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Sorghum, Millet and Maize Project
in Africa

1964

by
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O. J. Webster
Maurice Futrell
S. A. Eberhart

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SORGHUM, MILLET and MAIZE PROJECT IN AFRICA

G. F. Sprague

The PASA authorizing this project was signed in April 1963. The objectives are three-fold: (1) To conduct research on these three basic cereals in order to increase food production in Africa through improvements in agronomic practice, plant breeding and disease and insect control, (2) To encourage and stimulate cooperation among existing research agencies in Africa and thereby increase the effectiveness of all aspects of crop production and (3) Provide an opportunity for the training of Nationals to the end that they may more effectively adopt and utilize improved agricultural research practices.

It is felt that the first objective could best be achieved by associating our staff with strong existing research organizations. A much greater impact can be achieved by supplementing existing staff and programs than by the establishment of new and independent centers. Since the areas of ecological adaptation of sorghum, millet and maize are different all work cannot be concentrated at one location. Five locations have been planned, three in West Africa and two in East Africa. The main location in West Africa will be at the Agricultural Research Institute of Ahmadu Bello University, located at Samaru, Nigeria. It is visualized that three professional scientists and an Administrative Assistant will be posted to this location. The scientific staff will include 1 Agronomist (Plant Breeder and Geneticist), 1 Pathologist and 1 Soil scientist who will be concerned with fertilization and cropping practices as well as soil and water conservation. Sorghums and millets will receive primary emphasis although some studies will also be conducted on maize.

A maize breeder will be posted to the Moor Plantation at Ibadan, Nigeria. An Entomologist will be posted to Bambey, Senegal.

In East Africa the cooperative sorghum and millet work will be headquartered at the Uganda Research Station at Serere under the sponsorship of EACSO. Three scientists will be posted to this location: 1 Geneticist, to work on the improvement of millets and sorghum, 1 Entomologist who will be concerned with the identification of serious insect pests and their possible control by either chemical means or through the development of resistant types, 1 Soil Scientist who will investigate management and fertilizer practices and other broad aspects of soil and water conservation.

The maize work will be located at the Maize Research Centre at Kitale, Kenya. The existing program at Kitale has been giving major emphasis to inbreeding and hybridization techniques. New work is being initiated which will stress various selection schemes. The combined program, therefore, should provide improved types which will be of value to East Africa and at the same time provide information which will be valuable to any developing country interested in initiating a maize breeding program.

Many delays have been experienced in initiating the total program. One of the obstacles has been housing. PIO/T's have been issued for the construction of 3 houses at Samaru, Nigeria, 1 house at Ibadan, Nigeria, and three houses at Serere, Uganda. Arrangements for 1 additional house at Samaru, Nigeria and at Bambey, Senegal have not yet been completed. Housing was available and is being utilized at Kitale, Kenya. The project in West Africa has been approved by CCTA and Dr. Webster has been designated by them as coordinator. Many organizational and administrative problems remain but considerable progress has been made.

Three scientists have been posted to Africa; O. J. Webster (Plant Breeder), M. Futrell (Pathologist) to Samaru, Nigeria and S. A. Eberhart (Geneticist) to Kitale, Kenya. It is planned that additional staff will be posted as soon as living accomodations become available.

This first report is necessarily brief. Drs. Webster and Futrell were posted to Nigeria in August and September. The report for this area therefore is necessarily limited to a review of work in progress and a brief presentation of some of the needs for additional research.

Dr. S. A. Eberhart visited Kitale, Kenya in January 1964 and in collaboration with Mr. M. N. Harrison developed plans for the expanded program for 1964. The necessary plantings were made. Dr. Eberhart arrived in July so it was possible to carry through the research planned for the first season.

The reports for the West and East Africa segments of the project are given in the following pages.

WEST AFRICA

O. J. Webster
Maurice Futrell

Personnel -

Dr. Maurice Futrell, plant pathologist, arrived at Samaru, August 31. Dr. O. J. Webster, plant-breeder-geneticist arrived September 17. Webster was named Coordinator for the CCTA project JP-26 by A. O. Odelola, Secretary General by letter dated August 13, 1964. The crop production man to be located at Samaru and the maize breeder for Ibadan will be posted in 1965 if qualified persons can be recruited.

Mrs. Elisabeth Canin was given a temporary appointment as bilingual secretary and translator to the Coordinators Unit, October 1 and was given a permanent appointment after the necessary arrangements had been completed.

Implementation documents -

The Project Agreement and PIO/T for constructing three houses at Samaru and one at Ibadan were signed at the end of June 1964.

