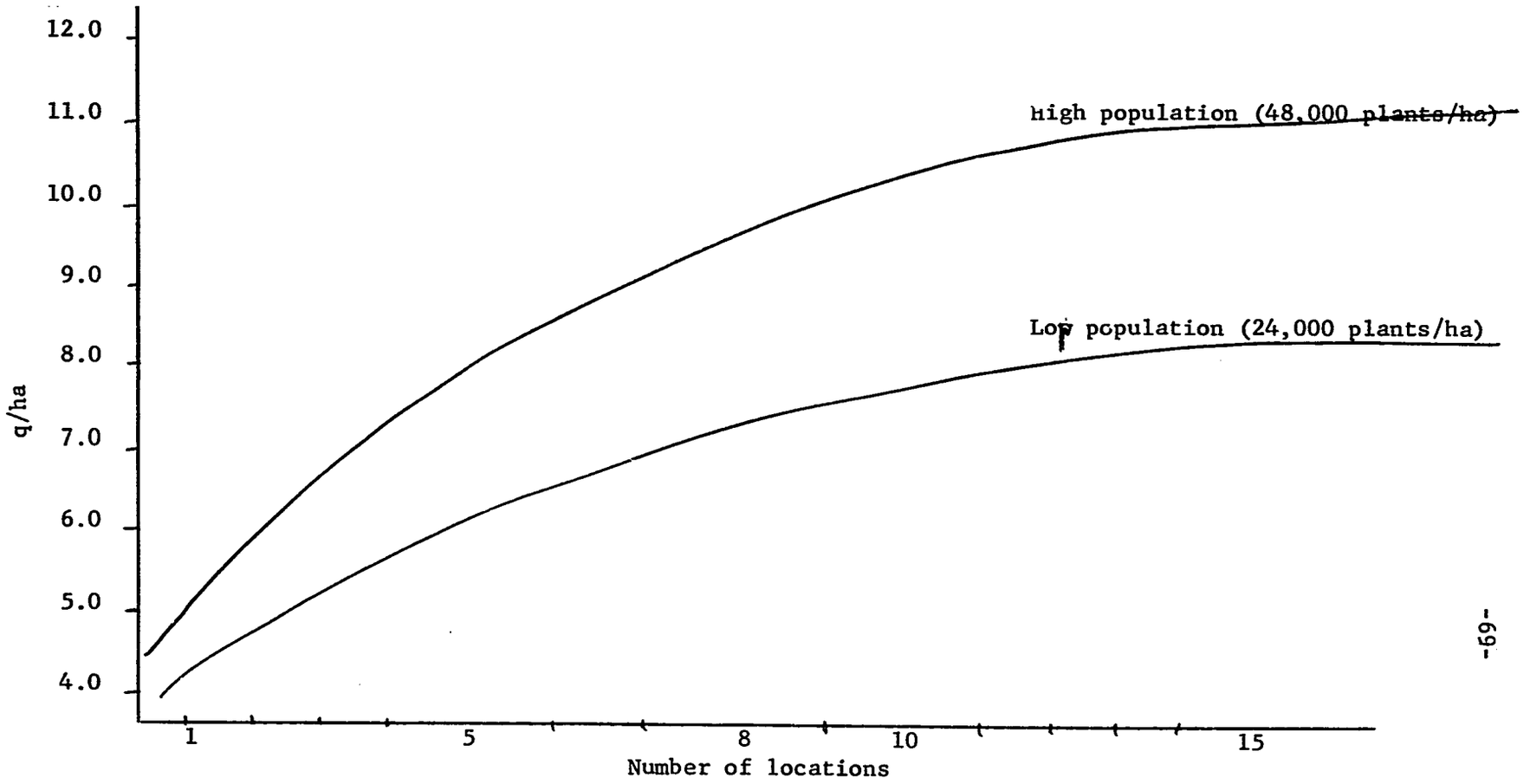


Figure 2. Expected gain from half-sib family selection in Kitale Composite A with varying numbers of locations.

Table 6. Observed and predicted yields for 3 varieties and for improved selections grown at 10 locations in 1966 and 8 locations in 1967.

Variety	Yield (q/ha)			% Improvement	
	1966	1967	Mean	Observed	Predicted
Kitale II C_0	50.9	46.1	48.5		
C_2 (plant-row)	53.7	50.6	52.2	8	11
Ec.573 C_0	38.7	31.0	34.9		
C_2 (plant-row)	47.5	46.2	46.8	34	18
Kitale Comp. A C_0	51.2	52.1	51.7		
C_2 (plant-row)	53.2	61.9	57.6	11	11
C_2 (mass)	--	55.0	--	6*	9
C_2 (low-yield)	48.0	47.8	47.9	7	
Kitale II x Ec. 573	62.7	67.5	65.1		
Kitale II C_1 x Ec.573 C_1 (RRS)	--	73.4	--	9*	7
(F x G) x Ec. 573 C_0	--	76.4	--		
(F x G) x Ec. 573 C_1	--	76.4	--		
(RRS)	--	75.4	--	-1*	-

* Computed with 1967 data only.

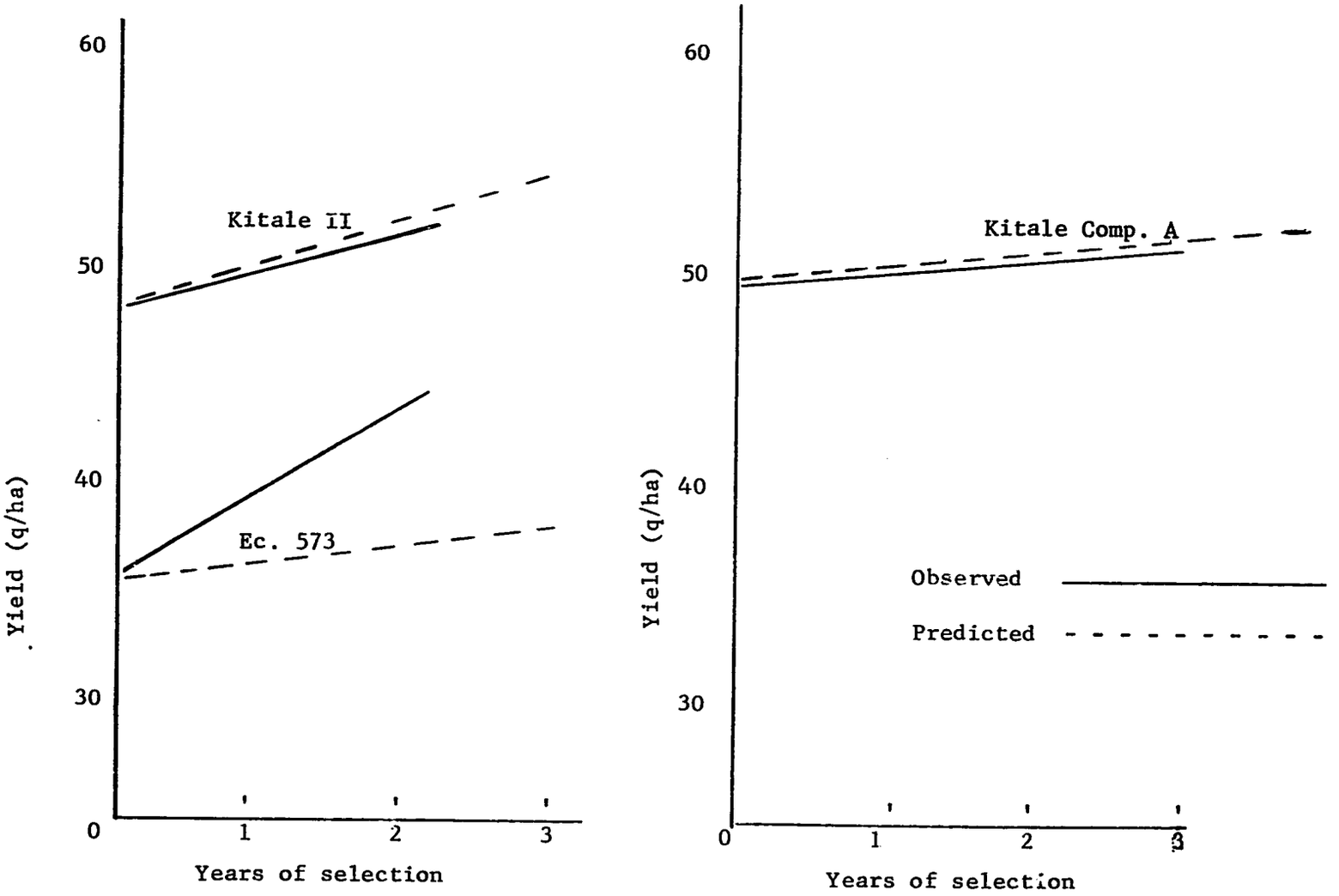


Figure 3. Observed and predicted gain from plant-row selection.

inbred lines were extracted cannot be expected to be greater than 20 to 30%. During this time 4 to 5 cycles of recurrent selection will have been completed and the new variety cross hybrid should outyield the original variety cross by 50 to 80%. Hence, the improved variety cross will outyield any double crosses that could have been produced in the same length of time.

All facilities will now be devoted to making maximum progress with the Comprehensive Breeding System. The information obtained by the Maize Genetics section is being utilized to select the most suitable recurrent selection method and to increase the efficiency of the method selected. From information currently available, S_1 testing has been selected as a method to be used for the conditions at Kitale. The number of entries tested each cycle would be kept large (847 or 968) so that 5% selection can be used. This will permit 42 to 48 selected lines to be recombined c each cycle to prevent rapid loss of genetic variation because of finite population size. The field design to be used will be 11 x 11 simple lattices at 4 locations. The entries will be randomly assigned to these lattices and 6 entries will be selected within each of the 7 or 8 lattices. Since the amount of seed available from selfed ears is limited, small plots of 22 plants will be used so that 2 replications can be grown at 4 locations. Very high plant populations will be used in the yield trials (58,000 - 62,000/ha). Cultural trials by the Maize Agronomist show that higher yields can be obtained with higher plant populations by the commercial farmer. Also preliminary studies show that progress from selection will be greater at high populations because of the greater genetic variation among entries. This is probably because some stalks have no ear at high populations and selection under this form of stress may well tend towards populations performing well at high yield level but also able to withstand stress, including possibly stress from some other factors.

One cycle involving both half-sib and S_1 testing has been completed in Kitale Composite C and the second cycle of S_1 testing has been initiated. A small amount of Ec. 573^1 (25%) was added in an attempt to increase the genetic variance and S_1 testing will begin in this composite in 1968. Because of the unexpectedly good performance of Kitale Composite E, this population will be split into two parts. S_1 testing will be initiated in one portion, but mild mass selection will be continued in the other in order to maintain a germ-plasm pool for future use if genetic variance is lost because of the intense selection with S_1 testing. A new germ-plasm pool is also being formed to serve as a "back-up" population for Composite B. This new composite will include new Central American varieties, Corn-belt varieties, Jimma selections from Ethiopia, Embu I and Embu II as well as Kitale Composite B.

Table 7. Yields q/ha of improved varieties released as commercial varieties at 27 locations in 1966 and locations in 1967.

Variety	1966	1967	Mean	% of Local
H.632	61.2	68.4	64.8	140
H.622	58.1	68.9	63.5	137
H.611 B	61.9	69.7	65.8	142
H.613 B	67.0	71.1	69.0	149
Kitale II	46.2	53.0	49.6	107
Local Farmers	--	--	--	100*
H. 511	--	54.7	--	111
Muratha	--	39.4	--	80

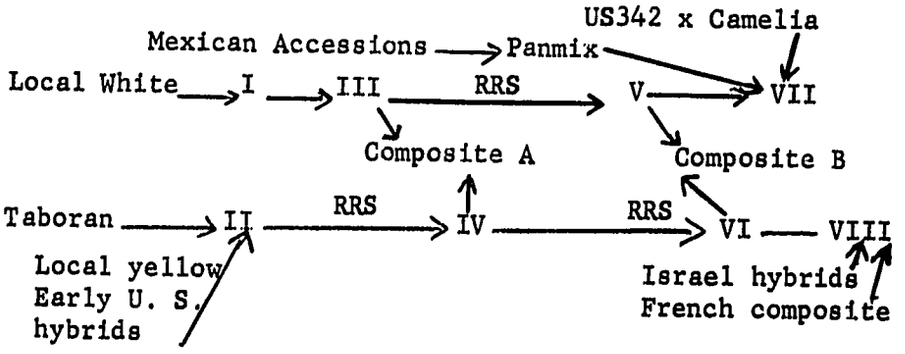
* Yield of local farmers' maize was estimated from previous trials.

High priority is also being given to the development of hybrids with higher quality protein. The opaque-2 gene is being incorporated into all composite varieties in order to increase the percent of lysine and tryptophane in the subsequent hybrids. The irrigation nursery is being used to obtain two generations per year in this back-crossing program. The genetic factor producing a dwarf maize (brachytic-2) and cytoplasmic male sterility are also being incorporated into the composite varieties. The use of combine harvesters is increasing rapidly in the large scale farming areas and the tall variety cross hybrids are not as well suited for mechanical harvesting as shorter varieties would be. Cytoplasmic sterility can be used to simplify the task of producing high quality hybrid seed by eliminating the possibility of pollen shedding in the female rows.

