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A Major Cereals Project to Improve Maize, Sorghum and Millet Production in Africa[1]

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ABSTRACT

The objectives of this project, initiated in 1963, were 1) to increase cereal production in Africa through cooperation with and support of research organizations in Nigeria, Kenya, and Uganda, 2) to stimulate and sponsor cooperative research in all aspects of cereal production throughout the area, and 3) to provide in-service training at the headquarters stations to individuals sponsored by their governments. This integrated program included plant breeders, entomologists, pathologists, and cereal technologists to develop new high-yielding, disease and insect resistant varieties with increased food values, agronomists to develop a package of recommended cultural practices to exploit the potential of the new varieties, and research-extension liaison officers to help extension personnel to reach the local farmers with the new varieties and recommended agronomic practices. Encouragement and assistance were given to cooperating agencies and companies for seed production, the development of marketing systems, and the utilization of the excess production. Kenya has been greatly increasing its maize production, and other African countries are moving forward.

ALTHOUGH food supplies are now adequate in most African countries, except in marginal rainfall areas, steady population growth will soon cause demands to exceed food supplies unless cereal production increases and the rate of population growth decreases.

Most African countries have had cereal research programs under way for many years. These programs were usually organized and developed with support from Great Britain and France, and considerable assistance is still provided by the British Overseas Development Administration and the French Institute de Recherches Agronomiques Tropicales. To strengthen this cereal improvement research, the U.S. Agency for International Development and the U.S. Department of Agriculture agreed in 1963 to cooperate in a Major Cereals Project in Africa. A survey in West and East Africa indicated a strong interest by the local organizations in such assistance. The Major Cereals Project, as initially outlined, had three major objectives: 1) to increase cereal production capabilities in Africa through cooperation with and support of research organizations in Nigeria, Kenya, and Uganda; 2) to stimulate and sponsor cooperative research on all aspects of crop production throughout the area; and 3) to provide in-service training at the headquarters stations to individuals sponsored by their respective governments.

In West Africa the sponsoring agency is the Scientific and Technical Research Committee (STRC), one of the committees authorized by the Organization of African Unity (OAU). Nigeria serves as the host country and cooperative research programs have been developed with the Institute for Agricultural Research, Ahmadu Bello University, Zaria, and the Federal Department of Agricultural Research, Moor Plantation, Ibadan. Staff at Zaria are concerned with maize (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench), and bulrush millet [*Pennisetum typhoides* (Burm.) Staph Hubb.] breeding, insect and disease control, and soil-water-fertility-plant relationships. Work at Ibadan is limited to maize breeding and pathology.

Two Field Trials Officer positions (research-extension liaison) have recently been established in neighboring Francophone countries with headquarters in Senegal and Cameroon. Personnel are provided by the French Fonds d' Aide et Corporation (FAC), but the operating expenses are provided by the Major Cereals Project through STRC. Similar arrangements have been made with the British Overseas Development Administration for Field Trials Officers in Nigeria and Ghana.

In East Africa the sponsoring agency is the East African Agriculture and Forestry Research Organization (EAAFRO). Cooperative research programs are conducted at four locations: Serere Research Station of the Uganda Ministry of Agriculture, Serere, Uganda; National Agricultural Research Station of the Kenya Ministry of Agriculture, Kitale, Kenya; East African Industrial Research Organization, Nairobi, Kenya; and Tanzania Ministry of Agriculture, Dar-es-Salaam, Tanzania. Research at Serere is concerned with sorghum and millet breeding, soil-water-fertility-plant relationships and insect control. The research at Kitale is concerned with maize breeding. Work on cereal milling and processing, with primary emphasis on sorghum, was initiated in 1968 at Nairobi, Kenya. Field Trials Officer positions were established at Dar-es-Salaam, Tanzania, in 1970 and at Serere, Uganda, in 1971.

Support provided by the Major Cereals Project to the African research institutions supplemented the local programs and became an integral part of these operations. The activities and results obtained by these overall cereal-improvement programs will be discussed in this report.

Experience has shown that at least six major areas are important for increased cereal production:

1) Breeding research to produce improved varieties with satisfactory insect and disease resistance.
2) Agronomic research to determine the cultural practices needed to give maximum economic returns from the improved varieties.

[1] Contribution from the Plant Science Research Division, ARS, USDA, U.S. Agency for International Development, East African Agriculture and Forestry Research Organization, East African Industrial Research Organization, Scientific and Technical Research Committee of the Organization of African Unity, Kenya Ministry of Agriculture, Nigeria Ministry of Agriculture, Tanzania Ministry of Agriculture, Uganda Ministry of Agriculture, Ahmadu Bello University, and Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa, cooperating. Journal Paper No. J-7143 of the Iowa Agriculture and Home Economics Experiment Station. Project No. 1897. Presented at the Agronomy in Africa Symposium at the 1971 American Society of Agronomy meetings. Received April 26, 1972.

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Table 1. Yields of improved maize varieties grown at 11 Kenya locations in 1967.*

Variety	Yield q/ha	% of K II
K II	46.1	100
Ec573	31.0	67
KCB(MC)C2	59.3	129
KCC(MC)C2	54.4	118
KCE(MC)C2	60.3	131
H611	67.5	146
KCA	52.1	113

* From the 1967 Annual Report of the Major Cereals in Africa Project.

3) An extension program to acquaint the farmers with the potential of the improved varieties and to demonstrate to them the recommended cultural practices required to obtain this potential production.
4) Seed production and a distribution system for seed, fertilizer, insecticides, and fungicides to make the necessary inputs readily available to farmers.
5) Credit facilities to enable subsistence farmers to purchase the inputs.
6) Marketing and utilization to permit the farmer to sell his surplus at a fair price to obtain funds to repay his loans and buy inputs for the subsequent crops.