Office - Supplies - Equipment -

Futrell and Webster have been provided office and laboratory space by the Institute for Agricultural Research. The space provided for Futrell will take care of his needs temporarily until his laboratory supplies and equipment arrive. If he is to provide in-service training, additional space will be required. The proposed quansett type of building to be used for seed processing and storage will relieve the pressure for office and laboratory space. This structure will also make it possible to expand the cereal breeding program.

Two pick-up trucks were delivered on November 27. The 1½ ton truck and carry-all will be delivered from Kaduna when needed.

The first shipment of supplies ordered in July was delivered December 11.

Travel and meetings -

Futrell and Webster traveled to Lagos, September 21-25 to visit with the officials of AID on operational procedures and with Mr. Odelola, secretary general for CCTA. Mr. Odelola reviewed the purpose of the project and stressed the importance of publicizing the project.

On October 7, Webster was called to Lagos and Ibadan to assist in working out problems relating to the construction of the house for the maize breeder on the campus of the Federal Station at Ibadan. Since housing was first discussed in 1963, the cost of construction has increased by an estimated 20% and the $15,000 allotted for the approved house appeared to be inadequate. At a later meeting (December 2), the engineering branch of AID/Lagos was instructed to ask for bids for the house. If contractors do not give a favorable bid, then alternative steps will be taken. (1) Request the Nigerian Federal Government to make up the deficiency, (2) provide additional funds from the project, or (3) reduce the cost of the house until a house has been built.

Webster, Futrell and Curtis were invited to visit the Kagoro Ranch near Kachia on November 18. This is a project of the Ministry of Agriculture with AID assistance. Laybourne Larson is managing the development and operation of the ranch. The objective will be to purchase 4 year old cattle as near 700 pounds as possible and attempt to produce a 1000 pound animal in 6 months by pasturing and supplemental feeding. The cereal project technicians and

specialists for the IAR have been requested to make recommendations as to the variety of crops which should be grown as well as production practices to be followed.

A similar ranching project is under development at Mokwa under the guidance of a West German staff. Curtis and Webster briefly discussed the projected plans with the staff while visiting the experiment station at Mokwa on November 29. The chief source of carbohydrate will be molasses from the new sugar cane development project nearby. Local grasses will be ensiled and 100 acres of maize is planned in 1965 for silage.

The local sorghums at Mokwa were 16 to 20 feet in height and badly lodged. Yields were generally low. Breeding for shorter types has been started. A few years ago, the yellow endosperm variety, Short Kaura was grown with considerable success on the mechanization scheme. The grain was not palatible to the local people. A mixed population of short plants with yellow and white grains was found on a farm near the station. Curtis speculated that a natural cross had occurred between Short Kaura and a local white seeded strain. From this cross white seeded segregates had apparently been selected by the farmer. It is entirely possible that a good adapted variety can be derived from heads harvested from this field.

On November 25, Webster and Futrell assisted Curtis and Andrews in harvesting 6 uniform sorghum nurseries located at 8 to 10 miles intervals, 50 miles northward on the Zaria-Kano road. The trials included 3 local varieties planted in 1/40 acre plots with 2 replications. Other similar trials between mile 50 and Kano were harvested by the staff from Kano. The purpose of the

test was to attempt to delineate the ecological zones between Zaria and Kano where these varieties were best adapted. Yields at one location ranged up to nearly 4,000 pounds of grain per acre. The plots had been given a fertilizer application of 32 pounds of nitrogen and 28 pounds of P_2O_5. The impressive part of the harvest was the interest shown by the villagers in the thresher. This is the first time the local people had ever seen a mechanical thresher. One village chief expressed his thought: "My wives would sure like a machine like that". The same interest was shown by villagers who for the first time saw a threshing machine operating at the station.

Mechanization of seed bed preparation and threshing are essential for an increase in grain production. The use of improved varieties and improved cultural practices will increase yields per unit areas but without some mechanical aids, there will be a tendency for the farmer to reduce his acreage accordingly. Inquiries are being made concerning the possibility of obtaining a relatively inexpensive thresher which might be within the reach of a village's finances.

Curtis and Webster attended a Nigerian Maize Worker Conference at Ibadan, December 4. Dr. Okiy, Director of the Federal Station served as chairman. The 1964 phases of the project were discussed by representatives of the different regions and Cooperative work was planned for 1965.

Cereal Improvement Project at IAR -

Sorghum - Several fertilizer and plant population trials have been conducted in recent years in the Northern Region using local varieties. The results of trials at Samaru using the variety Farafara suggests that the maximum yields are obtained from populations of 10 to 14 thousand plants per acre.