Maize Breeding - Katumani

The Katumani area has a mean annual rainfall of approximately 550 mms. (22"). Since there are two seasons and two crops a year, the average rainfall per crop is only 275 mm. and it is very variable and erratic. During the rain season the moisture supply is usually enough but a rainfall period of only 60 to 65 days can be relied on and plants have to come to harvest on the moisture remain-in the soil. Early maturity, combined with yield, is the main object of this station, so that a maize plant can complete all essential stages of development before the moisture supply comes to an end. The work of the station is most important for an area that in a poor year always faces hunger before the rest of the country.

The essential features of the Comprehensive Breeding System have been in use in Katumani for several years and the program is now being modified as knowledge of improved techniques is developed at Kitale. The flow diagram given below shows the material used in this program.



The local white variety from Kangundo, Machakos, was too late for the average season at Katumani (Table 8 and Fig. 4). Katumani I and III were produced by selection in this material for earliness but there was little change in yield in normal seasons. Taboran is from the Mexican Salvadorian race obtained through Tanzania. Reciprocal recurrent selection (RRS) at Katumani was extremely effective in increasing yields from Katumani III to Katumani V and from Katumani II to Katumani VI. Since the original introductions were limited, additional accessions have been obtained. Preliminary results indicate that Katumani VII and Katumani VIII will give as high yields as current Katumani varieties, but the genetic variation should be increased because of genetic divergence of the new material. Hence, subsequent progress should be relatively greater.

Since it has not been feasible to produce the Katumani variety cross hybrid as yet, the commercial release has been the advanced generation of the variety cross. Katumani Composite A was obtained from Katumani III x IV. Seed was produced by the Katumani Research Station and the Kenya Seed Company and releasted to farmers in 1965. Katumani Composite B is the advanced generation of Katumani V x Katumani VII and was released in 1967. Although only a limited amount of the improved Katumani varieties have been sold, the spread to neighbouring farms has been fairly rapid. The rainfall during two of the past four seasons has been so limited that many fields of the local variety were a complete failure and Katumani maize from the farmers that had early-planted was the main source for future seed (Figure 4). With Katumani I and II the farmers were able to obtain

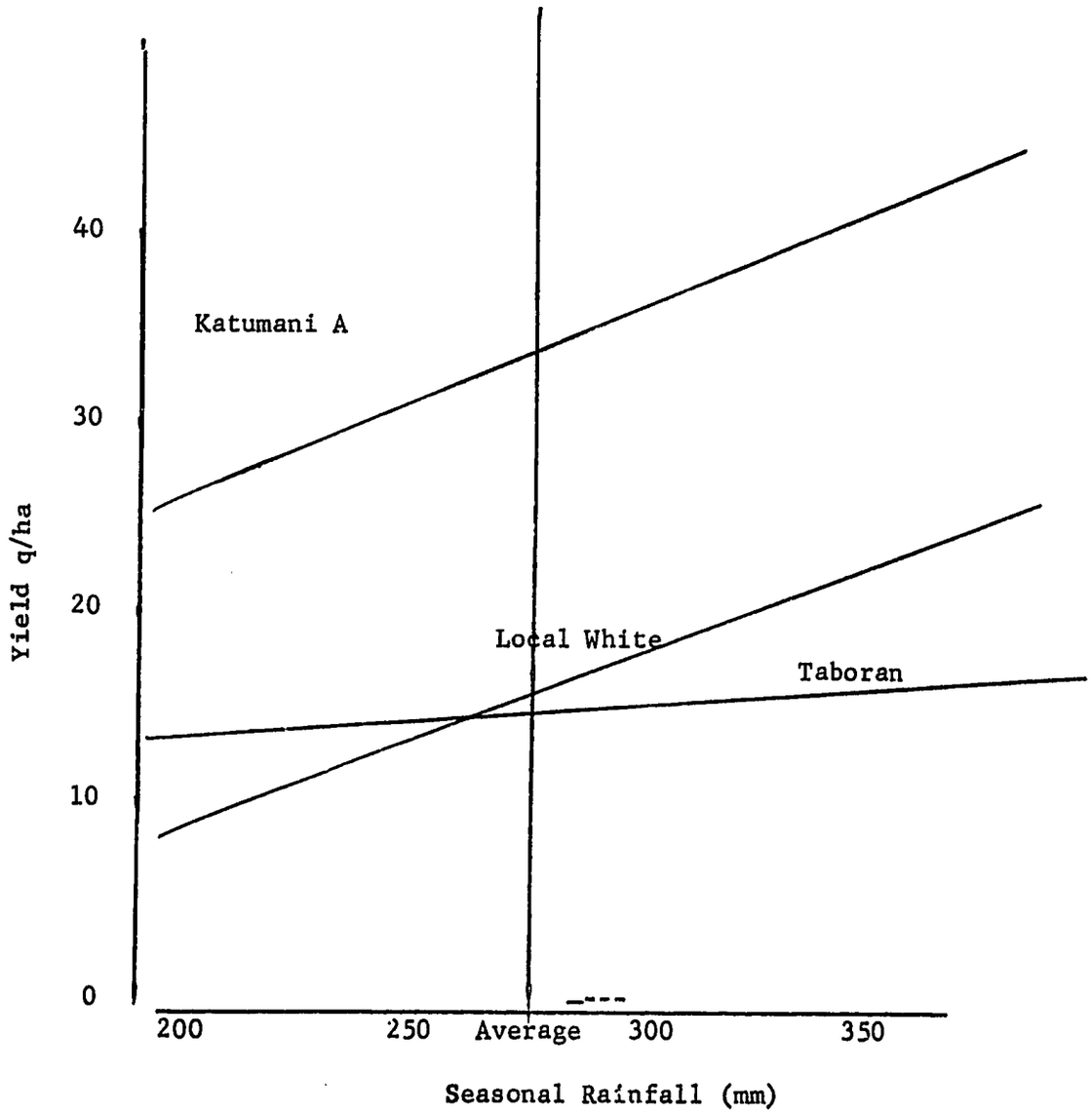


Figure 4. Response of Katumani varieties to rainfall

Table 8. Performance of improved varieties at 6 locations in the Katumani area in 1966 and 1967.

Variety	Yield (q/ha) 1966	Yield (q/ha) 1967	Days to Tassel
Katumani V x VI	----	45.7	63
Katumani Comp. B	----	39.7	62
Katumani Comp. A	27.8	40.0	63
Katumani V	29.6	37.1	63
Katumani VI	----	35.0	62
Katumani IV	30.7	----	62
Local White	19.5	42.9	76

some maize in the years of low rainfall when the local variety was usually a complete failure. But in years with a long season, yields were less with the local maize. Now with the improvement in yields from recurrent selection, the farmer will get higher yields from Katumani Composites except for very exceptional years as occurred in 1967 (Table 8). The Katumani area has been traditionally a famine area but research has now produced the improved varieties and determined the required cultural practices for good yields. The Katumani Research Station and the Kenya Seed Company have made seed available. The remaining step in maize improvement for that area, a vigourous extension programe to convince the farmers of the advantages of accepting the new varieties and methods of maize production, is now gaining momentum. When this step is completed successfully famine should be eliminated in this area except for rare occasions.

Maize Breeding - Embu

Many areas of Eastern Africa require a medium maturity variety. The development of a medium maturity hybrid could be speeded up considerably if use could be made of improved late Kitale hybrids and the improved Katumani varieties. Consequently crosses between these types of material were made in 1964 by the Maize Geneticist at Kitale. Two medium maturity varieties were developed from these crosses; Embu 11 from H.621 x Katumani IV and Embu 12 from Cometico I x Katumani III. The variety cross hybrid from these two varieties, H.511, has proved to be approximately 24% superior to the local variety Muratha (Table 9). With a long season, H.632 continues to outyield H.511 but the subsequent crop is delayed. In an average

or shorter than average season H.632 will not mature properly and a crop failure may result. The October planting in 1966 was such a season. Hybrid 511 has been released for commercial use in the October rains, 1967, for the Meru district near Embu. Seed sufficient to plant 750 acres has been sold. One of the big advantages of variety cross hybrids is the speed with which they can be developed and put into commercial production. This hybrid is now in commercial production only three years from the time the first crosses were made.

With H.511 serving as a "stop-gap" hybrid, the main efforts at Embu have been devoted to establishing the breeding program utilizing the Comprehensive Breeding System. Many new accessions have been obtained and were top-crossed to Muratha and grown in the East Africa Co-operative Trial in 1966 (See page 95). From this trial and other Embu trials, 28 entries were selected to form the new Embu composites. Previous experience at Kitale and Katumani indicate that greater progress in maize improvement can be made by recurrent selection following composite formation than by extending preliminary evaluation trials. Hence, these varieties were arbitrarily divided into 2 groups in an attempt to maintain as much diversity as possible between the 2 composites:

Embu I	Embu II
1. Muratha	1. Eto
2. P. Rico GPO 1Y2	2. Amar.Syn. X Stiff Stalk Syn.
3. P. Rico GPO 6	3. Ver.168 x (Jarvis x Indian chief)
4. Cuba 40 - Hawaii 5	4. Ver. 212 x (Jarvis x Indian chief)
5. Antigua GPO 2	5. Embu 12
6. H.632	6. Cometico II x Katumani V
7. Embu 11	7. V.520C x Var.Amarillo
8. (F x G) x Katumani VI	8. Comp. T.C.S.
9. Kitale Comp. B x Katumani VI	9. Diacol 353
10. USA 342 x Camelia	10. Narion 330 x Peru 330
11. USA 342 x Guadaloupe M	11. Late Katumani Panmix
12. F.F. de Peru x Ver.151	12. (Jarvis x Indian Chief)F_4C_3
13. Iowatigua	13. Kitale Composite E
14. Usatigua	

Since adequate isolation was not available for the March planting at Embu, the first cycle of composite formation for Embu II was done at Kitale. Two cycles per year of composite formation will be done henceforth at Embu using Harrison's method of keeping entries separate while forming the composite. The mild mass selection (25%) within entries eliminates the most undesirable material and crosses within a variety so

that recombination is increased and some improvement is obtained. During the 3rd cycle, selection for white kernel types will be initiated as well as selection for green silks in Embu I and red silks in Embu II to serve as a marker gene in seed production fields. After 4 or 5 cycles of recombination, full-sib selection will be initiated in part of each population while mild mass selection is continued in the remainder to preserve a wide-base germplasm pool.

The Opaque-2 version of Eto have been obtained from Colombia as a source of high lysine maize for incorporation into Embu I and II. This should reduce the number of backcrosses required and hence speed up the program considerably.

Table 9. Performance of improved varieties at 5 locations in 1966 and 5 locations in 1967 in the Embu area.

Variety	Yield q/ha		% of		Days to
	1966	1967	Average	Muratha	Tassel
H.632	62.3	61.2	61.8	151	88
H.511	50.2	50.7	50.4	124	75
Eto x Muratha	48.2	49.1	48.6	119	79
Muratha	40.8	40.8	40.8	100	76
Local farmers	--	41.7	--	-	76

Maize Agronomy - Kitale

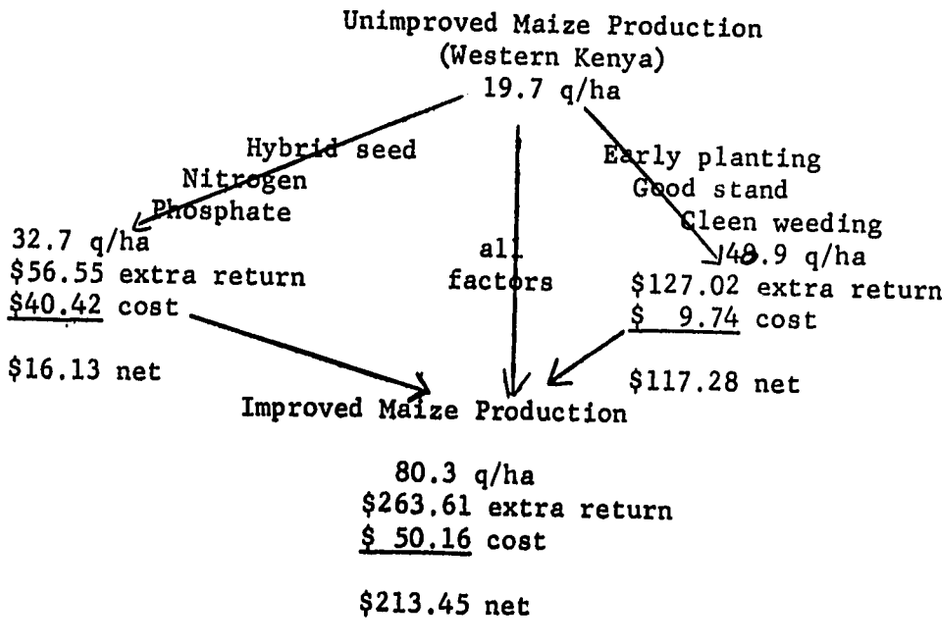
Yields of the improved hybrids can be increased by far greater amounts if agronomic factors limiting yields can be identified and corrected. A trial to study six of the major factors and their interaction (a 2^6 factorial) was laid down at 6 locations in Western Kenya. The low level of each factor represented the unimproved cultural practices used previously by local farmers whereas the high level represented the recommended practices. The treatments and results are shown in Table 10.

Clearly, the time of planting is one of the most important factors and the decline in yield due to delays in planting averaged 68 kg/ha for each day's delay after the rains began. The most important factor was improved seed which gave greatly increased yields averaged over both good and bad husbandry conditions. These factors, which cost the least, are the ones that give the greatest yield increases.