Maize Improvement in Kenya

The success of the maize improvement program in Kenya illustrates what can be achieved when all six areas are developed simultaneously. The Maize Research Section was organized at Kitale under the guidance of a British scientist, M. N. Harrison, in 1955. This cooperative program has involved the Kenya Ministry of Agriculture, the British Overseas Development Administration, the Rockefeller Foundation, and the Major Cereals in Africa Project through the East African Agriculture and Forestry Research Organization.

Harrison (7) developed an improved variety 'Kitale II' (K II), as well as the conventional hybrids 'H631,' H621,' and 'H622.' He also introduced varieties from South and Central America, and the variety cross 'H611' (K II × Ec573) was released for commercial use. The composites 'KCB,' 'KCC,' and 'KCE' were formed to be used as breeding populations; these composites out-yielded Kitale II (Table 1). A comprehensive breeding system was outlined for maize improvement (6). This system is flexible since two composites (Comp. B and Comp. R) are developed and improved by recurrent selection as outlined in Fig. 1. After each cycle of improvement, a commercial variety can be released (B C1 or R C1, B C2 or R C2). In areas where hybrid production is not yet feasible, direct commercial use can be made of these improved varieties. When facilities for producing hybrids have been developed, the variety cross (B C0 × R C0, B C1 × R C1) can be sold as a commercial product, or conventional hybrids can be developed from the improved populations.

An extensive study is under way to compare various techniques and methods within this comprehensive breeding system and to demonstrate that the system is effective. A preliminary evaluation (3) indicates that the system has been very successful as shown by a 26% improvement in H611(R) from 2 cycles of reciprocal recurrent selection (Fig. 2). The improvement in Ec573(R)C2 over the original Ec573 resulted in an improved topcross hybrid 'H613C' [(FxG) × Ec573(R)C2] which is superior to 'H613B' [(FxG) × Ec573] as shown in Table 2. This increase in yield represents profit to the farmer, despite greater harvesting and transportation costs.

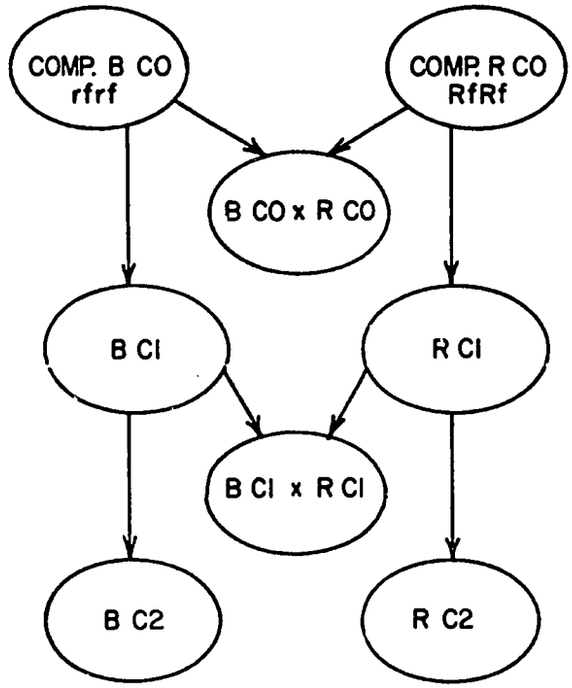

Fig. 1. An outline of a comprehensive breeding system with recurrent selection in two random mating breeding populations.

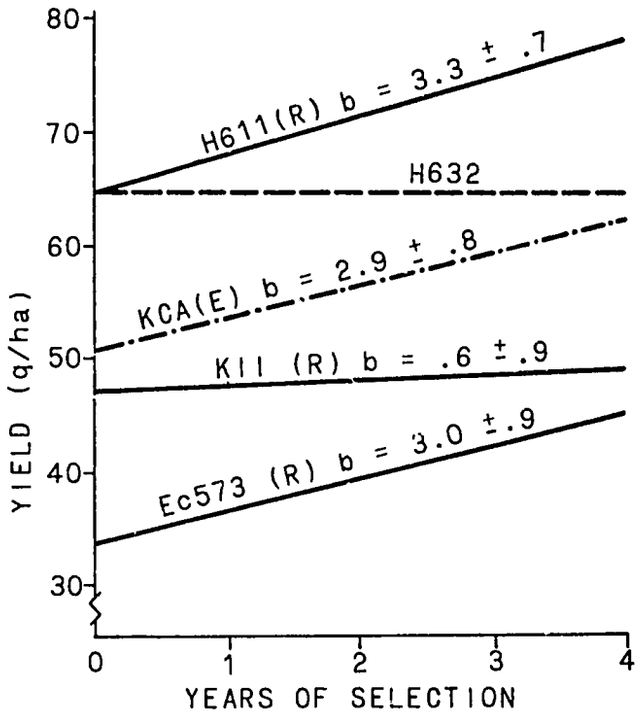

Fig. 2. Progress from reciprocal recurrent selection (R) and modified ear-to-row selection (E) in Kenya maize varieties [from Darrah et al. (3)].

Table 2. Performance of maize varieties in the Kenya Late Maturity Variety Trial grown at 28 locations in 1970 [from Darrah et al. (3)].

Variety	Yield q/ha	Yield % of K II	Lodging %	Ears per 100 plants
K II	40.1	100	47	75
H622	51.2	128	51	86
H611B*	52.7	131	43	80
H611(R)C2*	64.4	161	37	93
H613B*	57.0	142	48	84
H613C*	66.7	166	41	95
LSD, 0.05	5.1		6	6

* H611B is K III × Ec573 and H611(R)C2 is K II(R)C2 × Ec573(R)C2. H613B is (F × G) × Ec573 and H611C is (F × G) × Ec573(R)C2.

Genetic variance studies suggest that we can expect this same rate of improvement for at least the next few cycles of improvement. Although the improved hybrids have slightly less lodging than the original versions, lodging was a severe problem in Kenya in 1970, and breeders will increase the selection pressure for lodging resistance and shorter plant height.