With this population and adequate fertilization, yields of 2,000 pounds per acre are the maximum to be expected. An increase in the amount of fertilizer on this tall growing guineensia type only increases plant height and the degree of lodging. Yields of a shorter growing Short Kaura (Kafir type) have exceeded 4000 pounds per acre.

The major breeding objective is to reduce plant height. Such plants will respond to thicker planting and heavier applications of fertilizer. One of the commonly grown types is illustrated in figure 1. A more desirable type is illustrated in figure 2. The variety illustrated in figure 2 is known as W X L (Websters Cross). It was developed from a cross of Farafara x Hegari made by Webster when he was posted at Samaru in 1951. The selection work was done by Mr. Curtis. This variety is the first to be developed in Nigeria from a planned breeding program. The variety meets most of the requirements except for poor head exsertion and poor threshability of the seed from the glumes. These faults will be corrected by breeding. For hand threshing, seed must come free of the glumes with a minimum physical effort on the part of the "thresher". "Free threshing" is also essential if the grain is to be used as food for humans.

No suitable varieties for the Zaria-Mokwa area have been found in collections obtained from other parts of Africa or the World. Improved varieties will have to come from the local breeding program. As improved varieties are being developed they are being tested as potential parental lines for hybrids.

In the northern areas of Nigeria and southern Niger, trials have indicated that introduced short, early types are of potential value. Varieties such as hegari perform well but the grain quality will need to be improved.