Table 10. Factors affecting yields at six locations in Western Kenya in 1966 with economic implication

Factor	Level	Yield	Difference	Increased return	Cost
Planting time	Early Late	52.8 34.2	18.6	$ 80.91	Nil
Plant population	36,000/ha 18,000/ha	49.1 37.91	11.2	$ 48.72	$ 2.78
Variety	H.613 B Local	52.9 34.1	18.8	$ 81.78	$ 4.17
Weeding	Clean Once-late	48.4 38.6	9.8	$ 42.63	$ 6.96
Phosphate (P_2O_5)	0 56 kg/ha	44.6 42.4	2.2	$ 9.57	$11.65
Nitrogen (N)	0 79 kg/ha	45.0 42.0	3.0	$ 13.05	$24.60

The following diagram illustrates 3 pathways to increased yields with Figures from these factorial trials.



The fact that maize production can be greatly increased in Kenya by the simple cultural practices of early planting, clean weeding, and recommended plant populations, has been recognized for some time, although experimental evidence to support this had not been obtained until now, nor data on the magnitude of the increase. Even though the cost is small and the return is great, there was essentially no progress in getting these practices adopted until hybrid maize was introduced as a "new" crop. Only the better farmers willing to carry out all recommended cultural practices were advised to grow the new hybrid maize. The demonstration plots where the methods and results were presented to neighbors by these better farmers gave such outstanding yields, with such high increases in returns over costs, that the acreage of hybrid maize spread rapidly (Table 11) and much of it is grown with recommended agronomic practices.

The mistake is often made by personnel newly arrived in developing countries that the only requirements for increased yields are hybrid varieties and fertilizers. The above illustrates the futility of this approach. Only when the basic husbandry practices are improved does it pay to use expensive fertilizer.

Table 11. Hectares of long season hybrid maize varieties grown in Kenya

Year	Large scale farms hectares	Small scale farms hectares	Total Hectares	Total acres
1963	156	4	160	400
1964	11,300	700	12,000	30,000
1965	21,900	8,000	29,000	74,800
1966	25,200*	15,100*	40,300*	100,000
1967	52,100	53,900	106,000	265,000

* Sufficient seed was not available in 1966 because of a drought in 1965.

Trials have been underway in Western Kenya for 4 years to determine the optimum plant populations, and economic levels of nitrogen and phosphorous under improved husbandry practices, and similar trials were started in Central Kenya in 1966. The results are being summarised but are not ready for presentation. There is a large interaction of fertilizer with plant population so that the net return for fertilizer is much greater with higher plant populations and the new hybrid varieties. The recommended populations have been increased from 31,000 plants/ha in 1963 to 42,000-48,000 plants/ha in 1967.

The district cultural trial in Kitale in 1966 illustrates the type of information that is being obtained (Figure 5). With maize at

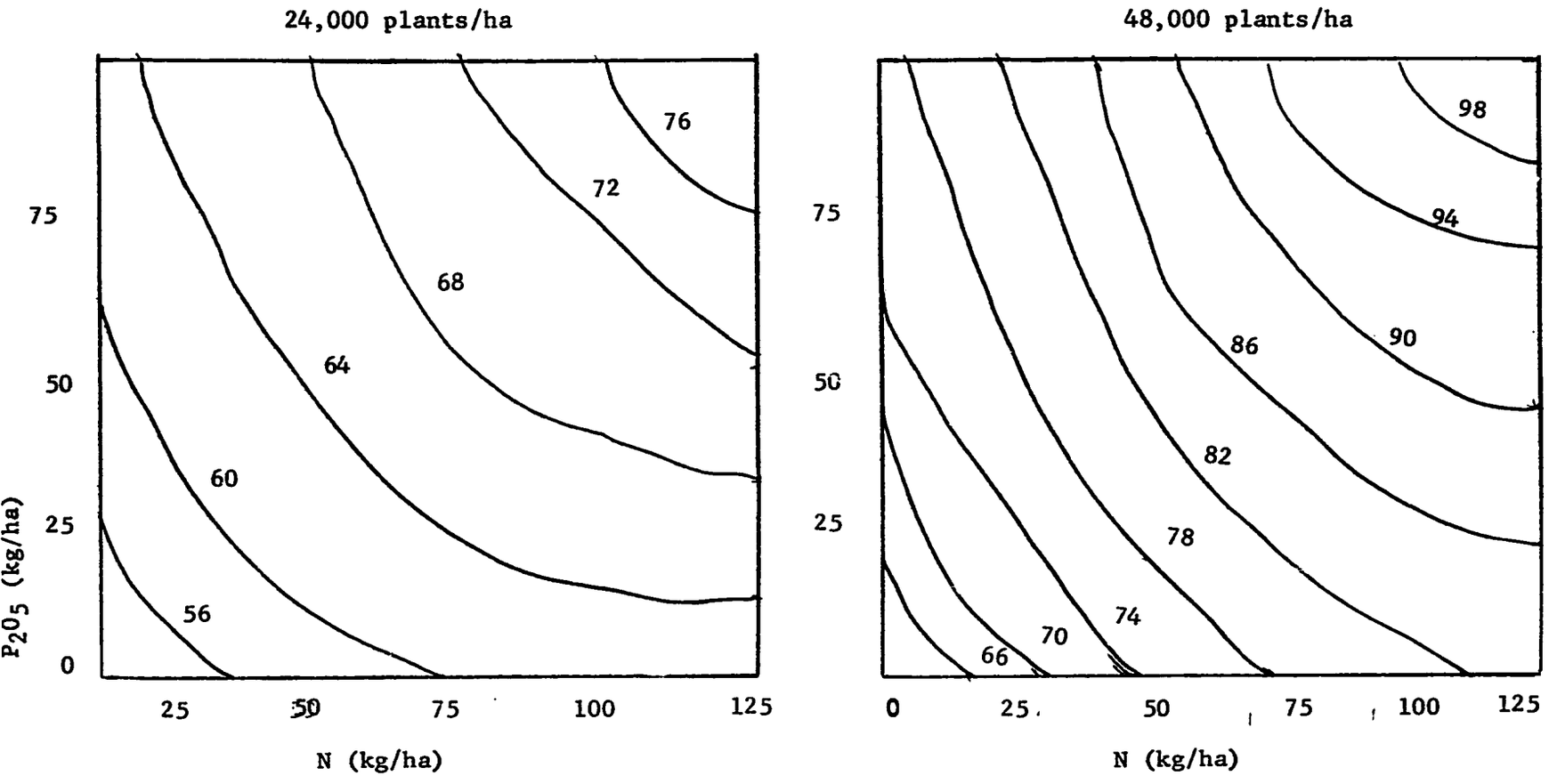


Figure 5. Response of H.613B to varying rates of fertilizer and plant populations (yield in q/ha) at Kitale in 1966.

$4.35 a quintal ($1.10/bu), Nitrogenous fertilizer at $31.15/q (14.14/cwt.), nitrogen (N) and phosphorous fertilizer at $20.80/q ($9.44/cwt.) of P_2O_5, a farmer could profitably apply 114 kg of N per hectare, and 119 kg of P_2O_5 per hectare, under conditions similar to those in this trial. The expected increase in yield is 36.2 q/ha, the fertilizer cost is $60.78, leaving a difference of $96.52/hectare to cover the cost of application, the extra harvesting costs and profit.

The evaluation of improved varieties is done annually at a large number of locations throughout Kenya. Average yields and main agronomic characteristics are presented in Table 12 for 27 locations. Plant populations were 36,000/ha with 56 kg P_2O_5 per ha banded at planting time and 79 kg N per ha applied as top-dressing at knee height. Even though the variety-cross hybrids (H.611 B and H.613 B) are extremely tall, the lodging is less than for Kitale II and no greater than the shorter 3-way and double cross hybrids, H.632 and H.622The proportion of bare tips was very high for H.613 B, but this can be reduced with higher plant populations, which will also give higher yields.

A large genotype x environmental interaction is obtained because of varying responses to changes in the altitude of trial sites, with corresponding changes in ecological conditions. The variety cross hybrids do relatively better at higher elevations because of the adaptation of the male parent, Ec. 573, to such conditions (Figure 6).

Table 12. Performance of long-season varieties at 27 locations in Kenya in 1966.

Variety	Yield		Usable ears/ 100 plants	Lodging %	Bare tips %
	q/ha	% of local			
H.613 B	67.0	155	98	18	43
H. 611 B	61.9	143	93	22	21
H. 612	61.7	143	98	28	21
H. 632	61.2	142	100	22	10
H. 622	58.1	134	103	28	13
Kitale II	46.2	107	87	27	10

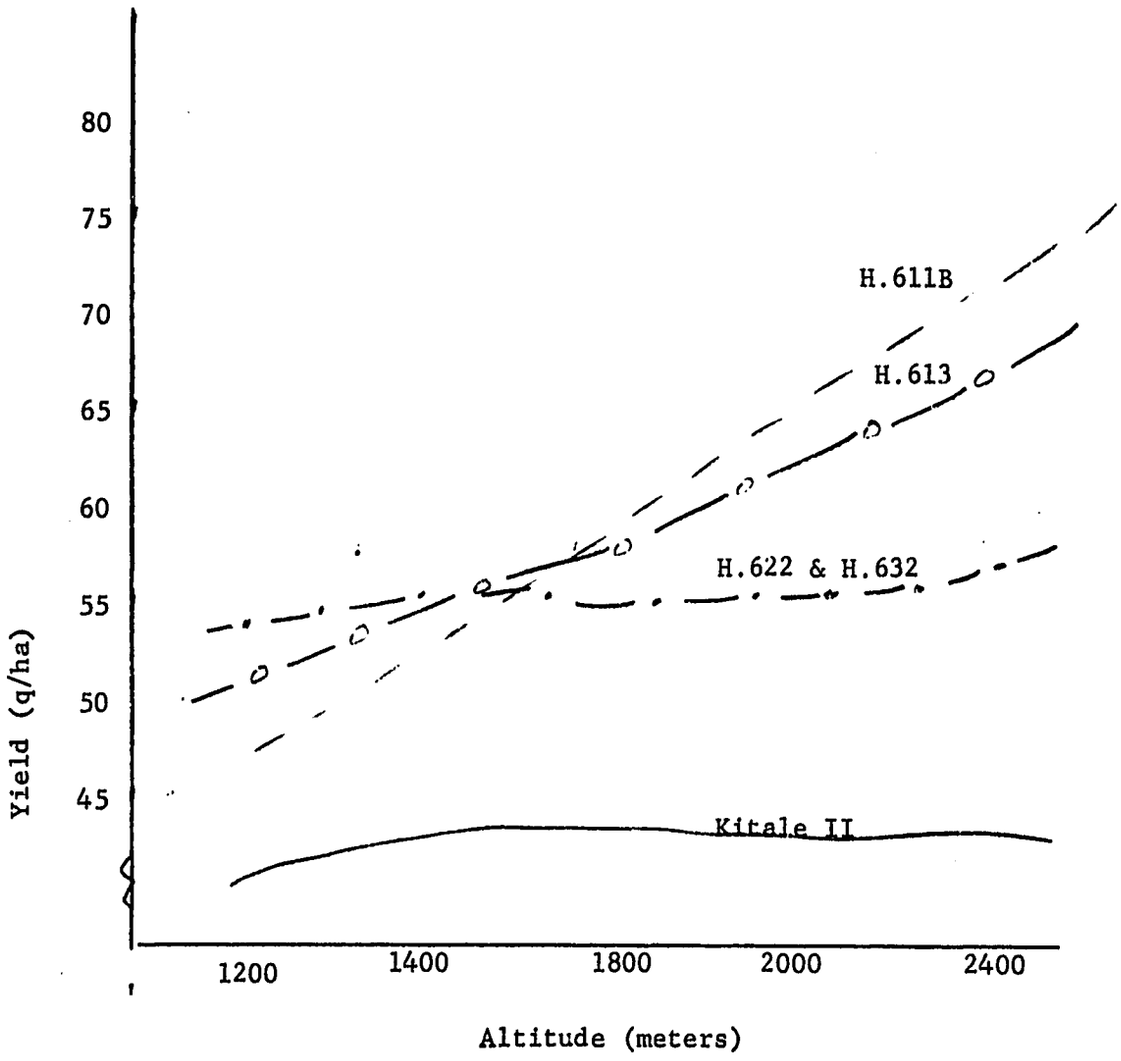


Figure 6. Yields of long season varieties at 27 locations in Western Kenya in 1967 at varying elevations.

Maize Agronomy - Embu

The six main factors affecting maize yields in Kenya have also been studied in the Embu area. Results have been very similar to those in Western Kenya except the date of planting becomes even more important because the length of the rainfall season is also limiting. H.632 has been grown in increasing amounts in this area although it has not been recommended because it requires a longer season than the average length of the rainfall season. With the availability of the medium maturity hybrid, H.511, the extension service will now be using demonstration plots to get this new hybrid grown in as many places as possible with the correct agronomic practices.

Trials to establish the plant population and the levels of fertilizer required have been grown in the past two years and the results are now being summarized. Preliminary results indicate a good response from increasing the plant population from 36,000/ha to 48,000 and from phosphorous fertilizer. However, under the present cultural conditions, nitrogen does not seem to be limiting maize yields in this area. This is very encouraging because it means a farmer can increase his yields greatly with very little ex[illegible]e: (1) Prepare his land properly, (2) plant early, (3) plant [illegible]ll at the proper plant population with (4) a moderate amount of phosphorous fertilizer and (5) keep his fields clean of weeds.