If the potential yields of these new hybrids are to be exploited, appropriate cultural practices must be used. A. Y. Allan, maize agronomist for the Kenya Ministry of Agriculture, has demonstrated that inexpensive practices, such as early planting and clean weeding, can be relatively more important than a hybrid variety and fertilizer (1)[3]. As shown in Fig. 3, experimental yields from normal peasant farming practices were 19.7 q/ha. Use of a hybrid with fertilizer increased yields by 13.0 q/ha without early planting and clean weeding and 31.4 q/ha if early planted and clean weeded. Similarly, the recommended husbandry practices increased yields 29.2 q/ha with the local variety and no fertilizer and gave a 47.6 q/ha yield increase with a hybrid variety and fertilizer. Yields were quadrupled from 19.7 q/ha to 80.3 q/ha, and profits were increased by $209/ha in the trial with the recommended practices: a hybrid variety, early planting, moderate rates of nitrogen and phosphorus fertilizer, and clean weeding. The extra profit is shown in parentheses in Fig. 3.

Agronomic research has shown that responses can be obtained from nitrogen and phosphorus with a large interaction (Fig. 4). Potassium does not limit yield in the Kitale area, although sulfur can be limiting on certain soil types.

Planting at the beginning of the rainy season at Kitale not only gave the highest yields, but also gave a greater response to nitrogen. When the recommended rate of nitrogen was used (1.58 q/ha N), the farmer lost 6.5 q/ha for each week of delay in planting (Fig. 5). The yield potential was thus halved by a 6-week delay in planting. Because the rainy season was long enough for the maize planted 8 weeks late to mature before the rains stopped, length of the rainy season was not involved in this response. The early growth check and the reduction in the number of kernels per plant caused by the wet, poorly aerated soil when planting was delayed may cause some of the yield reduction[3].

Yields can also be increased greatly by using the correct plant populations. The optimum population for the tall hybrid, H613C, at Kitale is about 40,000 plants/ha, whereas 47,000 plants/ha are recommended for the medium height hybrid, 'H512' (Fig. 6).

[3] Allan, A. Y. 1971. The influence of agronomic factors on maize yields in Western Kenya with special reference to time of planting. Ph.D. Thesis. University of East Africa, Kampala, Uganda.

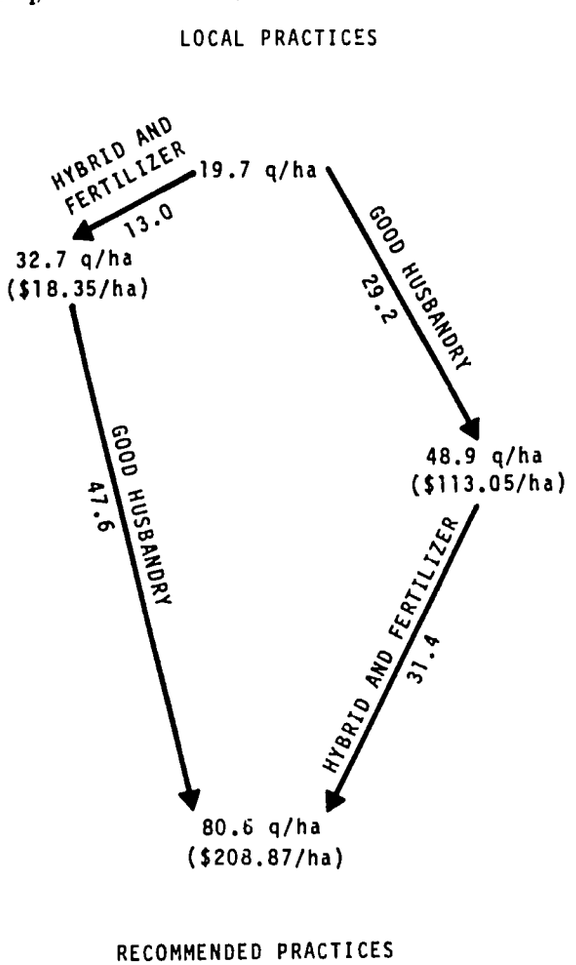

Fig. 3. Maize improvement in Kenya through improved husbandry and the use of hybrid seed and fertilizer. Increased profit per hectare is shown in parentheses [from Allan (1)].

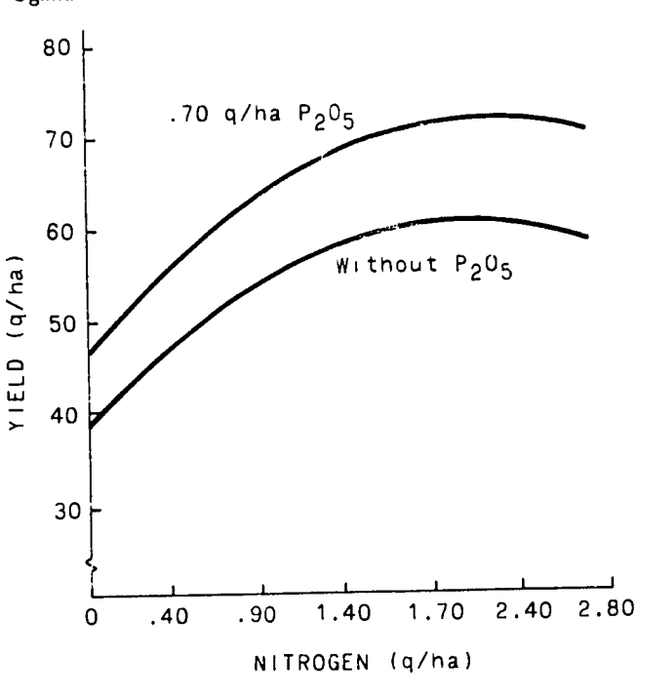

Fig. 4. Nitrogen response obtained for the maize hybrid H613B with and without phosphorus in Kenya, 1968-70.