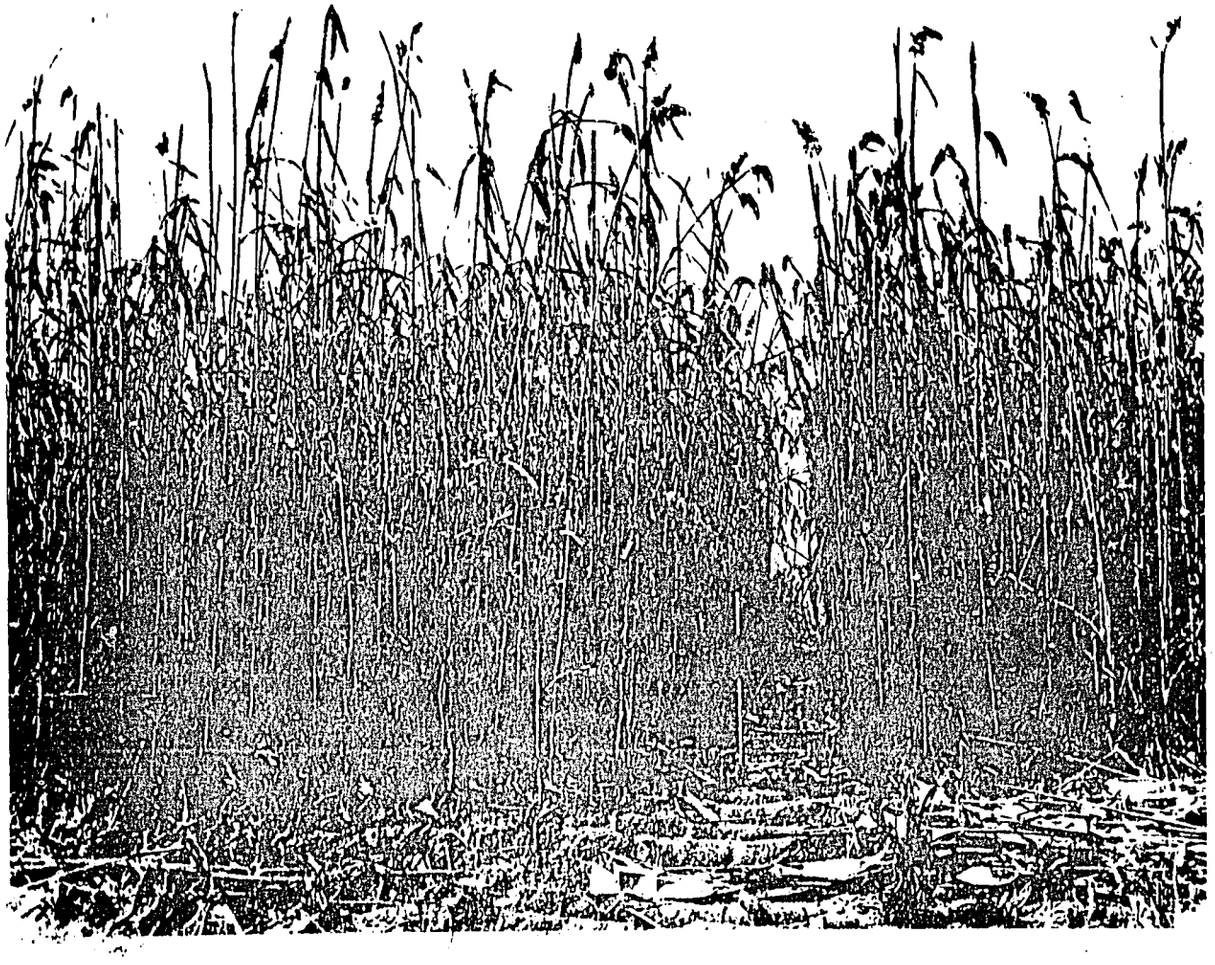


Figure 1. Farafara - a sorghum variety commonly grown in Northern Nigeria. (note the extreme height and loss of heads due to stem borer attack. A 5 foot range pole is shown in the center alley).

Figure 2. The sorghum selection, WX, the first variety developed in Nigeria from a planned breeding program.

Maize - The maize work at Samaru has been confined largely to growing the uniform trials as a cooperation project with the Federal Station at Ibadan. The only breeding work under way is the simple transfer of the sugary gene into local varieties by backcrossing. Maize yields in 1963 ranged up to 6,000 pounds of dry grain per acre. In 1964, the reduction in yield (2,000-3,000 pounds) was probably due to a high water table, 18-24 inches below surface. The potential of maize in the Zaria area is evident. A concentrated effort is to be made to find adapted materials by growing a large collection from other parts of the world.

In addition to the Uniform Yield test grown in 1964, Dr. Craig (AID Plant Pathologist Western Region) provided seed for a small observation nursery and seed for planting ½ acre isolation plots for beginning a mass selection program. One F_1 hybrid in the observations nursery was not only outstanding for yield but also for resistance to lodging.

Dr. Henry Wiggan (AID Corn Breeder Western Region) and Dr. Marvin Lindsey (Rockefeller Foundation, University of Ibadan) assisted in making the selection in the isolation plots.

Over 1,000 rows of maize material have been planted in the 1964-65 dry season irrigation nursery at Samaru. If the development of this crop is satisfactory, most of the controlled breeding work in the future will be done during the dry season and a minimum during the rains.

Millet - The millet work in Nigeria is under the direction of Dave Guymer at Kano. A breeding program suggested by Dr. Glenn Burton, U.S.D.A., Tifton,

Georgia is being followed. Dave Guymer will be leaving Nigeria before the next season. Until a replacement is employed, Davis Abifarin (Nigerian with a MS degree from the University of Nebraska) will assume leadership of the millet work as well as the sorghum work for the Kano area.

Plant Pathology

General - The major plant disease problems must be determined before any progress can be made in a plant pathology program. Disease loss estimates serve to measure the economic value of a research program. Precise disease losses are very difficult to make. Attempts were made to evaluate disease losses on sorghum and millet for the 1964 growing season in Northern Nigeria even though only 3 months of the growing season remained when this program was initiated on September 1, 1964. Three field trips were made and a limited number of fields and experimental plots were examined for disease development. The field trips were as follows: (1) Samaru to Kano, (2) Samaru to Kagoro Ranch near Kafanchan and (3) Samaru to Funtua. Disease loss estimates were tentatively assessed by eye as follows: Sorghum smuts (Sphacelotheca spp.) and (Tolyposporium sp.) caused 10% loss in yield. Leaf blights exclusive of downy mildew caused 5% loss in yields in both sorghum and millets. Downy mildew (Sclerospora graminicola) of millet caused an additional 5% loss. Between Samaru and Kano there were no losses from sorghum smuts in demonstration yield plots planted with seed treated with a fungicide. These observations suggested that a good seed-treatment program would be of value to growers.

Sorghum Diseases- One-thousand and fifty three lines or varieties of sorghums from 15 countries of the world were evaluated at Samaru for response to downy mildew (Sclerospora sorghi) ergot (Sphacelia sorghi) and leaf blight caused by a combination of a number of species of fungi including (Helminthosporium spp.), (Colletotrichum graminicola) and (Ramulispora sorghi). The epidemic of all diseases except ergot was eratic. Disease reactions ranged from resistant to susceptible. These data indicated that production losses from diseases in growers fields can be reduced by growing improved, disease-resistant varieties of grain sorghum.