Maize Agronomy - Katumani

Past work at Katumani has shown that early planting and clean weeding with the improved Katumani varieties are the most important factors in increasing maize yields in the Katumani area with the very limited rainfall conditions. Fallow the previous season is also highly recommended or a crop such as beans that has a lower water requirement. It has been found that a spacing of 90 x 25 cm will give higher yields than 90 x 50 cm if the other recommended agronomic practices are used. Studies on soil-water relations are being conducted in cooperation with the E.A.A.F.R.O. Physics Department. Nitrogen has not been found to be a limiting factor and is not recommended. However, moderate applications of phosphorous at planting time will produce increased yields.

Seed Production

The Kenya Seed Company expanded rapidly in order to produce high quality hybrid maize seed for the increasing demand in Kenya. Although the number of hectares in seed production was doubled in 1964 and again in 1965, the demand increased at an even more rapid pace than anyone

thought possible. Only when the area in seed production was increased threefold in 1966, which also happened to be a very good growing season, did the supply exceed the demand. With the carry-over from 1966 to 19,000 quintals, the 1967 acreage was reduced somewhat (Table 13). This carry-over plus the current production should provide seed sufficient to plant 166,000 hectares (410,000 acres) in 1968. The seed is produced by large scale farmers under a contract with Kenya Seed Company at a guaranteed price of $12.42/q (3.15/bu) if seed certification standards are met. A certification program is carried out by the Maize Research Section and each farmer is charged $3.45/ha ($1.40/acre) for this service. Certification standards are the same as those of the International Crop Improvement Association or higher for some factors.

For the small scale farmer, the seed is packed in 9 kg (20 lb) bags and since it will be hand planted is not graded. For the large scale farmer the seed is graded and packed in 45 kg (100 lb) bags which sell for $22.97 (5.83/bu) plus transportation costs from Kitale. An excellent seed distribution system has been established using the Kenya Farmers' Association, Dalgetty's and the Elgon-Nyanza Farmers Cooperative as the three main stockists who then distribute to shopkeepers and local cooperatives in villages as retailers. A nationwide price structure, fixed at each stage and with variations for different provinces according to varying transport costs, has been agreed with the Ministry of Agriculture. The Kenya Seed Company staff are extremely active in promoting the sale of hybrid seed in Kenya and encouraging the use of improved cultural practices. Now that supplies are available above the local demands, they are extending their activities to surrounding countries including Tanzania, Uganda, Ethiopia and Malawi. Approximately 1,200 hectares (3,000 acres) of Kenya hybrids were grown in Tanzania in 1966-67 and seed sufficient to plant 2,800 hectares (7,000 acres) has already been sold for the 1967-68 season.

The Effect of Maize Research on the Kenya Economy

Kenya has gone from a deficit in 1965 of 45,000 metric tons of maize (which had to be imported from the United States under P.L. 480 funds) to a surplus of 135,000 tons in 1966 and an expected surplus of 225,000 tons in 1967. The weather has been a contributing factor in the increase from 1965 to 1966 in that 1965 was a dry year whereas rainfall was adequate in most locations in 1966. The largest deficit occurred in 1961-62 when 270,000 tons were imported. The impact of the improvement from the hybrid varieties is very apparent this year. In the large scale farming areas, past yields in normal years were around 22 q/ha. In 1966, when only 50% of the area was planted with hybrid seed because of the shortage of seed, average yields increased to approximately 31 q/ha. With 100% hybrid seed this year, the average yield is expected to be even higher. The ownership of about half of these large scale farms has now been transferred to Kenyans. As these new large scale farmers gain experience

with large scale production methods with the advice of West German Extension Specialists, yields of maize are increasing on their farms as well. In 1964 and 1965 yields were estimated to be 14 q/ha but in 1966 the average yield jumped to 27 q/ha.

The estimation of maize yields in the small scale farming areas is extremely difficult. The best estimate, prior to the introduction of hybrid maize, was 11 q/ha. With the extensive program by the extension service with the demonstration plots, and the emphasis that hybrid maize should be grown only by those farmers willing to accept the improved agronomic practices, yields have also greatly increased in these areas. The average yield of hybrids is probably between 22 and 28 q/ha. With the conservative estimate of an increase of 10 q/ha of hybrid maize over unimproved maize, the increased production in 1967 due to additional acres of hybrid will be 66,000 metric tons over 1966 and 106,000 tons above production prior to 1964.

Table 13. Hybrid seed production in Kenya

	Certification		Av. Yield (q/ha)		No. of Growers	
	Hectares	Seed (q)	Total	Seedrows	Euro-pean	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	18,530*	27.0*	36.0*	33	24
			Medium Maturity			
1966	24	254	10.6	16.0	2	0
1967	15	225*	15.0*	22.5*	1	0

* Only estimates of yield are available for 1967

Because only 10% of Kenya's maize production is grown by large scale commercial farmers and intended mainly for sale, small changes in seasonal weather patterns can cause big fluctuations in the amount of maize coming on the market from the other 90% grown by peasant farmers mainly for their own subsistence. Consequently, there has been a continuous cycle of surplus and deficit. In order to partly counteract this situation, greatly increased conventional and

"Cyprus bins" storage is now under construction. The Cyprus bins (first used in Cyprus for wheat) have been designed for long-term strategic storage whereby the maize is kept under anaerobic conditions. The construction of these bins is being financed by proceeds from the sale of maize obtained with the P.L. 480 funds in 1965. Each bin holds approximately 1,360 metric tons. Forty are being constructed in Kitale and 30 in Nakuru, giving a total storage capacity of 95,200 metric tons. Additional conventional storage is being constructed in order to handle the crop as it is marketed.

As the average yield of maize increases with the expanding use of hybrid seed, the surplus in a normal year will continue to increase with severe embarassment to the Kenya Government unless some action is taken. There are two main alternatives possible: (1) reduce the acreage of maize and put the diverted acreages in grass leys for livestock production or in cash crops, or (2) find outlets for the increased maize production and develop maize into a major cash crop. There are several problems associated with either alternative. It is very difficult to find additional high value cash crops that have the steady demand on a world market.

If the breeding program continues to produce the expected improvement in the genetic potential of the hybrid maize, production costs will decrease, and the price of maize can be lowered. The price has already dropped from $5.82/q ($1.48/bu) for the 1965 crop to $4.35/q ($1.10/bu) for the current crop. Although the current price is below the world market price, transport and handling costs from the maize growing areas to the seaport mean that maize can only be exported from Kenya at a big financial loss. These costs could be reduced somewhat by efficient bulk handling en route and in the port facilities. However, the price paid to farmers will still have to be reduced considerably before maize can be exported at a profit. As the maize price drops it becomes more economical to feed the surplus to livestock. However, because of the livestock diseases (primarily foot-and-mouth and rinderpest) export markets for Kenya meat are somewhat restricted. Steps are being taken to set up quarantine disease-free areas to overcome this difficulty. Kenya has already built up a small pork exporting industry to surrounding countries. The expansion of this market appears promising. The possibility of interesting external capital in a maize processing plant is also being investigated.

Regional Cooperation

Although research studies of the Eastern African Maize Improvement program are conducted at Kitale, the main objective of the program is maize improvement throughout the region.

Biannual Workshop Conference

The second Eastern African workshop conference was held at the Plant Breeding Station, Njoro; Maize Research Section, Kitale; and Sorghum and Millet Research Section, Serere, Uganda, Sept. 18-23. Thirty-nine delegates from 7 Eastern African countries attended as well as Dr. G. T. York and Dr. S. B. King from Nigeria and Dr. G. F. Sprague and Dr. P. Luginbill from Washington. The field tour at each station was followed by a conference session. The topics were: (1) Breeding Procedures, (2) Regional Cooperation, and (3) Agronomic Research, Seed Production and Extension Methods.

Research results from all participating countries were distributed as mimeographed reports as the program did not permit verbal presentation.

Plants were made for the regional maize and sorghum trials in 1967-68. The discussion of common problems and the exchange of breeding material, research results and ideas was most useful.

Regional Visits -- Tanzania

An invitation was extended by the Chief Research Officer, Tanzania, for Eberhart and Doggett to attend the Tanzania Maize, Millet and Sorghum meeting at the Northern Research Centre, Tengeru, February 8. The National trial of 25 entries growing at 20 locations throughout Tanzania, was discussed. Seventeen of the entries were accessions selected from the 1965-66 E.A. Cooperative trial crossed to Ukiriguru Composite A. The remaining entries were local varieties and hybrid entries provided by the Maize Research Section, Kitale.

Discussions were held with Mr. A. Bolton, Western Research Center, Ukiriguru, and Mr. D. Haswell, Central Research Center, Illonga, to revise their maize breeding programs. The Comprehensive Breeding System will be used by them to develop improved varieties and variety cross hybrids. Ukiriguru Composite A will be used as one breeding population at Ukiriguru as it includes a wide range of local and Central American varieties. Selected entries from Kitale Composite E were sent to Ukiriguru in 1965 to form this composite. Mr. A. Scaife, Agronomist, continued the formation and selection at Ukiriguru. Mr. Bolton now plans to intensify selection by using full-sib selection. Irrigation during the dry season will permit a cycle per year or recurrent selection by this method. A second composite will be formed from selected accessions in the current National Maize Trial.

Illo[illegible] Composite had been formed by Dr. Turner from local selections and [illegible]al American accessions provided by Dr. Wellhausen of the

Rockefeller Foundation. Additional accessions are being provided by the Maize Research Section for evaluation as possible components of a second composite. Even though Mr. Haswell is responsible for the improvement of several other crops, he plans to begin full-sib selection in Ilonga Composite in 1967-68. A set of the Western African Trials have been requested for Ilonga for the 1967-68 season as ecological conditions in West Africa are more similar than at Kitale.

Results of the Western Tanzanian maize trial in 1965-66 (Table 14) and the 1966-67 Tanzania National maize trials have been provided by Mr. Scaife and Mr. Bolton (Table 15). In the medium altitude areas H.622, S.R.52 and Ukiriguru composite A are giving extremely large yield increases over the local farmers' maize. The superiority of Ukiriguru Composite A over Ukiriguru Katumbili illustrates the importance of forming wide-base composites with varieties from the center of origin. Ukiriguru Katumbili is the result of several years of mass selection in the local Katumbili type maize. Similarly the Ilonga composite with adapted Central American varieties included has a large yield advantage at the lower altitudes.

Table 14. Yields of maize varieties at 6 medium altitude locations in Western Tanzania in 1965-66

Variety	1965 - 66	
	q/ha	% of Katumbili
Ukiriguru Katumbili	26.7	100
H.622	44.6	167
H.632	40.8	153
H.612	34.4	129
Kitale II	31.0	116
Ukiriguru Comp. A	33.4	125
Israel Hybrid 1147	18.7	70
Average	32.8	---

Unpublished data supplied by Mr. A. Scaife, Agronomist, Western Research Center, Ukiriguru, Tanzania.

Table 15. Performance of local and improved maize varieties at 15 medium altitude (3,000-5,000') and 4 low altitude (0-2,000') locations in Tanzania for the 1966-67 season

Variety	Medium altitude (15)		Low altitude (4)	
	q/ha	% Local	q/ha	% Local
S.R. 52	49.1	192	31.0	140
H.62	47.2	184	31.8	144
Ukiriguru Composite A	38.2	149	27.9	126
Ukiriguru Composite A x Accessions	40.2	157	32.1	145
Ilonga Composite	32.8	128	34.2	155
Ukiriguru Katumbili	30.4	119	27.9	126
Local Farmers' maize	25.6	100	22.1	100
Average	27.6	-	29.4	-

Unpublished data supplied by Mr. A. Bolton, Maize Breeder, Western Research Center, Ukiriguru, Tanzania, E.A.

Regional Visits -- Malawi and Zambia

Soon after his new regional CIMMYT appointment, Mr. Harrison paid brief visits to Zambia and Malawi. These are both countries where maize is the most important food crop and where growing conditions favor high yield levels.

Zambia

Dr. Eberhart had visited Zambia in April 1966, and it was found that the Maize Breeder, Mr. Abington, had accepted a number of our ideas. A local composite, in which recurrent selection is to be practiced, has been formed of a large number of the best selected inbreds and other material. Accessions, especially from Latin America, and their crossing value to local maize are being studied. Use of a nearby irrigation scheme has been started in order to obtain two breeding generations a year.

Inbred lines from the Rhodesian hybrid program have been obtained and are being screened. The Rhodesian single cross S.R. 52 is outstandingly good; in fact so good that the main breeding program had only the limited objective of finding another one or two good inbreds that would combine well to produce a three-way cross or double-cross hybrid

of similar yield to S.R. 52. This would simplify seed production problems and reduce the seed price. Nevertheless, the Zambia Hybrid Maize Seed Growers' Association has achieved production of S.R. 52 that is now equal to the demand. Due largely to S.R. 52, the country is moving into surpluses of maize and, since there is plenty of land not yet developed, there is no urgency to increase maize yields.

There are two subsidiary programs for peasant African small-scale farmers, one in the Northern high rainfall country wanting late maturity and the other in the Southern low rainfall country wanting early maturity. We discussed the possibility of forming composites for these two programs, incorporating Kenya material and center of origin material screened in Kenya. Recurrent selection would be practiced in these composites.

Malawi

The Malawi maize breeding program has been running continuously for more than fifteen years. Concentration has been on flint kernel type and an ear well covered by the sheath. The local method of food preparation strongly favours flints and the flintiness and good sheath cover are thought to be the main defence against weevil losses. Improved synthetics and hybrids have been available for a number of years, but without a commercial seed organisation and without the enthusiastic effort by the extension staff, little headway has been made with the African peasant farmers who produce all the maize of the country. The research program in maize agronomy is an excellently conceived, strong and effective program.