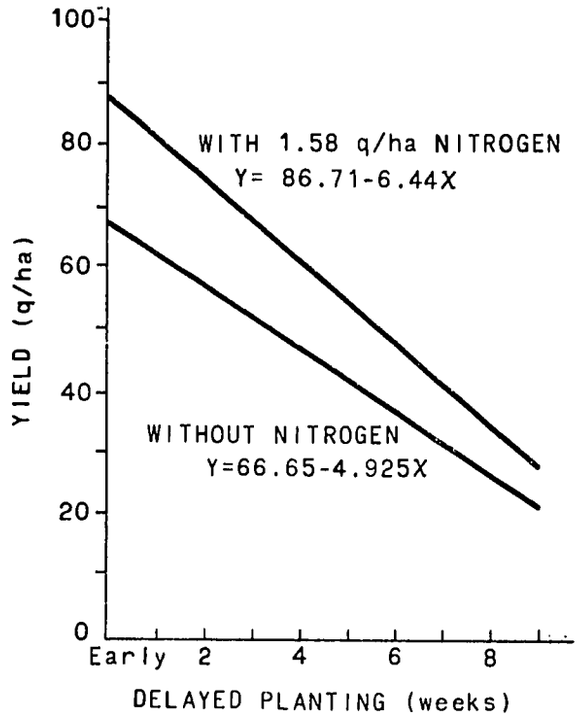

Fig. 5. Date of planting response with and without nitrogen for the maize hybrid H613B in Kenya, 1968-70 [from Allan (1)].

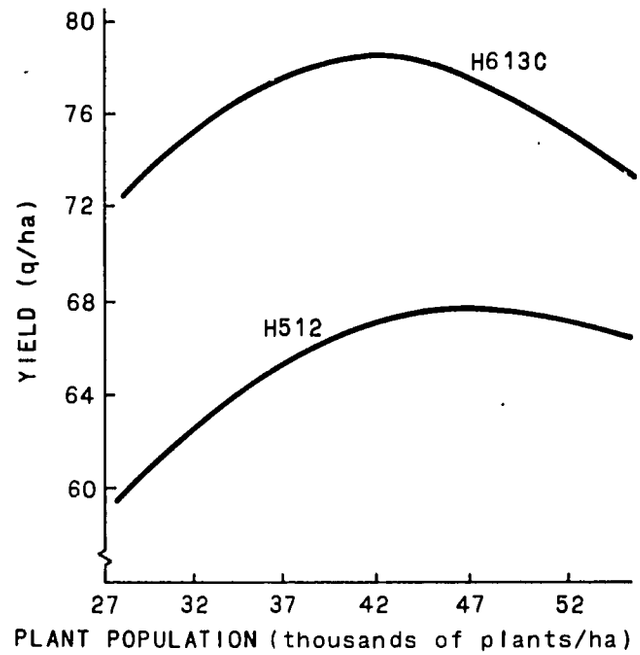

Fig. 6. Response to plant populations for maize hybrids H512 and H613C in Kenya in 1970.

In addition to conducting their research projects, Harrison, Allan and F. Ogada (Senior Maize Research Officer for the Kenya Ministry of Agriculture) also worked as research-extension liaison officers to be sure the extension service personnel were familiar with the recommended hybrid varieties and agronomic practices needed to obtain economic returns from the new hybrids. P. T. S. Mirie, Director of Agriculture, knew that the peasant farmers did not respond very enthusiastically to Maize Field Days on Government Stations. Hence, the extension staff was directed to contact leading farmers to obtain their cooperation in conducting maize demonstration plots on their farms.

The farmers bought the inputs and tended the plots under the guidance and supervision of the extension officers. Neighboring farmers were invited to a "methods demonstration" at planting and a "results demonstration" at harvest. Each cooperating farmer was encouraged to describe how the hybrid maize and the recommended cultural practices had enabled him to double or triple his yields. These demonstration plots were extremely successful in getting the peasant farmers to adopt the complete maize improvement package.

This success could have been nullified without adequate seed production and distribution. Kenya was fortunate, however, to have a commercial company, the Kenya Seed Company, willing to undertake the production of the hybrid seed. They contracted with large-scale commercial farmers near Kitale to produce the seed under a certification program conducted by the Kenya Ministry of Agriculture. Originally the farmers were European, but many of the present seed growers are Kenyans who have purchased some of the large farms. The Kenya Seed Company made arrangements with the Kenya Farmers' Association (a cooperative) and MacKenzie, Dalgety, Ltd., Inc. to distribute the hybrid seed with the same outlets used for fertilizer and other agricultural production supplies.

No extensive credit program was organized, but credit was available through the Government, coffee cooperatives, small storekeepers, and other sources.

The Kenya Maize and Produce Marketing Board provided a fair price and a ready market throughout Kenya, regardless of the amount of maize offered for market. These prices and those for hybrid seed are shown in Table 3. Hybrid seed prices after 1965 included transportation charges and were uniform throughout Kenya.

The area planted to hybrids has increased every year except in 1968 (Fig. 7). The sudden drop in the maize price in 1967 caused a large reduction in the number of hectares planted with maize on large farms the following year. Use of hybrid maize seed on small farms has increased steadily with no sign of leveling off. The amount of maize handled by the Maize and Produce Marketing Board through 1969 is shown in Table 4. Before the advent of hybrid maize, Kenya fluctuated between slight surpluses and large deficits, depending on the weather conditions. As the amount of hybrid maize increased, deficits were reduced, and large surpluses were produced in 1967 and 1968. The population growth and a mild drought produced a small deficit in 1969.

Table 3. Price of hybrid seed and commercial maize in Kenya (1964-71).