Experiments with sorghum ergot showed that the sterility so often associated with this disease is not caused by the pathogen. The ergot fungus infected flowers only when they were not pollinated. Cytoplasmic male sterile plants of the Combine Kafir A lines had 50% of the flowers infected with ergot when they were not pollinated. Pollination of the flowers at the time they became receptive reduced ergot infections to 8%. Some of the lines and varieties of sorghum in the world collection from India were susceptible to ergot. Fertile lines and varieties of sorghum in the world collection showed resistance to ergot even where the inoculum load was heavy. Ergot could become a serious disease in hybrid sorghum seed production with male sterile lines in Africa, India and other countries where the ergot disease is prevalent. These experiments indicated that this disease can be controlled or markedly reduced by having an abundance of pollen available from the male pollen parent when the female flowers become receptive.

Corn - An epidemic of corn rust (Puccinia polysora) developed during August and September at Samaru in experimental nurseries. The reaction of 10 lines or varieties of corn to this rust was recorded. Local Nigerian corn varieties were susceptible to the rust. The Mexico-5 variety and a number of experimental lines were resistant.

Insect infestation associated with virus diseases prevented corn seeded in July from flowering at the Kagoro Ranch near Kafanchan. A detailed study of virus diseases of corn and other grass host plants is needed in West Africa.

Millets - Observations made in experimental plantings of millets and sorghums at Kano, Nigeria, and Bambey, Senegal, indicated that long smut incited by Tolyposporium sp. was spreading between the two crops. Research work is needed on the host range and infection process of this pathogen.

Projected Plans for Future Work in Plant Pathology -

Additional laboratory, greenhouse and class demonstration space is needed to carry out the training phase of the CCTA project JB-26. An additiona laboratory 18 feet by 36 feet is needed to facilitate the equipment currently on order from the United States. The currently allocated space is not sufficient for the equipment.

The three potentially serious diseases of millet and sorghum are (1) smuts, (2) downy mildew and (3) ergot. The smuts are probably causing the greatest damage at the present time, but fungicide treatment will reduce these losses if applied properly by growers. Field research work will continue on screening varieties, strains and hybrid material in a disease garden to select new varieties that are resistant to downy mildew. Further studies will be made on the epidemiology, spread and control of the ergot disease. This disease could be a real threat to hybrid sorghum seed production with male sterile lines in Africa.

MAIZE BREEDING

S. A. Eberhart

The maize genetics and breeding program (jointly sponsored by the U. S. Agency for International Development, the Agricultural Research Service of the U. S. Department of Agriculture and E.A.A.F.R.O.) was initiated in cooperation with the Maize Improvement Centre, National Agricultural Research Station, Kitale, Kenya in February 1964. The purpose of this program is to evaluate the relative efficiencies of the most promising breeding methods for the production of improved synthetic and hybrid varieties.

The Kitale location possesses several unique advantages. Nursery plantings may be made in different seasons. This makes it possible to complete a recurrent selection cycle in two years and to advance other phases of the program equally rapidly. In 1964 the February, April and August nurseries involved 300, 390, and 1100 plots, respectively. Approximately 17,000 pollinations were made in the three nurseries. Yield trials were grown at 4 locations and involved approximately 1600 plots.

During the past several years many varieties from the several races adapted to the high plateaus of Central and South America have been introduced and tested by the Kenya maize breeding section. Many of these varieties proved to be reasonably well adapted to the 5,000 to 7,000 feet elevations in Kenya. Considerable heterosis was obtained when these varieties were crossed to Kitale synthetic II and also when crosses were made among introduced varieties. This extreme amount of heterosis indicates divergent genetic material and hence considerable genetic variation so that rapid improvement of synthetics derived from these variety crosses should be possible if efficient breeding methods are used.

Although theoretical quantitative genetic studies and empirical evaluations suggest several methods which might be satisfactory, information concerning the actual relative efficiencies of these methods is very limited. Since many breeders throughout the world are also interesteed in such information, this program was planned to compare the relative efficiencies of the more promising breeding methods and at the same time to produce improved synthetic varieties for release to farmers. Because of the extreme genetic diversity between Kenya and Central and South American varieties and the conditions permitting a cycle of recurrent selection in two years with irrigation of the nurseries, differences in the relative efficiencies of the breeding methods should be detected much sooner here than in many other breeding programs.

The superior S_1 lines identified in the yield trials of the various breeding methods will be evaluated further and utilized in the Kenya hybrid breeding program. As hybrids gradually replace synthetics in commercial production, the continued improvement of synthetics as source material for new inbred lines is one of the most important (and often most neglected) parts of a hybrid breeding program.