Although this was the first visit to Malawi by anyone from the regional program at Kitale, Mr. Selley, who has recently taken over maize breeding in Malawi, had attended our 1965 workshop conference and had already put a number of our ideas into practise. Especially, he has started seed production and encouraged extension work so that the improved maize varieties are now beginning to reach farmers in thousands instead of only in hundreds of acres. However, there is a limit to what one research worker can do by himself on these aspects and it is hoped the initial small success will result in better support. Malawi is a small country with a dense population and, though there is no desperate urgency, it will be necessary to do something soon to make sure that increase in food production keeps pace with the expanding population. With the price of maize only recently increased to $3.26 a quintal and the close proximity to a port, surplus maize can be exported without loss if necessary. Hence, there is no fear of a temporary surplus in good seasons being an embarassment to the efforts of increasing food production to achieve self sufficiency for expanding internal needs.

Mr. Selley's plans for making the breeding program more effective and to accelerate progress were thoroughly discussed. Center of origin material has been in the program for a number of years and more has been obtained on a larger scale with a view to making one composite of local and one of center of origin material. A proposal for irrigation in the dry season at a slightly lower, hotter, sub-station was discussed. This would be only for nursery generations because conditions are too abnormal for yield trial evaluation. In this case, as will be seen from Table 5 discussed near the beginning of this report, the full-sib method will be the most effective form of recurrent selection. At the end of the visit, these and other proposals for accelerating progress were discussed with the Chief Research Officer, Mr. Ambrose. Mr. Selley has since been given the help of an assistant.

Regional Visits - Uganda

Mr. Mukasa, Senior Botanist, Uganda in charge of all plant breeding of food crops, and Mr. Musisi, Maize Breeder, both attended our 1965 and 1967 conferences. Mr. Musisi spent several weeks in Kitale in 1966. Breeding source material and ideas have been exchanged and Uganda has taken part in regional trials for the last two years. An opportunity for further cooperation was taken with the invitation to Mr. Harrison to spend a week at Kawanda in December. The recent Uganda agricultural census has shown that maize and sorghum, about 500,000 acres each, have together a combined total less than the acreage of Eleusine finger millet. Moreover, the central densely populated Buganda area has two rainfall seasons a year and high humidity so that there is a serious drying and storage problem with any cereal. Probably for this reason the main food crops of this area are bananas, sweet potatoes and cassava. Nevertheless, an increasing quantity of maize is being grown. If the problems of common insect pests with cotton (the country's main export crop) can be overcome, far more maize would be grown. A breeding program has been operating for a number of years and improved synthetics are being introduced into the Western Region this year. The breeding program was reviewed in detail with Mr. Musisi and suggestions for improvement were thoroughly discussed.

Mr. Musisi has provided results of the Uganda National Yield Trials for 1966 (Tables 15 and 16). Hybrid 632 showed some superiority over the Uganda synthetics, White Star and Western Queen, but not as much as shown in the Eastern African Hybrid trial in 1967 (See page 101).

Table 16. Yields of Kenya hybrids at Kawanda (Kampala, Uganda, 1966)

Variety	Yields q/ha	% of Local
H.622	81.1	110
H.632	85.3	115
H.612	82.9	112
H.613	84.3	114
Local	74.0	100

Table 17. Yields (q/ha) of varieties in National Maize Variety Trials in Uganda in 1966*

Variety	Regions**					
	Northern (6)	Eastern (9)	Midlands (6)	Western (5)	Average (26)	%
Western Queen	52.6	56.0	65.0	52.6	56.6	100
White Star	56.9	58.7	72.3	50.8	59.9	106
H.632	66.2	64.4	66.1	56.7	63.7	113

* Unpublished data provided by Mr. Y. H. Musisi, Kawanda Research Station, Kampala, Uganda.

** Figures in parenthesis are the number of trial sites in each region.

Regional Visits - Ethiopia

Following the workshop conference an invitation was extended to Harrison, Eberhart and Hazelden (Kenya Seed Company) to visit the research programs in Ethiopia by Dr. Werqu Mekasha, Director, Institute of Agricultural Research and Dr. Melak H. Mengasha, Director of Research, College of Agriculture of the Haile Selassie I University-October 22 to November 3. Only 11% of the total cereal acreage of Ethiopia is planted to maize, and in the Central Highlands maize, due to a combination of ecological factors, will never replace t'ef which is the most important cereal of the country. Nevertheless, national yields of maize can be increased by bigger percentages with greater ease than with t'ef and other cereals. Moreover maize has an increasingly important part to play in the land being opened up in the high rainfall South West and in the irrigation schemes now being developed on a large scale in the lowland areas. Any considerable

contribution to increased food production is essential in Ethiopia which will find it more difficult than any other country in East Africa to meet the needs of its rapidly expanding population. All aspects of maize improvement were reviewed and a number of detailed suggestions were well received. Comments were made on other crops and arrangements for future cooperation were agreed.

The agricultural research is being conducted by the following organizations:-

(1) The Institute of Agricultural Research at Holetta, Melka Werer, Bako and Jimma, (2) the College of Agriculture at Alemeya and Debre Zeit, (3) The Swedish Regional Development Project at the Kulumsa farm near Assella, (4) the Ethio-German Agricultural Experiment Station, Bako (in cooperation with the Institute of Agricultural Research) and (5) the Community Development farm (with French assistance) near Awassa. The Institute of Agricultural Research is placing strong emphasis on the coordination of research efforts. National t'ef, wheat and barley trials were grown this year and the Eastern African Variety served as the National Maize Trial. This trial was grown at five sites in the main maize areas.

Ecological conditions in these maize areas seem very similar to those in Kenya and the Kenya varieties are doing extremely well. Collections of local farmers' strains have been made near Jimma, and Jimma synthetics had been developed at Jimma and Alemaya by mass selection. Samples have been requested for the 1968 E.A. Variety Trial. These synthetics also will be incorporated in the new Kitale Composite F.

Five factors appear to be essential for maize improvement in Ethiopia and elsewhere.

1. Breeding Research to develop superior varieties.
2. Agronomic Research to find cultural methods to get maximum yields with economic inputs.
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 farmer how to grow the improved varieties.
5. Marketing facilities to ensure that the farmer will find a ready market at a price that gives him an incentive to get better yields. (The landlord-tenant relation must also be such that he has an incentive to increase production).

The most rapid improvement of maize production in Ethiopia can probably be made by using Kenya varieties and devoting research efforts to establish the optimum cultural practices. Discussions were held concerning the establishment of 2 national cultural trials for 1968. One trial would compare dates of plantings and varieties at moderate levels of fertilizer and plant population. The other trial would be a 3 factor design to estimate the response surface for nitrogen, phosphorous, and plant population. Our improved hybrid (H 632) and composite (Kitale Composite E) were recommended with early planting and clean weeding. Once the research has determined the variety and cultural practices to be recommended in a "package deal", an extensive extension program will be required to demonstrate to the farmers how maize yields can be increased. Attention must also be given to marketing and seed production problems.

Regional Trials
East African Cooperative Trial (1965 - 66)

Many areas of East Africa require medium-maturity maize varieties. Breeding programs have been very limited for this type of maize although considerable work has been done in Kenya on late maturing and early maturing types of maize. Much of the success of these latter programs has been due to the introduction of Central American material and the formation of local and exotic composites.

A regional trial to evaluate local and introduced medium-maturity varieties seemed desirable for 2 reasons: (1) to obtain information on the variety by location interactions and (2) to select the better varieties to use in forming new breeding population.

Mr. Munyo, Maize Breeder, Ukiriguru, Tanzania, in cooperation with the Maize Research Section, Kitale, Kenya had obtained 42 varieties from the Rockefeller Foundation in Mexico. Twenty four of these entries were selected and topcrossed to Kitale III and to Muratha. Other entries available from Mr. Kagira, Maize Breeder, Embu, Kenya, were also topcrossed to Muratha.

These 72 entries were grown in 2 replications in a randomized block design at 13 sites. The trial was grown in 2 seasons at Embu and Katumani giving a total of 15 locations. Since the Kitale III topcrosses were taller and somewhat later in maturity, they were grown in a block within each replication except for Ilonga and Ismani, Tanzania. In these locations 9 local controls were added and the trial was grown as a 9 x 9 simple lattice. Small 2-row plots were used with 22 plants per plot at a plant population of 36,000 plants per hectare. Stands were good at most locations. Covariance analyses were computed at locations with poor stands

since the relative potential yields of these varieties were desired and most poor stands were due to inadequate rainfall at planting time. The relative efficiencies at Tengeru, Ilonga, Ismani, Ukiriguru, and Nabbongo for the Muratha topcrosses were 113, 138, 169, 138, and 109% respectively. Hence adjustments for stand were made except for Nabbongo. Efficiencies for the Kitale III topcrosses were 137, 138, 169, 100 and 105% respectively and adjustments were made only for Tengeru, Ilonga and Ismani.

Extremely good yields were obtained from this material (Tables 18 and 19). Only 4 entries failed to outyield the local controls (Muratha and Katumbili). Even though Muratha yields were low, several Muratha topcrosses approached the yields of the late maturity hybrid check variety (H 621). These varieties tassel about a week earlier than H 621 and nearly 2 weeks earlier than Kitale III.

Kitale III seemed to mask the yield differences of the entries as there was no significant difference among topcrosses to Kitale III except for the very early variety (USA 342 x Camelia). Although only 2 reps were grown at each location, the relative ranks at the 15 locations were in fair agreement. The greatest cause of interactions was the short rain season at Embu and Katumani for the October, 1965 season. Late maturing varieties such as H 621, H 621 x Mu., etc. yielded relatively less than at the other locations.

Although most entries had slightly higher disease ratings than H621, Kitale III (H 621 x Katumani III) and (5314 RRM58 x Muratha), disease was not a serious problem at any location. Lodging and bare tips of all entries was also acceptable.

The error and variety by environment variance components are presented in Table 20 for each of the 4 major areas. The interaction was least for the 4 Uganda and the 4 Tanzania locations and greatest for the Central Kenya locations. The large estimate of σ^2_{ve} at Embu and Katumani resulted from the extreme variation in length of the rainfall season.

Table 18. Performance of medium maturity varieties and topcrosses to Muratha at 15 locations in East Africa in 1965 to 1966

Entry	Yield (100 kg/ha)					Days to tassel
	Kitale Kakamega Busia	Embu (2) Katumani (2)	Kawanda Kakumiro Nabbongo Abi	Tengeru Ilonga Ismana Ukiriguru	Mean	
H 621	64.5	39.2	51.3	36.3	46.7	81.8
(P.Rico G.P.O. 1Y2) x Mu.	48.4	46.6	43.7	39.7	44.2	73.2
(V 520C x Var.Amar.) (Y) x Mu.	41.5	46.4	47.8	36.3	43.0	77.2
H 621 x Mu.	56.0	39.5	43.3	34.3	43.4	79.0
(Amar.Syn. x Stiff Stalk Syn.) x Mu.	44.8	49.7	38.1	35.2	41.9	73.8
(P.Rico G.P. 6) x Mu.	48.2	39.0	46.0	33.2	41.2	79.2
(Cuba 40 x Hawaii 5) x Mu.	45.3	43.0	43.7	33.0	41.0	77.0
(V 520C x Var.Amar.) (W) x Mu.	47.1	41.9	44.4	31.4	40.8	80.0
Kitale III x Mu.	53.6	38.8	41.2	31.2	40.4	82.8
(Ver.168 & 212) x J.xI.C.) x Mu.	46.2	41.7	47.5	27.4	40.4	76.8
(Ec.573 x Kat.III) x Kitale III) x Mu.	52.2	40.4	37.0	32.5	39.7	78.8
(Cometico x Kat.III) x Mu.	48.2	39.2	43.9	29.4	39.7	75.6
Comp. T.C.S. x Mu.	38.8	40.1	44.8	34.1	39.5	73.2
(USA 342 x Guadaloupe M.) x Mu.	46.0	41.0	41.0	30.0	39.2	74.2
Cometico x Mu.	51.3	40.8	39.7	26.5	38.8	80.6
Eto (W) x Mu.	45.1	44.2	36.3	31.2	38.8	76.0
Diacol 353 x Mu.	43.1	36.7	45.5	29.6	38.6	79.8
(Ec.573 x Kat.III) x Kitale III	59.9	37.4	34.1	26.0	38.1	80.8
(Amar.Syn. x Cametia) x Mu.	45.5	40.1	39.5	29.2	38.1	73.6
(Narino 330 x Peru 330) x Mu.	45.1	34.3	43.5	30.0	37.7	75.6
(Kitale III x Kat IV) x Mu.	43.3	37.2	39.5	22.1	37.7	72.6
(F.F. de Peru x Ver.151) x Mu.	41.3	38.8	37.7	33.0	37.4	75.6
(H 621 x Kat III) x Mu.	42.2	36.1	40.1	32.3	37.4	72.2
Nicaragua II x Mu.	37.4	37.9	40.6	31.2	36.8	71.8
(H 621 x Kat. IV) x Mu.	46.9	36.8	36.3	29.2	36.5	67.8
(Ucatigua x Iowatigua) x Mu.	39.7	38.6	37.2	30.9	36.3	72.4
H 621 x Kat. II	39.2	38.1	36.1	32.1	36.1	69.6

continued..... 98

Table 18 (Contd.)