Crop year	Hybrid seed		Commerical maize	
	$/q	$/bu	$/q	$/bu
1964	20.14	5.13	5.04	1.28
1965	20.14	5.13	5.04	1.28
1966	21.69	5.52	5.73	1.46
1967	22.93	5.84	4.34	1.10
1968	22.93	5.84	4.34	1.10
1969	24.51	6.24	3.87	.98
1970	24.51	6.24	4.65	1.18
1971	24.51	6.24	4.65	1.18

Table 4. Maize handled by the Kenya Maize and Produce Board in thousands of metric tons.

Crop year	Purchases	Exports	Imports
1959	150	9	0
1960	144	0	17
1961	149	9	65
1962	203	87	0
1963	98	53	0
1964	106	0	14
1965	134	0	192
1966	228	63	0
1967	326	271	0
1968	294	230	0
1969	192	0	13

Sorghum and Millet Improvement in Uganda

Sorghum and millet are the major cereals in Uganda. Sorghum usually is grown in the second-season rains and is harvested early in the dry season. An excellent variety of medium height 'Serena' was developed by H. Doggett, the EAAFRO breeder, and released several years ago; a new hybrid, 'Hijak,' was released in 1970. Progress had been hampered because satisfactory techniques and breeding methods to develop high-yielding, insect-resistant varieties were not available.

The central shoot fly (*Antherigia* sp.) and the stem borers (*Chilo zonellis* and *Buseola fusca*) cause serious losses in susceptible varieties (5, 8, 9). Chemical control is expensive and impractical. Serena and selections from Serena crosses, such as 3DX57/1, have good tolerance to the shoot fly as shown by the percentages of recovered plants and heads per 100 plants (Table 5). Yields of these varieties were not reduced as much under severe infestations as were those of the less tolerant varieties.

Sorghum yields and responses to fertilizer can be reduced greatly by stem borers (Table 6). The former Major Cereals entomologist, K. J. Starks, developed a technique for obtaining uniform infestations of shoot flies (8) so that the breeder and entomologist can develop more resistant varieties, and D. Barry has been working out the techniques for artificially rearing the stem borers.

Modifications have been outlined to apply a comprehensive breeding system to sorghum (4). Populations have been developed and are under selection for insect resistance and for high yield under improved cultural conditions. Preliminary evaluations of these new populations after only one cycle of S_1 selection are most encouraging.

Extensive fertilizer trials on farmers' fields by a Major Cereals agronomist, G. Schumaker, have shown that yields can be increased from 9 to 27 q/ha with moderate rates of nitrogen and phosphorus (Fig. 8). Better cultural practices and improved varieties with insect resistance would permit even higher responses (9).

Although the yield potential of finger millet (*Eleusine coracana*) seems much less than for sorghum,

Table 5. Grain yields and shoot fly recovery ratings on sorghum varieties in Uganda [from Doggett et al. (5)].

Variety	Shoot fly % recovered	Heads per 100 plants	Yield q/ha
Serena	75.0	186	25.6
3DX 57/1	63.3	182	27.0
5DX 61/6/2	45.8	112	16.8
SB77	44.2	88	13.6
Redlan	40.8	78	12.3
SUK 1	29.2	97	11.6
CK60	25.0	51	7.8
LSD, P = 0.05	9.5	28	5.2

Table 6. Performance of the Serena sorghum variety at Serere, Uganda, as affected by fertilizer and stem borer infestation in 1968* [from Starks et al. (9)].

Fertilizer, q/ha† N	Fertilizer, q/ha† P_2O_5	Avg. plant height, cm: Uninfested plots	Avg. plant height, cm: Infested plots	Grain yield q/ha: Uninfested plots	Grain yield q/ha: Infested plots
0	0	136.8	121.2	39.5	26.8
0	0.9	143.7	131.7	43.4	30.3
0	1.8	144.2	133.3	42.3	29.2
0.9	0	130.5	129.8	41.5	34.4
0.9	0.9	155.2	136.5	62.7	46.1
0.9	1.8	155.3	142.5	63.5	45.7
1.8	0	134.2	129.5	41.3	31.5
1.8	0.9	148.7	144.2	56.0	47.9
1.8	1.8	155.7	146.8	63.5	40.1
Mean		144.9	135.1	50.4	36.9
LSD, P=0.05		8.0	8.0	0.6	0.6
CV, %		7.0	7.0	11.0	11.0

* Data are averages of 2 trials. † To change quintals/hectare to lb/acre multiply by 89.2

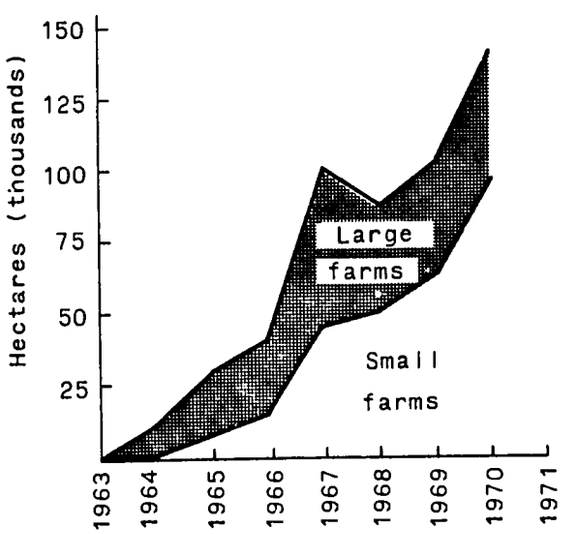

Fig. 7. Estimated hectares planted to commercial hybrid maize on small and large farms in Kenya.