The following characteristics were desired in material selected for this program: (1) the varieties would be random-mating populations in linkage equilibrium, (2) the variety cross would exhibit considerable heterosis indicating that gene frequencies differ in the two populations for many loci and that non-additive gene action is present, (3) there would be considerable genetic variation within the varieties themselves and also in the advanced generations of the variety cross, and (4) the varieties are to be reasonably well adapted to the environment in which they will be grown (the high plateaus of Western Kenya between 5,000 and 7,000 feet elevation). This adaption includes moderate resistance to blight (*H. turcicum* and rust (*P. sorghi*).

Of all the material available in the Kitale breeding program, the two varieties that most nearly fulfilled these qualifications were the synthetic variety developed from the local Kenya Flat White maize, Kitale II, and the Central American variety, Ecuador 573. Kitale II was developed by one cycle of testcross evaluation from Kitale Station open-pollinated maize. Ec. 573 apparently is a variety of the Montana race introduced from Guatamala through Ecuador. Ec. 573 is reasonably adapted and the variety cross (Hybrid 611) greatly exceeds the yield of Kitale II as shown in table 1. A new synthetic variety has been formed by random mating the vareity cross.

Table 1. Yield in cwt.*/ acre of varieties, the variety cross, and the variety cross synthetic at three locations in 1964.1/

Entry	Location			Mean	
	Kitale	Endebess	Kakamega	Observed	Predicted**
Kitale II	36.7	38.0	51.5	42.1	42.1
Ec. 573	41.2	36.3	23.6	33.7	33.8
Kitale II x Ec. 573	58.9	50.1	48.5	52.4	52.6
(Kitale II x Ec. 573) syn 1	48.9	37.9	50.1	45.6	48.3

* Cwt. = 100 pounds.

** Predicted with the model including additive and dominance effects but no epistasis.

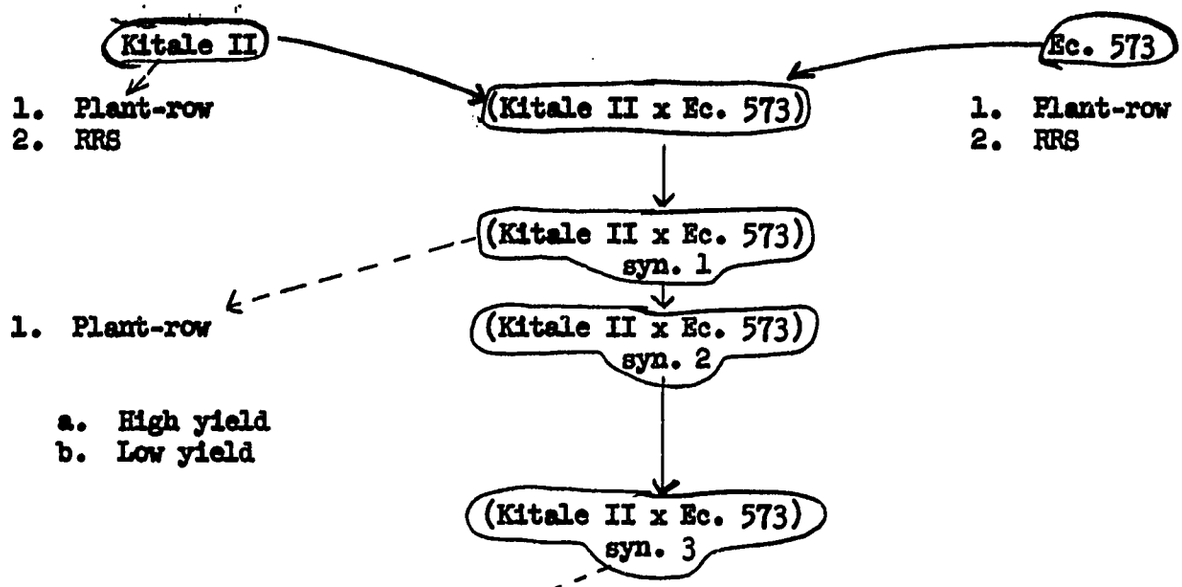
1/ Unpublished data obtained from Mr. A. Y. Allan

The analysis of variance obtained from the model proposed by Gardner and Eberhart[1] is as follows:

Source	d.f.	M.S.
Location (L)	2	34.23
Entries	3	184.64
Varieties	1	104.99
Heterosis	1	436.95*
Epistasis	1	8.99
L x Entries	6	64.01**
Error	42	6.13

1/ The variety cross diallel. (In press)

The outline of the proposed program is presented in Figure 1. These procedures may be grouped into two classes depending on the primary importance of the type of gene action. If many loci show over-dominance for yield, the parental varieties should be maintained separately and improved through reciprocal recurrent selection (RRS). Conversely, if gene action of this type is only of minor importance, the most rapid progress can be obtained by one of the many recurrent selection procedures in the advanced generation of the variety cross.