Entry	Yield (100 kg/ha) Kitale Kakamega Busia	Embu(2) Katumani (2)	Kawanda Kakumiro Nabbongo Abi	Tengeru Ilonga Ismana Ukiriguru	Mean	Days to Tassel
Antigua G.P.O. 2 x Mu.	38.3	41.7	36.5	28.5	36.1	73.2
5314 RRM 58 x Mu.	42.6	35.4	38.3	28.7	35.9	74.6
Barretal x Mu.	41.9	33.8	40.6	27.8	35.6	73.0
Kitale III x Kat. IV	38.3	37.9	35.4	30.7	35.2	69.6
(USA 342 x Camelia) x Mu.	35.9	36.3	36.3	31.2	34.8	69.4
(Cometico x Kat.III) Syn. 1	42.2	36.3	33.8	27.4	34.5	74.8
(C 102 x Homa Bay Bulk) x Mu.	39.5	36.3	35.6	27.6	34.5	75.4
Katumbili (Ukiriguru) x Mu.	38.8	36.3	36.1	27.2	34.3	75.4
Eldoret yellow (streak) x Mu.	43.3	34.8	34.5	33.0	34.1	77.0
Muratha (streak) x Mu.	43.5	30.5	35.9	26.7	33.4	72.2
Late Kat. Panmix x Mu.	35.6	35.6	33.4	21.2	33.4	72.0
(USA 342 x Dent.Com. & D.K.S.) x Mu.	31.4	36.3	36.1	28.3	33.2	71.8
Muratha (Embu)	46.4	29.2	29.8	28.7	32.7	79.8
K.M. 54 x Mu.	34.3	32.1	36.8	27.4	32.5	72.4
Muratha (Embu Grade I)	34.5	31.6	34.3	27.8	31.8	72.2
Katumbili (Ukiriguru)	28.7	30.5	34.9	25.1	29.6	75.2
Sonora G.P.O. 2 x Mu.	20.4	30.7	37.9	23.1	28.5	70.1
Maizon x Mu.	25.6	30.7	32.3	23.1	28.0	78.0
Cuzco (Streak) x Mu.	30.0	31.4	26.5	22.6	27.4	76.6
Nal-tel x Mu.	22.2	24.7	28.7	20.8	24.2	65.8
Muratha (Kiambu)	22.6	23.8	22.2	26.7	23.8	73.0
Mean	41.5	37.2	38.3	29.6	36.3	75.0
L.S.D. (.05)	10.5	10.9	8.4	6.3	4.7	

Table 19. Performance of medium maturity varieties in topcrosses to Kitale III at 11 locations in East Africa in 1965 and 1966

Entry	Yield (100 kg/ha)				Days to Tassel
	Kitale Kakamega Busia	Kawanda Kakumiro Nabbongo Abi	Tengeru Ilonga Ismana Ukiriguru	Mean	
Diacol 353 x Kit. III	60.6	51.7	39.4	50.7	85.2
Comp. T.C.S. x Kit. III	58.7	48.4	43.1	49.3	83.9
Eto. x Kit. III	68.7	50.8	32.9	49.1	85.5
(V 520C x Var.Amar.)(Y) x Kit.III	63.3	54.5	29.1	47.5	86.6
(Cuba 40 x Hawaii 5) xKit.III	59.1	43.4	39.3	46.2	82.0
(USA 342 x Guadaloupe M.) x Kit.III	56.0	46.8	37.9	46.0	80.6
P.Rico G.P.O. 1Y2 x Kit. III	55.4	49.0	35.2	45.7	80.9
P.Rico G.P.O. 6 x Kit. III	58.3	46.8	35.0	45.7	80.8
Tuxpeno Comp. (W) x Kit. III	63.7	43.6	34.1	45.7	84.2
(Amar.Syn. x Stiff Stalk Syn.) x Kit.III	53.5	46.0	36.7	44.6	82.5
Katumbili (Ukiriguru) x Kit III	53.8	46.4	26.2	44.4	83.5
(V 520C x Var.Amar.)(W) x Kit.III	57.1	43.7	35.6	44.4	86.9
(Narino 330 x Peru 330) x Kit.III	56.8	47.1	31.8	44.2	85.5
Antigua G.P.O. 2 x Kit. III	52.7	44.4	36.7	43.9	79.5
Kitale Comp. E x Kit III	60.4	42.0	32.5	43.7	88.0
(Ver.168 & 212)(I.C. x J.) x Kit III	56.3	45.9	32.0	43.7	83.9
Cometico x Kit. III	68.0	39.1	27.3	42.6	87.4
(USA 342 x Dent.Com.&D.K.S.) x Kit III	51.8	42.4	35.1	42.4	78.1
(Amar.Syn. x Camelia) x Kit. III	56.0	43.5	31.1	42.4	80.6
(Usatigua x Iowatigua) x Kit. III	50.3	43.2	33.3	41.5	81.1
Tarime local x Kit. III	54.1	41.4	29.6	40.6	84.7
(F.F. de Peru x Ver.151) x Kit. III	48.9	38.7	36.5	40.4	80.3
Kitale III	56.1	37.1	30.6	39.9	86.6
(USA 342 x Camelia) x Kit. III	44.1	38.9	24.6	35.2	77.6
Mean	56.8	44.8	33.6	44.2	83.1
L.S.D. (.05)	12.6	9.1	10.7	6.1	--

Table 20. Estimates of variance components from medium-maturity varieties and topcrosses to Muratha

Variance Component	Kitale Kakamega Busia	Embu Katumani	Kawanda Kakumiro Nabbongo Abu	Tengeru Ilonga Ismani Ukiriguru	Combined
σ^2_{ve}	3.86	6.12	.76	.63	3.13
σ^2_{e}	8.72	9.60	9.53	12.79	10.25

σ^2_e is the experimental error and σ^2_{ve} is the variety by environment interaction component of variance.

Future Breeding Program

Previous breeding work at Kitale and Katumani indicate that composites should contain as much divergent material as possible since the yield of the composite (Y) can be expressed as:

$$Y = \overline{VC} - \left(\frac{\overline{VC} - \overline{V}}{n} \right)$$

where $\overline{VC}$ is the mean of all variety crosses, $\overline{V}$ is the mean of the random mating parental varieties and n is the number of varieties. Although Y tends to increase as n increases, this may be offset by the decrease in the variety cross performance of extremely poor varieties. Hence, it is sometimes desirable to produce a variety cross diallel and obtain estimates of varietal and variety cross performance so that yields of composites resulting from various combinations can be obtained. Experience at Kitale, however, suggests that more progress will be made from selection once the composites have been formed from a large number of entries than from spending 2-3 years obtaining slightly higher yielding composites as base populations. Consequently, the better varieties have been selected and will be combined to form composites at Embu.

E. A. Variety Trial (1966 - 1967)

This trial was designed to study the adaptation of improved varieties in Eastern Africa and to study the interaction of varieties and environments. Nine varieties from Kenya, Zambia, and Malawi were included. The seed was not prepared in time for planting in Malawi Zambia and Tanzania, but the trial will be planted in the 1967-68 season. Seed for eight locations was sent to Uganda, six locations in Ethiopia and nine locations in Kenya. Results currently received are included in Table 21. H 632 and S.R. 52 have done well in most trials below 6,000 feet. The Katumani variety cross is too short term for most areas. The Malawi varieties have not performed well because of susceptibility to disease (rust - P. sorghi and blight - H. turcicum).

The Kenya Seed Company is making a special effort to make H 632 available in Tanzania, Uganda and Ethiopia as an adequate supply of seed is now available. New experimental hybrids are being produced of S.R. 52 crossed to Kenya single crosses and varieties for evaluation in 1968. This may provide a means of utilizing S.R. 52 in East Africa as the cost of the single S.R. 52 is much greater than Kenya hybrids.

Table 21. Yields of the Eastern African Variety Trial at 7 locations in Kenya and 4 locations in Uganda in 1967

	Kenya		Uganda		Days to tassel
	q/ha	% of local	q/ha	% of local	
H 632	59.4	128	44.5	155	87
H 613 B	64.1	138	45.6	159	90
H 511	52.3	113	37.5	131	75
Katumani (V x VI)	31.0	67	30.0	104	64
L H 11	36.4	79	40.5	141	86
S.R. 52	56.9	123	49.5	172	84
S.V. 28	36.3	78	38.1	133	84
Local farmers	46.3	100	28.7	100	83
Local synthetic	53.9	116	32.2	112	81
Mean	48.5	-	38.5	-	82

East African Medium Maturity Trial

In order to obtain additional information on the superiority of H 511 over Muratha (a local Kenya variety) and other medium maturity varieties, this trial was offered to East African maize breeders. Eight locations in Tanzania, 8 locations in Uganda and 11 locations in Western Kenya were planted in 1967. The results currently available are given in Tables 22 and 23. H 511 shows considerable improvement over the local varieties. The Eto x Muratha variety cross also performed well.

Table 22. Yields (q/ha) of medium maturity varieties in Tanzania in 1967

Variety	Ilonga	Ukiriguru	Tengeru	Moshi	Mean
H 511	9.5	45.4	28.5	74.4	39.5
Eto x Muratha	20.9	32.1	45.5	72.6	42.8
Muratha	18.1	46.7	45.5	75.0	46.3
Local synthetic	39.7	56.1	54.3	52.7	50.7
Local farmers	3.6	36.8	24.5	46.9	28.0
Average	18.4	43.4	39.7	64.3	41.5

Table 23. Yields (q/ha) of medium maturity varieties in Western Kenya at 5 locations (1,200 to 1,500 meters) at 6 locations (1,800 to 1,900 meters) and 5 locations in Uganda in 1967

Variety	Yields					Days to tassel
	Western Kenya (5)		Uganda	Mean	% of Muratha	
	1200-1500	1800-1900				
H 511	57.9	49.3	43.6	50.3	129	76
Eto x Muratha	60.6	42.4	48.6	50.5	129	79
Embu 12	54.5	52.3	--	--	-	--
Embu 11	50.0	42.6	--	--	--	--
Muratha	44.6	32.7	39.6	39.0	100	77
White Star	--	--	35.7	--	-	75
Western Queen	--	--	34.4	--	-	74

Because Embu 11 and 12 were the products of very divergent crosses, additional selection was required to reduce the variation in maturity and eliminate colored kernels resulting from epistatic gene action. Two cycles a year of mass selection will be continued until the new wide-base Embu Composites are ready for commercial production. The high yields of the current selections Embu 11 and 12 relative to H 511 produced from the first unselected population suggest that 2 cycles of selection have already produced improvement that should be reflected in the next commercial production of H 511. Selection has been initiated for the $_{r}g$ allele in Embu 11 and the $_{r}r$ allel in Embu 12, to give green and red silks respectively. Seed certification is difficult in variety cross hybrids unless each variety has distinctive morphological characteristics.

Western African Trials

Seed was obtained for a trial at the Coastal Research Station, Mtwapa, Kenya, in 1967 but results are not currently available. Three trials have been received for Malawi, Tanzania and Kenya Coastal Areas. Three locations of the Eastern African Variety Trial have been requested by Dr. Craig for Western African locations in 1968.

Training

The Rockefeller Foundation has provided funds for a student hostel at the National Agricultural Research Station, Kitale. As soon as this building is completed, invitations will be extended to Eastern African countries to send staff members for a short (6-9 months) in-service-training course. It is suggested these students have a minimum of 2 years college training. Methods and technical details of maize breeding, agronomy, seed production and extension would be covered. The students also would be expected to participate in the work of the Maize Research Section in order to gain practical experience.

Meanwhile the positions of Assistant Maize Geneticist, Assistant Maize Breeder and Assistant Maize Agronomist serve as training positions for Kenya staff. Mr. S. Oburra, after experience at Kitale and handling the Katumani program for a year in 1964, is now nearing completion of an M.Sc. degree in Australia. Mr. Mugambi, after a short while under Mr. Allan At Kitale, is now studying Agronomy in New Zealand to the M.Sc. level. Mr. E. Omolo took charge of the Katumani maize breeding program after serving 6 months as Assistant Maize Geneticist in 1964. He is now completing his B.Sc. at Iowa State and expects to continue for the M.Sc. degree. Mr. B. Gichui served as Assistant Maize Geneticist 1965-66 and is now in charge of the Embu maize breeding program. He hopes for a scholarship in 1968 to enable him to complete his B.Sc. and M.Sc. degrees in the U.S.

IMPROVEMENT OF SORGHUM

H. Doggett, and B. N. Majisu, assisted by H. Ojulong,
R. Okello and B. Okwi

Selections from the 1964 series of crosses were planted in a 10 x 10 triple lattice in the first rains. Yields were generally good, 77 of the entries outyielding Serena, which gave 3,860 kg/ha. The best entry gave a grain yield of 6,700 kg/ha. The best entries were multiplied for regional testing in 1968.

Selections from the 1965 series of crosses were screened in 5 triple lattice trials in the first rains at Serere, and 1 trial each in Kenya and Tanzania. Serere yields were satisfactory: 3 of the trials contained entries which recorded yields of over 7,000 Kilos of grain per ha, and the control varieties Serena, Dobbs and SB 79 were much below the best entries. Within its own maturity class (60 days to flower) Serena was surpassed by only 1 entry. Yields were much better at the 65-70 days to flower maturity length. The next variety released will be of that maturity length, as Serena is still satisfactory as an early sorghum. Disease scores showed that good progress had been made towards improved resistance to both Helminthosporium turcicum and Colletotrichum graminicolum. However, less progress has been made towards reducing height, which does not matter much in varieties but which tends to be enhanced unduly in the hybrids. It was interesting to note that out of the 39 best entries over all, 44% were crosses to Namatare. This variety is a Buganda beer sorghum, which has good levels of pest and disease resistance, and although rather unattractive as a grain type it has proved to be a good parent.