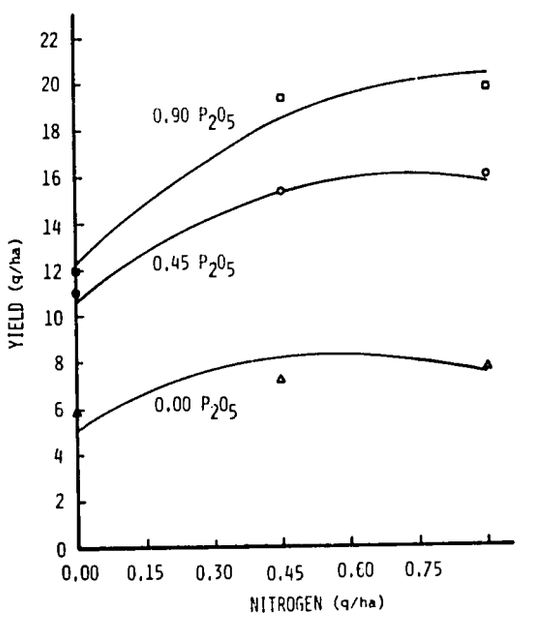

Fig. 8. Nitrogen and phosphorus responses for Serena sorghum obtained from 4 × 4 factorial trials grown in farmers' fields near Serere, Uganda.

large acreages were grown in the first rainy season because of the drying and storing qualities of this small-seeded crop. Extensive trials have not shown great differences in yields among local or the better introduced varieties. The variety 'Engenyi,' selected from these trials, is expected to be released for use while a Major Cereals millet breeder, L. V. Peters, is developing new varieties.

Bulrush millet seems to have a good yield potential with few insect and disease problems. Preliminary evaluations indicate that the protein quantity is high and that the quality is good. An extensive breeding program based on a comprehensive breeding system is well under way.

Cereal Processing Laboratory

Bird damage to the bulrush millet and sorghum crops usually is severe throughout East Africa. Losses in brown-seeded sorghum varieties, which have a higher tannin content, are much less than those in white-seeded types. However, brown-seeded varieties are much less palatable for human consumption. The cereal-processing laboratory staff of EAIRO in Nairobi has been studying methods of removing the seed coat.

A Major Cereals chemist, A. Shepherd, has shown that a small rice polisher produces an excellent product from the white flinty seeds of sorghum varieties that have the tan plant color when approximately 5% of the seed coat is removed. The polished kernels can be used as a rice substitute or they can be ground and used in the traditional cereal preparation "posho." The rice polisher is now being evaluated in a village operation. This process does not appear practical for colored sorghum because 20 to 25% of the kernel must be removed to eliminate colored pigments. Because the outer layers are highest in protein, the finished product is not desirable from a nutritional point of view.

The cereal laboratory is also evaluating various sorghum products in commercial preparations. New recipes for home utilization of sorghum products from the polished whole or cracked kernels and semolina flour have been developed in cooperation with the Home Economics Department, University of Nairobi. These products created considerable interest when demonstrated at agricultural shows in Kenya and Tanzania.

The protein quality and quantity of sorghum, finger millet and maize are low. Because posho made from ground meal of these cereals is the main food for babies after weaning, severe protein deficiencies often develop. The cereal laboratory is cooperating with breeders in developing new varieties with protein of higher biological value.

Eastern African Regional Activities and Training

Regional cereal workshop conferences have been held biennially since 1965. The first two were held at Kitale, Kenya, and Serere, Uganda; the 1969 meetings were held at Chilanga, Zambia, and Lilongwe, Malawi; and the 1971 meeting was held in Ethiopia.

Most east African countries have participated in these workshops, and the exchange of ideas, techniques, and breeding materials has been invaluable. Regional trials have been organized to evaluate introduced varieties to facilitate development of diverse breeding populations and to evaluate improved East African varieties and hybrids. At each location where the trial was grown, local farmers' strains were collected and used as check entries.

Table 7. Yields in q/ha of varieties in East African Maize Variety Trials in 1968-69.*

Country	Hybrids			Local variety	
	H611(R)C1	H632	SR52	Improved	Farmer's
		High Altitude			
Kenya	104.7	84.7	69.0	69.7	69.8
Ethiopia	70.1	66.2	62.2	51.4	53.7
		Medium Altitude			
Kenya	54.2	47.4	38.1	41.1	32.0
Tanzania	38.0	33.2	38.8	25.9	24.1
Uganda	36.2	42.6	46.8	30.6	33.1
Zambia	49.8	58.5	61.0	42.2	48.6
Malawi	40.5	45.2	52.8	41.7	33.0
Cameroun	74.2	82.2	79.7	39.1	51.4

* From the 1970 Annual Report of the Major Cereals in Africa Project.

Trials with 23 maize varieties were distributed to more than 50 locations in 1968, and 38 trials were completed and summarized. Hybrids that will greatly outyield local farmers' strains and the local varieties in all countries have been identified (Table 7). The Kenya hybrids, H611C, H613C, and H632, produced by the Kenya Seed Company were recommended at the high and medium elevations, except in Zambia and Malawi. The Rhodesian hybrid SR52, produced by the Zambian Seed Growers Association, was recommended in Malawi and Zambia. SR52 also yielded well in Uganda and Tanzania unless either blight (*Helminthosporium turcicum* Pass.) or rust (*Puccinia sorghi* Schw.) was severe. Maize breeders in Tanzania and Zambia were also using a comprehensive breeding system (6), and varieties and variety crosses from their breeding programs were very promising.

Regional sorghum trials have shown that Serena is well adapted to Kenya and also to Tanzania. The new hybrids and varieties from Serere also seem to have a good potential in other areas. Regional millet trials have been established and will provide information on the adaptability of the new varieties and hybrids.

On-the-job training has been provided by the maize breeding program at Kitale to one Tanzanian and to several Kenyans. The Kenyans are now conducting breeding programs for the Ministry of Agriculture and one has been employed by the Kenya Seed Company. Similar training is provided by the sorghum and millet program in Uganda. Fellowships have been provided by the U.S. Agency for International Development and by the Rockefeller Foundation for graduate work in the U.S.