1. <u>Mass selection</u>
   a. 2% selection intensity.
   b. 10% selection intensity.

2. <u>Plant-row</u>
   a. No selection of male plants (49 plant-rows).
      (i) 9,680 plants per acre.
      (ii) 19,360 plants per acre.

   b. Selection of male plants and 19,360 plants per acre.
      (i) 49 plant-rows.
      (ii) 100 plant-rows.

3. S_1 testing and recombination of selected S_1 lines.

4. Testcross evaluation and recombination of selected S_1 lines.
   a. High-yield tester.
   b. Low-yield tester.
   c. Inbred line tester.

5. Full-sib and half-sib family selection.

Figure 1. An outline of the Maize Breeding Program

The reciprocal recurrent selection method as proposed by Comstock, et al. (1) will be used with slight midifications in the Kitale II and Ec. 573 varieties. In this selection method the reciprocal variety is used as the tester; i.e., Kitale II will be used as the tester variety for Ec. 573 and Ec. 573 will be the tester for Kitale II. The modification of the original method will be selection for agronomic characters during recombination and in the choice of plants to test-cross to the reciprocal variety. Unless there is a large negative correlation between the agronomic characters and yield due to pleiotropy, progress in improving yield should not be reduced but high yielding varieties with acceptable agronomic traits should be produced. The highest yielding 10% of the 100 entries will be selected each cycle for recombination.

Most of the quantitative genetic studies investigating the types of gene action involved in maize indicate that gene action of the over-dominant type is of lesser importance in random-mating populations than partial to complete dominance and that, at least initially, the selection method should be one of the recurrent selection procedures. Theoretical considerations suggest that this should be the plant-row or modified ear-to-row method developed by J. H. Lonnquist (2) although exact formulas for progress from selection probably cannot be obtained for this method. This procedure is a combination of a type of half-sib family selection and of mass selection within the selected half-sib families. The plant-rows (half-sib families) are grown in replicated trials at four environments so that selection will be more effective when genotype x environmental interactions are present. The yield trials at one location are grown in isolation with remnant seed from each plant-row bulked to provide pollen producing plants. The least

agronomically desirable of these pollen plants will be eliminated before they shed pollen. All plant-rows will be detasseled so that inbreeding is reduced by preventing crossing among the half-sibs in each plant-row. The highest yielding 10% of the plant-rows will be selected and within each selected plant row, only the highest yielding 10% of the plants will be selected to provide plant-rows for the next cycle.

Although progress per cycle is less with this method than for most recurrent selection procedures involving progeny testing, progress per year is expected to be greater because all other methods require two or more years per cycle. The shorter cycle also allows more chances for recombinations to break up undesirable linkage blocks. This method can be conducted satisfactorily without highly trained technicians because no hand pollinations are required.

As shown in Figure 1, plant-row selection will be conducted in Kitale II, Ec. 573, (Kitale II x Ec. 573) syn 1, and (Kitale II x Ec. 573) syn 3. Since the variety cross is being produced as the commertial hybrid, Hybrid 611, the comparison of the products of plant-row selection in the varieties will provide a direct comparison with reciprocal recurrent selection (RRS) as to the most efficient method of improving such a variety-cross hybrid. Also, if inbred lines can be obtained from two different populations, the amount of testing of these new lines in single and double cross combinations is reduced. Only 25 crosses need be tested for 5 lines from source A and 5 from souce 5 whereas all 45 crosses of 10 lines from a single cource should be tested.

The relative yields of hybrids subsequently produced from inbred lines derived from later cycles of plant-row selection and from RRS will provide additional evaluations of these two breeding procedures. Populations and hybrids

from the advanced cycles of plant-row selection in the (Kitale II x Ec. 573) syn 3 will provide another basis for the comparison of recurrent and reciprocal recurrent selection and also of the effectiveness of plant-row selection in the variety cross with plant-row selection in the parental varieties. Plant-row selection in (Kitale II x Ec. 573) syn 1 may provide information on the importance of permitting a few generations of random mating before selection is initiated in a variety cross.