The top 25% of the first rains' trials were put into triple lattice trials in the second rains, and were also bulked in readiness for the best to be included in the regional trials. Some good varieties should soon be available for release.

A series of 1966 crosses was run as progeny rows in the first rains, and screened in preliminary triple lattice trials in the second rains. This material represented the last from the conventional backcross breeding programme, and will be the source of new varieties until material from the recurrent selection bulks becomes available.

A series of hybrids was made in the first rains, and evaluated in triple lattices in the second rains. Results are not yet available. The hybrids were made from 9 male sterile parents, including 4 developed at Serere, and 14 good pollinators. Among these was the yellow endosperm type IS 2930, which gives acceptable food grain quality when crossed on to CK 60.

The Serere male-steriles give hybrids which are too tall. Two dwarf male-steriles which consistently give shorter hybrids were selected (Cody

Midland and one of Casady's short Kaura derivatives) and their maintainer lines were crossed and backcrossed to the 4 Serere male-sterile variety maintainer lines.

Two trials of the quality grain selections showed that derivatives of the backcross Dobbs^2 x Wiru were good for yield and grain quality, but had rather large glumes and a poor appearance. They will be crossed to some of the bold grain "zera-zera" types in the collection.

The recurrent selection programme progressed well. The backcrosses of good varieties to (locally adapted varieties x $\underline{ms}_3$) was grown as F_1 in the first rains, and the first generation of compositing was done in the second rains. The second generation was planted to be grown in the dry season. There are 4 bulks being composited in this way, restorer and non-restorer bulks subdivided into coarse and quality grains.

Recurrent selection was begun in the first cross of (locally adapted x ms_3) at 2 planting dates. Some of the material gives a favourable impression. One generation of selecting for male-steriles followed by 1 generation of selecting for male-fertiles have now been done. Generally, about 5% selection pressure has been applied on a grid system.

Eighty seven Ethiopian varieties crossed to $\underline{ms}_3$ were grown as F_1 in the dry season/first rains and F_2 in the second rains, when they were backcrossed to more Ethiopian material. Some of this material is very late maturing, but the Coes male-sterile is early, so plenty of early segregates were obtained. The Ethiopian material was also classified into restorer/non-restorer classes by crossing with Redlan. The great majority of the entries were restorers.

Forty-one varieties of high altitude sorghum crossed to $\underline{ms}_3$ were grown as F_1 in the first rains and as F_2 in the second rains. Fifty-eight additional high altitude varieties were crossed on to some of the segregating male-steriles from the second rains F_2. So far, the high altitude material has come entirely from Uganda and Kenya. Some of the Ethiopian material will be added soon The high altitude bulks will be grown at Kitale for selection purposes.

Segregation of $\underline{ms}_3$ in F_2 populations this season was well below the proportion found last year The proportion of steriles averaged just over 7 percent, compared with over 19% last year. This will doubtless improve under selection. In other respects $\underline{ms}_3$ is admirable, giving good seed sets with no trouble from Sphacelia disease which is so prevalent on the cytoplasmic steriles.

The top 25 percent of the entries of the first rains variety trials were crossed to $\underline{ms}_3$ in the second rains.

Four new $\underline{ms}_3$ stocks were developed, which now contain 50 percent of Serere material. They cover the main groups, restorer and non-restorer sub-divided as coarse and quality grains. These $\underline{ms}_3$ stocks are termed "Mesgen" at Serere, and are most robust and free from leaf disease than the original Coes material from Nebraska.

Screening and compositing of the collection continued. Crosses to Redlan for classifying as restorer or non-restorer totalled 487, and crosses to $\underline{ms}_3$ totalled 186 in the first rains. These were grown out as F_1 in the second rains, and in the Redlan crosses promising hybrids and male-steriles were identified.

Doggett and Majisu during a visit to Hydrabad in January screened the World Collection by eye judgement, and selected 644 entries which looked as though they might show promise for East Africa. Seed of them was kindly supplied by the Indian Agricultural Programme, and was grown at Serere in the second rains. Crosses were made both to Redlan A and to $\underline{ms}_3$ stocks from most of this material.

Out of the first 4,000 entries in the Serere collection 611 selected varieties were planted in the second rains, and also crossed on to Redlan A and $\underline{ms}_3$. Considerable progress has therefore been made this year towards getting a proportion of the good material from the collection into composites. This will be a start in utilising a proportion of the variability of the sorghum crop in the breeding programme.

One hundred and ninety hybrids from promising collection entries were screened in triple lattice trials in the second rains. Weights are not yet available, but some of the yields were evidently excellent: however, lodging was bad in some of the good entries, and it will be important to reduce height in these hybrids.

Male-sterile high altitude sorghums were pollinated with Sudan grass for trial in Kenya as forage. The material is still very mixed, but will give an indication of performance.

Tetraploid sorghum development continued to show promise. Tetraploid Serena, Dobbs and SB 79 crossed in to the best material produced some excellent plants. Mass selection was continued in a series of gridded bulks, and good progress can be seen. Tetraploid yields were again of the order of 80 percent of Serena yield in trials, but the trials have not yet been made of the newer material.

A series of new autotetraploids was made, and the diploids and autotetraploids were compared in a trial, using a split plot design. The $\underline{ms}_3$ male-sterile has been doubled, and should soon be available to allow of the application of recurrent selection at the tetraploid level.

Soils and Agronomy

Gilbert Schumaker

A large part of the soils and agronomy program has involved (1) crop response to fertilizers (2) optimum plant populations, and (3) use of herbicides with emphasis on weed control in sorghum. Some 70 trials were conducted on farmers fields in Kumi and Ngora counties in 1967 to assess the fertilizer requirements for sorghum and finger millet. It was shown that both nitrogen and phosphorus were required for maximum crop yields. Maize yields were increased when higher plant populations were used providing plant nutrients were adequate. Populations of 19,000 plants were most suitable in the trial conducted at Gulu. Much closer spacings than normal are necessary for high sorghum yields. Results from the spacing trial on sorghum conducted in the first rains indicates that sorghum can often compensate for low populations by producing tillers providing the level of fertility is adequate. Considerable progress was made in 1967 in the selection of a suitable herbicide for control of weeds and grasses in sorghum. Pre-emergence sprays of either atrazine or CIBA C-6313 were the most effective.

Farmers Fertilizer Trials. Crops in the 1967 trials were sorghum and f. millet. Conducting fertilizer trials on farmers fields serves two important functions.. First, such trials enable the farmer and others to see how increased yields can be realized by the use of fertilizers. Second, recommendations can be made regarding fertilizer use on similar fields. The trials were a 3 x 3 factorial design with nitrogen and phosphorus as variables. Trials were selected on the basis of uniformity of site, and soils representative of the area. A high level of management was obtained on most trials by selection of more progressive farmers as cooperators. Serena seed was used in all of the sorghum trials thus variability in yield resulting from different seed sources was not a factor. This was not possible on finger millet trials and each farmer provided his own seed. Sorghum yields from 9 trials grown in Kumi county during the 1st rains season are summarized by fertilizer treatment in Figure 7.

The results show that the major response is obtained from the application of both nitrogen and phosphate fertilizer. Although several individual trials showed a considerable increase in yield when phosphorus was applied alone these instances are the exception. While results for finger millet are not given in this report responses were very similar. Although levels of yield were not as high, yields from the numerous trials in Nogra county also show that yields can be increased measurably by applying both nitrogen and phosphorus. The two hundred weight level of calcium ammonium nitrate and two hundred weight level of single super phosphate proved to be the most suitable, level of application in these trials.

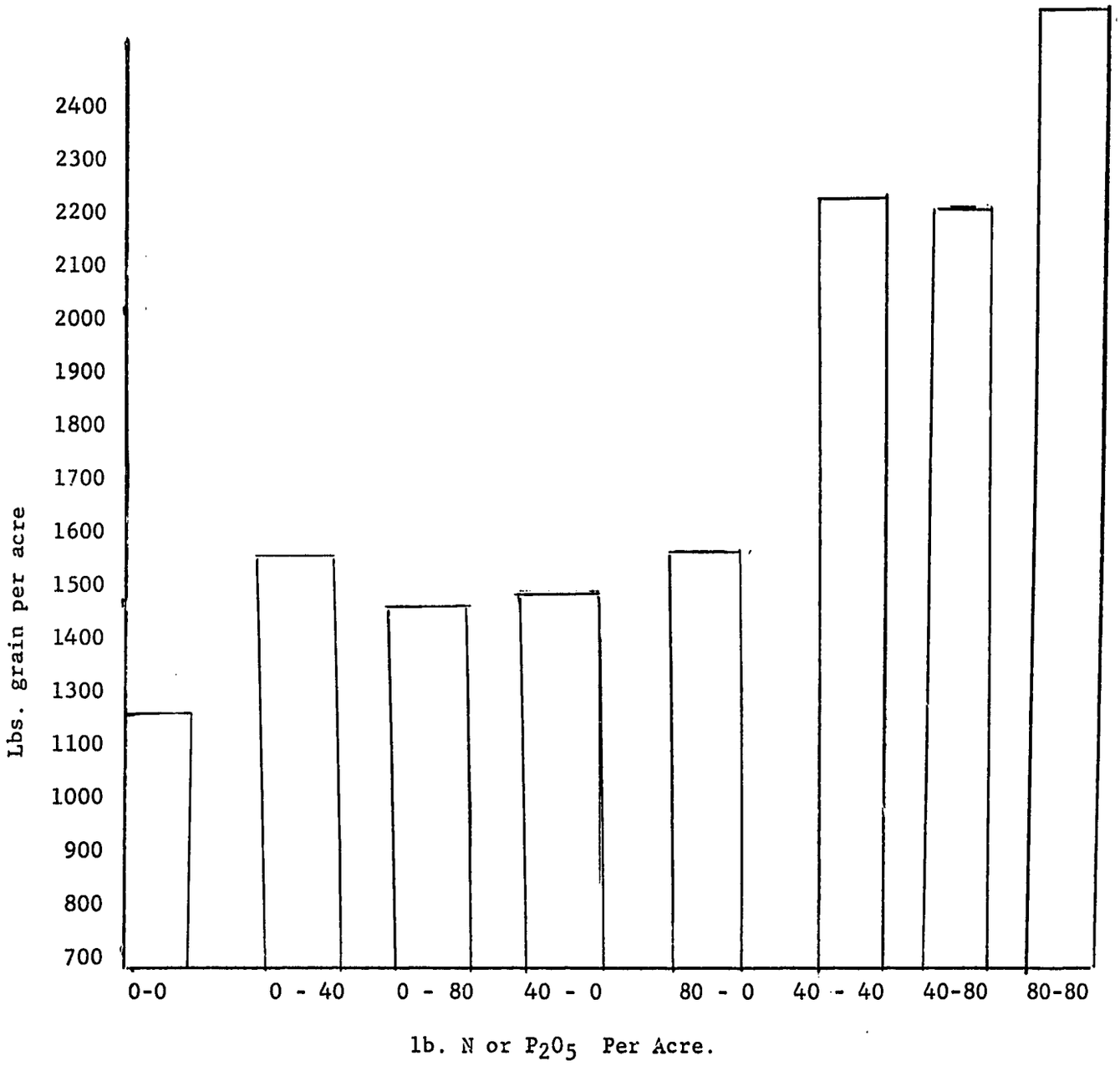


Figure 7. Average yield in lb. per acre of sorghum from 9 farmers' fertilizer trials, Kumi County 1967.

Soil samples taken from each of the trial sites have been analyzed for P and K. The available P at all sites was found to be in the very low range which indicates that one would expect a response to phosphate application. Tests showed a relatively high level of available K therefore deficiency of this element would not seem to be of immediate concern. Organic matter tests have not been completed, however in view of the responses from nitrogen and phosphorus combined it would appear the organic matter content is very low and therefore the amount of nitrogen release would also be extremely low.

Similar trials will be conducted in the 1968 season.

Other Fertilizer and Plant Population Trials. Somewhat more elaborate fertilizer trials were conducted at the Serere Station, and other research centres. More land was available and therefore it was possible to include more treatments and study other factors in conjunction with fertilizer application. Fertilizer and plant population trials on sorghum were conducted at a number of sites in East Africa each having different rainfall distribution. Two trials were conducted in Tanzania and a third at Serere. The Serere trial demonstrated that sorghum production can be at a very high level with fertilization and good management. Many plot yields were above 6,000 lbs. per acre.

Data from this trial indicate that when fertilizers were adequate, yields were at a high level regardless of whether plant populations were 30 or 50 thousand plants per acre. It was observed that both a variety and hybrid produced more tillers with larger heads when the population was 30 thousand plants, thus yields were equal to those from a stand of 50 thousand plants. Leaf area data were collected from the trial and will be useful in comparing the effects of fertilizer treatment and stand on density of plant cover. A variety and a hybrid were used in the trial. While the variety showed the greatest leaf area, yields were not nearly as high as from the hybrid. It appears that in the case of the hybrid a greater amount of nutrients are utilized in grain production.

Proper levels of fertilizer and optimum plant populations for maize were studied at the Labora farm in 1967. Present indications are that large treatment differences were apparent although analysis of the data is not complete.