Cereal Improvement in Nigeria

The soils of West Africa are highly weathered, moderately acid, and low in organic matter with low base exchange capacity. In the Sudan Zone, periods of droughts are common. Under these climatic conditions sorghum and millets usually are more productive and reliable than maize; however, average sorghum yields are approximately 6 q/ha. In the Guinea Zone rainfall is more dependable and extends over a long season from June to October. Local varieties grow very tall and mature at the end of the rains.

A figure of 4 million hectares is given for sorghum in Nigeria which is approximately half of the West African sorghum hectarage. Bulrush millet is planted

to another 3 million hectares in Nigeria. Not only does Nigeria have about half of the sorghum and millet production of West Africa but it also has about half of the population.

Sorghum and Millet Breeding

At Ahmadu Bello University, Zaria, two sorghum breeders, D. Curtis and D. Andrews, made many collections and, with an extensive breeding program, were able to develop improved local varieties 15 to 20% higher yielding than farmers' strains. These varieties were very tall and their main response to increased plant populations and fertilizer was increased lodging. The improved varieties were similar in appearance to the ones the farmers had been growing and the small yield increase was not readily discernable. Hence, their acceptance by farmers has been limited. To make an impact on the farmer, he must be given a "new model" which differs in appearance from his traditional varieties and which will give him a 50% or greater increase in yield when grown as recommended.

Improved long-season varieties and hybrids of intermediate height have been developed. Short Kaura, a mutant selection from a Nigerian cultivar which yields approximately 70% more than the tall varieties (2), was released in 1969 and two other semi-dwarf varieties were released in 1971.

A random-mating breeding population has been developed from local collections, introduced varieties, and selections from crosses made in 1966 involving the World Collection. A male-sterile gene, ms_7, isolated by breeders at Zaria from an irradiated local variety was used to enforce recombination. A population of intermediate height with white grain has resulted from the mass-selection practiced. Recurrent selection, S_1 selection (4), will be used to improve yield, disease and insect resistance, and agronomic characteristics. The improved population should be a valuable source of both pure-line varieties and parents for improved hybrids.

Breeders have now identified shorter, earlier hybrid sorghum varieties that give three- or four-fold increases in yield in the Sudan Zone when grown with the recommended cultural practices as shown by the yield of NK300 and 137-62 in Table 8. Sh-11 is a typical, tall, improved local variety. The seed of NK300 is red and would not be acceptable to most people. Varieties and hybrids with similar yields, but with acceptable quality, are being developed.

Use of these improved, short, early types poses a real problem in the Guinea Savana because of the long rainy season. If planted at the beginning of the rains, they mature before the rains cease and quality deteriorates rapidly unless they have the brown seed coat. If planting is delayed, yields are reduced drastically because of the build-up of insect pests and diseases.

Insect pests can be a serious problem for sorghum in West Africa. Resistance to the central shoot fly, the stem borer, and midge are needed. A Major Cereals entomologist, G. T. York, is working closely with the breeders to develop resistant varieties. Yield losses from the parasitic witchweed, *Striga hermonthica*, can be very great. Local varieties have some tolerance to *Striga* that must be transferred to new varieties developed from exotic germ plasm. The World Sorghum Collection is being screened for new sources of *Striga* tolerance or resistance.

Downy mildew (*Sclerospora sorghi* Weston & Uppal) is potentially destructive and a disease nursery is being established by a Major Cereals pathologist, S. B. King. When a high infestation level has been attained in this disease nursery, screening for resistance should be effective. Pathogenic variability of covered smut (*Sphacelotheca sorghi* (Lk.) Clint.) is being studied in regional trials in eight West African countries. Breeding materials are being screened for head smut reaction by use of artificial inoculation, and a head smut disease nursery for screening against natural infection is being established.

The improvement of bulrush millet is receiving considerable attention. New populations are being formed from local materials and the superior entries of the World Collection. Shorter, lodging-resistant types with resistance to downy mildew and smut (*Tolyposporium pencillariae*) are needed. Although yields of improved varieties generally range from 10 to 25 q/ha, the improved 'Bornu' variety has yielded 44 q/ha at Samaru.

Maize Breeding

Maize seems to have tremendous potential in areas of adequate rainfall when improved cultural practices are used. Without fertilizer, maize yields are nil, but with fertilizer and the recommended cultural practices, yields of 65 q/ha can be obtained (Table 9). Maize is affected less by the insect pests and can mature before the end of the rains without loss of yield or quality.

Many improved varieties and collections have been introduced by the Western States/USAID maize breeder, H. C. Wiggin, and by two Major Cereals breeders, J. Craig and O. J. Webster. Some of these varieties and variety crosses have given very high yields at Zaria (Table 10). Selections from the introductions have been used to develop the improved varieties 'SC3' and '094' and other very broad-based composites (NCA, NCB, NCC, NCD) to be used as the main breeding populations. The composite 094 has rust (*Puccinia polysora* Underw.) and blight (*Helminthosporium maydis* Nisik. & Miyake) resistance and has been select-

Table 8. Performance from 11 Regional Sorghum trials (Sudan Zone) in 1969.*

Variety	Country of origin	Average of 11 locations: Yield q/ha	Height, cm	Days to flower	Zaria: Yield q/ha
NK300	USA	34,7	174	63	54,2
137-62	Niger	25,9	173	71	45,1
Serena	Uganda	23,5	178	76	34,7
CSH-1	India	23,4	127	57	33,8
IS9290	Sudan	22,7	190	69	43,0
SH-11	Mali	18,0	326	73	15,8

* From the 1970 Annual Report of the Major Cereals in Africa Project.