Several variations in the plant-row method also will be compared in the (Kitale II x Ec. 573) syn 3. The plant-row selection with 100 entries will provide information as to possible drift or inbreeding depression in the plant-row procedure with only 49 entries as well as provide a comparison with RRS on the same average number of yield-plots per year. One plant-row procedure will be conducted at a low plant population to provide the control method to test the hypothesis that selection under population stress will produce material that yields well under both stress and non-stress conditions including fertility and moisture stress whereas selection at low plant populations does not. Progress from plant-row selections with and without selection of male plants before pollination will be conducted to provide a comparison of the effectiveness of selection for agronomic characters in the pollen parents.

Other methods of recurrent selection will be compared only in the (Kitale II x Ec. 573) syn 3. Because genetic variation should be greatest in this population, differential rates of progress among methods are expected to be detected sooner. As shown in Figure 1 these methods include mass selection, S_1 testing,

combined full-sib and half-sib family selection, and testcross evaluation with three types of testers.

Mass selection will be conducted at two selection intensities; i.e. 2% and 5%. For both selection intensities the standard plot size will be two rows with 25 plants each. The least desirable plants will be detasseled prior to pollination. 300 selected ears will be bulked to provide seed for the next cycle.

S_1 progeny of S_0 plants selected for desirable agronomic characters will be evaluated in yield trials and remnant selfed seed of the highest yielding 10% will be recombined for the next cycle.

In the recurrent selection methods involving testcross evaluation and recombination of the selfed seed of selected plants, three types of testers will be used. The positive heterosis in the variety crosses and the severe inbreeding depression in maize indicates that most genes for yield show dominance for the favorable allele. Hence the most desirable tester would be one that is homozygous recessive for as many unfavorable yield genes as possible as demonstrated mathematically by Rawlings and Thompson (3). Consequently, a low yielding tester will be developed from the variety cross population by selecting for low yield by the plant-row method until the level becomes as low as is practical. Sufficient testcross seed must be produced for yield trials. This low yielding tester will be selected from the same population so that the loci which are segregating in the population to be improved have been selected for the "recessive" genes unfavorable for yield. At the present time a common practice

is to use the population itself as a tester. This procedure will also be used in order to compare the increased efficiency of the low yielding tester. Another tester that may be useful is an inbred line developed from the low yielding tester variety. Such a line should also contain many recessive genes for yield and thereby reduce the masking effect of the tester. But it may be possible also to select populations which are more stable under varying environmental conditions with an inbred tester. Although the initial hypothesis was that an inbred line would test only for specific combining ability, considerable data are now available to indicate that the population itself shows considerable improvement under this selection method indicating that selection has been effective for general combining ability.

A recurrent selection method involving a combination of half-sib and full-sib family selection will also be compared. Selection for desirable agronomic characters during recombination and crossing will also be done in this method as well as in the three testcross evaluations.

Although preliminary studies indicate that the optimum rate of planting for Kitale II is approximately 12,000 to 14,000 plants per acre and 8,000 to 10,000 plants per acre for (Kitale II x Ec. 573), both the yield trials and the nursery material will be grown at 19,360 plants per acre except where specified otherwise. Since much of the maize in Kenya is grown under conditions of low fertility and some cases under drought stresses, it is desirable that the populations be improved so that they can take advantage of favorable environmental conditions when available, but at the same time they must be capable of giving improved

yields under less favorable conditions. The selection for Kitale II from the Kitale station variety resulted in 15 to 20% improvement under favorable conditions, but no improvement under adverse conditions. Selection was at 12,000 plants per acre. There is some preliminary evidence available to suggest that selection under high plant populations may give the ability to stand fertilizer stresses.

The plant-row experiments in Kitale II, Ec. 573, and (Kitale II x Ec. 573) syn 1 were begun this year and the results will be reported after harvest in the next annual report. Testcrosses were made to begin the reciprocal recurrent selection experiment. Two additional cycles of random mating have been obtained in the variety cross so that (Kitale II x Ec. 573) syn 3 will be available to begin all other plant-row experiments and the mass selection experiments in 1965. One cycle of plant-row selection for low yield in (Kitale II x Ec. 573) syn 1 was completed so that a low-yielding tester will be available next year. The inbred tester is also being developed. Selfs and testcrosses will be made for the other recurrent selection experiments so that the first yield trials can be conducted in 1966.

The many breeding methods involved in this program should greatly strengthen the planned "in service" training for maize breeders from East Africa under the Rockefeller Grant to the Maize Improvement Centre. Although training under this grant has not yet been initiated, Mr. John Munyo, maize breeder, Ukuriguri Experiment Station, Mwanza, Tanzania, was able to spend three months at the Maize Improvement Centre to become more familiar with these methods and other aspects of maize breeding.

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