Agronomic work on bulrush millet continued in 1967. Numerous plant spacing trials were planted at sites in the Northern and Eastern Regions as in 1966. Similar work is being conducted at Serere, however, the Serere trial included high and low levels of fertility. Field observations show that the low level of fertility high stand level have very small heads which are not full of grain. The optimum stand levels and levels of fertilizer will be determined after harvest.

Herbicide Trials. Information on suitable herbicides for weed control in sorghum and millet are not available. Screening of several herbicides for sorghum was conducted in 1st rains season.

These trials were purposely small but were helpful in determining any damaging effect the herbicide may have on the crop. Also observations could be made regarding the types of East Africa plants the herbicides were effective in controlling. Atrazine and C-6313 herbicides were found suitable in both respects and were used in a pilot spray trial in the 2nd rains season. Results from this trial will be useful to Group Farm-Cooperatives in Uganda as well as to researchers and others faced with weed control in sorghum.

Some herbicides have been investigated for weed control in finger millet. Only one herbicide showed a minimal damaging effect on the crop. However, it was difficult to tell whether weeds were being effectively controlled at that level of concentration of herbicide. Weed control in finger millet is most difficult by ordinary cultivation therefore screening new herbicides for this purpose will be continued.

Basic Soil Moisture Information. Pressure plate equipment for the measurement of percent moisture at wilting point and field capacity of soils was installed in 1967. Data has been collected for numerous soil profiles. Inches of available water per foot of profile are being determined.

Calibration of the neutron soil moisture probe for soils at trial sites was undertaken in 1967. The equipment will be used for soil moisture depletion studies in 1968.

Although rainfall is generally sufficient in the Eastern Region of Uganda the high water requirement for evapotranspiration can lead to moisture stress in crops. In order to more fully study crop water use a hydraulic lysimeter was installed in August 1967. Tests of the equipment have been completed and the lysimeter will be planted to sorghum 1st rains 1968.

Entomology

Kenneth J. Starks

The entomological work on the US/AID-ARS Major Cereals Project in Africa started at Serere, Uganda in January 1967. Emphasis has been given mainly to plant resistance to insect pests, and research has been confined to the sorghum shoot fly, Atherigona varia, and to lepidopterous borers attacking sorghum and maize in East Africa.

It was necessary to obtain a ready supply of insects to artificially infest plant in the field in order to screen for resistance. Larvae of the stalk borers Chilo partellus and Sesemia sp. (probably calamistis) were reared on stalk sections in the laboratory to supply most of the field infestation needs of these insects. However, an adaptation of the meridic diet used at the Southern Grain Insects Research Lab. was found to give a more dependable supply of insects with less labor and fewer disease problems but required more technical ability and ingredients which are scarce locally. A small amount of work with artificial diets for rearing the sorghum shoot fly was not encouraging. Nevertheless, adequate infestations were obtained in 4 field tests after using a high protein livestock meal to attract natural populations of the fly.

Egg masses of borers "pinned" on the plants were considered better for artificially infesting than the use of first instar larvae applied individually with a small brush which was tedious, or applied by a shaker method which gave comparatively uneven infestations. Leaf damage ratings of Chilo larval feeding gave a high positive correlation to both larval counts and total stalk tunneling in maize but not in sorghum. So far, leaf feeding ratings for Sesemia have not been reliable, presumably because the larvae often bore directly into the stem.

Limited screening of maize indicated that there is more Chilo resistance in White Star and Western Queen, Uganda varieties, than in some "introduced" lines. However, both these local varieties are comparatively low yielding at Serere. (A heavy population of Chilo partellus was found at Kitale, Kenya, on sorghum although this insect has been thought to be rare at this altitude). Borer resistance in sorghum has been difficult to define, perhaps because of the wide variation in stalk growth both among varieties and within a line. A test with sorghum indicated that stalks with relatively small diameters may not necessary have more borer damage but are more adversely effected in comparison to thick stalks.

Although differences in oviposition preference are indicated, sorghum shoot fly resistance seems to be largely a form of tolerance expressed by the ability of the plant to recover from repeated attacks

and still produce a high yield of evenly maturing heads. Screening has been done and will continue on selections from the World Collection of sorghum. A composite of shoot fly resistant lines currently in the first and second cycle is being rated in cooperation with the sorghum breeders.

Insecticide tests on sorghum indicated that the shoot fly is extremely difficult to control with economical applications of available contact insecticides. Some systemic organic phosphates would perhaps give satisfactory control with a single application but the successful ones used have a high mammalian toxicity. An even smaller test on borer control with insecticides suggested a need for application timing and that Chilo will be simplier than Sesemia to control.

Comparatively few insect pests were found on either bulrush or finger millet in 1967 at Serere.

SUMMARY

Sorghum regional trials were initiated with plantings made in Cameroon Republic, Chad, Dahomey, Ghana, Niger, Nigeria, Senegal and Upper Volta. Twenty-four items were included in these tests representing entries from India, U.S., and Uganda as well as from the cooperating countries. The information accumulated will be useful in delineating ecological zones and thus permit more efficient interchange of breeding stocks.

Cytoplasmic sterile and fertility restorer lines of the proper maturity have been developed at the Institute for Agricultural Research. Preliminary trials of hybrids produced from this material indicate a three-fold increase in yield potential. Problems have been encountered in combining disease resistance and an acceptable yield level in the female (cytoplasmic sterile) lines. Small scale experimental seed production trials are planned for Northern Nigeria in 1968.

A maize breeding program is being initiated in Northern Nigeria. The parental materials will involve both local varieties and introductions from Colombia and Central America. The breeding procedures utilized will follow those developed in the Kenya program. High lysine and brachytic types will be incorporated in these populations to increase protein quality and to avoid or minimize root lodging problems.

The production of hybrid millet is hampered by the marked susceptibility of the available cytoplasmic sterile sources to downy mildew (Sclerospora sorghi). In addition bagged heads, required in the breeding operations, exhibit a high incidence of smut (Tolyposporium penicillariae). An effective hybrid millet program will require solutions to both of these problems.

The important diseases of sorghum include covered smut (Sphacelotheca sorghi), loose smut (S. cruenta), head smut (S. reiliana), and long smut (Tolyposporium ehrenbergii). Inoculation techniques are being evaluated, and suitable techniques will be used in incorporating resistance into useful breeding stocks. Ergot (Sphacelia sorghi) is not usually serious in farmer fields but is of great importance in seed production and breeding studies. Cytoplasmic male sterile types are often heavily infested with this disease. Several foliar diseases may cause serious losses under certain environmental conditions. These include downy mildew (Sclerospora sorghi), zonate leaf spot (Gleocercospora sorghi), sooty stripe (Ramulespora sorghi), anthracnose (Colletotrichum graminicola), oval leaf spot (Ramulispora sorghicola), and rough spot (Ascochyta sorghina). Resistance to some of these diseases is apparently availabe in the World Sorghum Collection.

Witchweed (Striga hermonthica) is a major problem on maize, sorghum and millet. All fields in the Northern Region appear to have some degree of infestation. In some areas infestation is sufficiently heavy to severely damage or completely kill the crop. Additional studies on chemical control are needed. Some strains within the World Sorghum Collection appear to possess some resistance but these observations need to be verified under more adequate control conditions.

Improvements in crop production practices, water and fertilizer use are of vital importance in increasing agricultural productivity. The pattern of water use (evapo-transpiration) is being explored by means of a hydraulic lysimeter. The lysimeter was installed and equilibrated in 1967.

Soil fertility studies pose a number of unusual problems. In general the soils are extremely low in organic matter, buffering capacity, and are highly acid. In combination, these factors lead to the inefficient use of applied fertilizer and the probability of serious microelement deficiencies. The addition of manure gives yield increases which cannot be accounted for on the basis of major nutrients added. The buffering action of organic acids may be the important factor in this response.

Crop residues are normally not returned to the soil. The assumption has been that termites would destroy the residue during the winter season. The common practice, therefore, has been to stock residues on or near the field to be used as livestock feed. Evidence has been accumulated indicating that when residues are uniformly distributed over the field losses from termites are minimal.

Soils are low in pH and poorly buffered. The continued use of ammonium sulphate as the nitrogen sources has aggravated this condition. Small additions of lime to modify pH, appear to reduce aluminum toxicity. Further work on microelements is needed to clarify the limited response to additions of the major elements.

Shoot flies, stalk borers and midge are the primary insect pests attacking sorghum. The development of resistant varieties or of an effective chemical control program requires detailed information on life histories of the various species involved.

At least 9 different species are involved in "shoot fly" damage. Date of planting studies have provided information on seasonal aboundance. Early planting offers some promise for control.

The most important stem borer attacking sorghum is Busseola fusca while Coniesta ignfusialis is the primary pest of sorghum. Light traps have been useful in determining seasonal distribution of the moths.

A West Africa Regional Maize trial was grown in 8 countries; Cameroon Republic, Dahomey, Ivory Coast, Liberia, Nigeria, Senegal, Sierre Leone and Upper Volta. The data from Ibadan, Nigeria are included in this report.

Work is continuing on the development of broad-based populations. These provide the bases for the Nigerian maize program and will be distributed to other West African countries if they appear promising. The high lysine gene, $opaque_2$, is being introduced into these populations.

A survey was conducted to establish the prevalance and severity of the two major diseases of maize; leaf rust (Puccinia polysora) and leaf blight (Cochliobolus heterostrophus). New sources of resistance have been identified for both of these diseases.

A gional Conference of Cereal Breeders was planned for July 5-7 at Moor Plantation, Ibadan Nigeria. Circumstances forced the cancellation of this conference but English or French versions of the prepared papers have been distributed to the West African workers.

A Cereal Workers Conference was held in East Africa September 18-21. Seven countries were represented. Visits were made to the Wheat Research Station at Njoro, Kenya, the Maize station at Kitale, Kenya and the Sorghum and Millet Station at Serere, Uganda. At each location time was divided between presentation of formal papers and a review of the research program in progress.

The maize program in Kenya continues to function in a very satisfactory manner. The main research effort is centered at Kitale. Additional programs, supported entirely by the Kenya Government, have been established at Embu and Katumani to serve these additional ecological areas. Guidance on breeding stocks and procedures are being provided from the Kitale station.

The Kitale program exemplifies the close cooperation among breeding, agronomic research and extension necessary for the development and rapid adoption of new findings.

The breeding program involves a combination of population improvement and the utilization of these populations in the production of commercial hybrids. Significant progress is being made at each of the three stations. The details regarding the populations, breeding procedures and results are presented in some detail.

Extensive factorial experiments have been conducted to establish yield differences and economic returns from a series of practices. Listed in order of decreasing returns these are: Hybrid $81.78; Time of planting, $80.91; increased plant population $48.72; weed control $42.63; nitrogen fertilization $13.05, and phosphate fertilization $9.57. These results emphasize a common mistake of assuming all problems can be resolved by the use of improved varieties and fertilizers.

Optimum agricultural practices at Embu follow the same general pattern as at Kitale except higher plant populations and heavier phosphate fertilization are indicated. At Katumani, early planting and weed control become of major importance.

Maize production in Kenya in past years has fluctuated between surplus and scarcity. Production is most erratic in those areas having the greatest population density and therefore the greatest food requirements. Maize production now appears to be safely above the subsistance level. Provisions are being made for storage to minimize the problem of future scarcities and to stabilize prices. A reasonably stable excess of production over food requirements will permit the expanded use of maize as livestock feed.

The maize seed production program in Kenya continues to make satisfactory progress. In addition to meeting the seed demands of Kenya approximately 3,000 acres of Kenya developed hybrids were grown in Tanzania in 1966-67. Seed for 7,000 acres for the 1967-68 season has already been sold. Somewhat smaller quantities of seed have also been supplied to other eastern African countries.

Sorghum hybrids have been produced at Serere which have produced over 7,000 kilos per hectare. Progress is also being made in improving resistance to Helminthosporium turcicum and Colletotrichum graminicolum. The best of this material will be entered in regional trials in 1968.

Work is progressing on the development of shorter statured cytoplasmic male steriles. Current hybrids are taller than desired.

A population improvement program has been initiated which follows the same pattern as is being used in the maize program at Kitale. Genetic male sterility is being used to enforce random mating and recombination.

Additional material from the World collection is being screened for possible direct utilization and for incorporation in the random mating populations.

Tetraploid stocks continue to show promise. Selection for increased fertility and desired agronomic traits is being continued.

Fertilizer trials with sorghum, bullrush and finger millet indicate limited response to either nitrogen or phosphate applied singly. Yield

increases of 50 percent or more, however, can be obtained when a combination of the two fertilizers are used.

The customary plant populations are too low for maximum yield. Stands of 30 to 50 thousand plants per acre are required for maximum yield.

Weed control remains an important problem. Atrazine and C-6313 have proven satisfactory for sorghum. No herbicides have yet been found which are suitable for use on finger millet.

In spite of high total rainfall a high rate of evapotranspiration may lead to moisture stress. A hydraulic lysimeter has been installed. Wilting point and field capacity characterization of soils is being determined to aid in a detailed study of water use.

Plant resistance is receiving major emphasis in the entomological studies at Serere. Shoot fly and stalk borers are the primary insect pests. Studies are being initiated on mass rearing techniques to permit artificial field infestation.

Preliminary data suggest variation in resistance to the stem borer, Chilo partellus, but resistance levels are still unsatisfactory. Exotic appears to be more susceptible than adapted material.

Differential damage from "Shoot fly" appears to be largely a matter of tolerance. Heavy infestations of this insect can lead to almost complete crop failure.