Table 9. Performance from 8 regional maize trials in West Africa in 1969.*

Variety	Country of origin	Average at 8 locations: Yield q/ha	Days to flower	Zaria: Yield q/ha
Composite 2	Ghana	36,1	59	66,1
094	Nigeria	35,0	58	62,6
Massayomba	Upper Volta	33,8	57	58,1
BDS	Senegal	32,3	54	60,1
NSI	Nigeria	31,4	62	58,8
Jaune Hatif	Upper Volta	29,7	53	48,5

* From 1970 Annual Report of the Major Cereals in Africa Project.

Table 10. Performance from maize evaluation trials grown near Zaria, Nigeria.

Entry	1967-69 Mean yields q/ha	1969-70 trials Yield q/ha	1969-70 trials Ear height cm
Variety Crosses			
BY × C12	74.0		
A49 × C33	73.3		
BY × A154	72.2		
BY × C10	72.1		
Varieties			
C10 (Cub. 325×USA342)-4#×Dia. V254 #	61.5		
NS1 (Improved local variety)	59.4	54.8	140
A49 (Tsolo, local variety)	56.5		
BY (Synthetic from USA hybrids)	56.2		
A154 (Diacol V101)	53.2		
C12 (Yotoco × Dia. V351)-2#×Dia. V254 #	47.5		
C33 (Diacol V351)	38.6		
094 (Improved composite)		59.6	110
Mexico 5		59.8	160

ed for lower ear placement, lodging resistance, and higher yields. Sources of genetic resistance to blight and rust have been identified and incorporated into the strain of the populations to be selected at Ibadan where these diseases are serious. The Ibadan strains will be improved by one cycle (3 seasons) of S_1 selection per year. The two rainy seasons will be supplemented by irrigation during the dry season. These single gene sources of resistance will not be incorporated into the Zaria strains of NCA and NCB. The yield evaluation trials for S_1 selection will be grown at Zaria but cool winter temperatures only permit one winter season. Hence, recombination and selfing will be done at Ibadan. The breeders hope that the selection of resistant plants in the Zaria strains of NCA and NCB during these two seasons at Ibadan, where high levels of blight and rust occur naturally in the nurseries, will gradually develop multigenic resistance. Plants will be artificially innoculated with blight to insure uniform infections.

The improved Kenya variety, KCE, was introduced and grown on the Mambilla Plateau (approximately 1550 m). In trials during the last four years yields have been more than double the yields of the local varieties. Hence, farmers want to obtain seed of KCE and it is being multiplied by the Northeastern State Ministry of Natural Resources.

An opaque-2 variety 'Western White' developed by Wiggin has been released and distributed to small numbers of farmers. As with most opaque-2 varieties, Western White has not been accepted by the farmers because of its off-white appearance, slowness in drying, and greater susceptibility to ear rots. Opaque-2 strains of NCA and NCB have also been developed. Intense selection for better appearance, resistance to ear rots, and faster drying rates are expected to produce an acceptable variety.

When maize is prepared by the traditional Nigerian method (a wet-milling process), the additional lysine in opaque-2 maize is lost in the decanted liquid. Hence, studies are under way for possible modification of the milling process that might prevent this loss. A considerable amount of maize is eaten green, however, and the extra lysine in opaque-2 varieties is available to the consumer in this form.

Cereal Agronomic Research

Extensive research in management and agronomic practices is needed before high yields of maize, sorghum, and millet can be obtained regularly. A Major Cereals Soil Scientist, K. R. Stockkinger, and Ahmadu Bello staff members have been investigating various aspects. Large nitrogen and phosphorus responses usually are obtained in maize, but these may be limited by deficiencies of other elements such as potassium, magnesium, molybdenum, boron, and zinc. The role of organic matter content on water-holding capacity and cation-exchange capacity needs further investigation. Great variation exists from location to location as to limiting elements. Better techniques, utilizing soil and plant tissue tests, are needed so that recommendations can be made regarding economic levels of fertilizer application.

As new varieties become available and recommended cultural practices are determined, greater attention must be given to extension-liaison activities and seed production. Preliminary seed-production efforts with hybrid sorghum have not been successful, but further investigations should solve current problems. Commercial seed companies have been encouraged to initiate maize hybrid production in Nigeria, and a pilot project hybrid maize has been started in Ghana.

The West African governments have been encouraged to expand their marketing systems to include cereal crops so that farmers can sell their surpluses for a fair price. Of course, the main objective is to produce food crops on fewer acres in order to release land for the production of export crops.

West African Regional Activities and Training

West African workshop conferences were held in 1965 and 1969 at Zaria, Nigeria, and in 1971 at Bambey, Senegal. Simultaneous translations in French and English, both in the conference room and in the field, permitted full participation by all delegates. The papers were published in *African Soils*. These meetings have been very useful in encouraging the exchange of information and genetic materials to maximize the productivity of limited manpower and other resources available.

Regional trials have been organized to evaluate the improved sorghum, millet, and maize varieties. Ecological zones extend in an east-west direction across West Africa south of the Sahara, with rainfall decreasing from the southern (coastal) to the intermediate (Guinea Savana) and northern (Sudan) zones. The coastal zone has two rainy seasons, whereas the other zones have a single season with a progressively shorter period of rainfall toward the north. Sorghum trials indicate the need in each subzone for different varieties which reach maturity at the end of the rains. The same varieties are adapted across West Africa within the subzones. In contrast, maize varieties have a much wider range of adaptation because the husks prevent losses even if they mature before the end of the rains. Extremely low yields have been recorded in many of the regional sorghum and millet trials, indicating a need for more attention to cultural practices and bird control which will permit the varieties to express their full potential.

Funds to train African scientists have been available from local governments, the Rockefeller Foundation, and U.S. Agency for International Development and other sources. Graduate students are encouraged to obtain their M.S. from local universities, such as

Ahmadu Bello University, and to investigate local problems for their thesis research. However, fellowships are provided to permit them to attend U.S. universities for 12 months to supplement the courses of local universities. Fellowships are also provided to complete all requirements in the U.S.

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