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HOW HYBRID SEED IS REVOLUTIONIZING MAIZE GROWING IN KENYA

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Due to the rapidly increasing world population, it is essential to obtain higher yields from staple food crops. This vital problem has frequently been discussed at meetings of the American Society of Agronomy (2), and at the 1966 gathering Dr. Wortman (3) outlined some important principles which should be followed when attempts are made to increase the food production of developing countries in particular. This paper may be regarded as a case study of the application of these principles. It is also an example of successful cooperation between expatriate and local staff of the United States Department of Agriculture, an African Department of Agriculture, and a commercial African seed company. Grateful acknowledgment is made of joint use of funds from the Kenya Government, A.I.D., the Rockefeller Foundation, the British Ministry of Overseas Development, and last, but by no means least, a large contribution from the maize farmers themselves. No single organization could have carried out what has been achieved through cooperation.

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There is a huge difference, which is often not understood or may be overlooked, between crop improvement programs designed for developed countries and similar projects for developing countries. In developed countries, reasonably sound agricultural systems and methods have been developed by generations of farmers through a process of trial and error. Over centuries of experience, farmers learned which factors had the biggest effects on yields, and the necessity for such practices as early planting, clean weeding and crop rotation was fully appreciated. In recent times, agricultural research workers have investigated these systems and practices and have found out why many of them are basically sound. A relatively high standard of crop husbandry has been established as normal practice on nearly all farms. When research workers produce a new crop variety, or a new production method, these innovations can be and usually are adopted very quickly by farmers, who derive immediate economic benefits by so doing. Results of research work are directly applicable to the local farmer because the standards of crop husbandry are very similar. Further improvements in crop yields can be obtained only by more intensified efforts in narrower fields.

In developing countries, the situation is often completely different, because sound agricultural systems have in many cases never evolved, with the result that the standards of crop husbandry may be abysmally low. Research workers in these countries frequently carry out trials and experiments on their own research stations under good husbandry conditions, and then make recommendations based on these results without considering sufficiently the vast discrepancies in husbandry standards. The local farmers may be persuaded to spend money on trying out some of these recommendations but generally the

results are disappointing because the recommendations are applied under bad conditions. In order to improve food crop yields, the most rapid results are obtained by simultaneously raising the levels of all factors which influence yields; rather than by raising the level of one factor at a time. A major alteration of only one factor may merely upset the equilibrium.

In Kenya, average yields of the staple food crop, maize, have increased greatly in many areas since 1964 because a determined effort has been made to improve the levels of all the important factors simultaneously. The success of this maize improvement program is mainly due to the following factors:

1. An effective breeding program which produced hybrids with a superiority over local varieties of 30-80%, depending on altitude.

2. An agronomic research program which found out where and how to grow these hybrids in order to obtain their maximum potential.

3. An active field extension staff which organised a campaign to place a demonstration plot of properly grown hybrid maize in each locality within walking distance of most farmers.

4. A commercial seed firm which organised the production and distribution of high quality hybrid seed at a reasonable cost.

5. An organisation that combined under one direction all these stages from basic research, through applied research to development and extension; and integrated all parts of the program to a policy of using improved seed of the hybrids as a lever to stimulate better husbandry standards.

1. Breeding the Hybrids

The technical aspects of the comprehensive breeding system developed by the Kenya Maize Research Section have been described elsewhere (1). Modern

methods and recent theoretical findings have been combined into a systematic approach designed to give maximum progress for minimum cost. Introductions of new accessions are particularly important in a country where the crop is not indigenous and little previous work has been done. In Kenya, opportunity was taken of the fact that we have the same ecological conditions as certain areas of Latin American, on the Equator and at high altitude, so that we can use directly some of the great genetical range of variability of maize collected by Rockefeller Foundation and other workers and described in their series of bulletins on races of maize. A major "breakthrough" was made with the achievment of good crossing value between Kenya and Latin American maize types. The breeding program is now designed to exploit this breakthrough as rapidly as possible. Similar situations exist in other crops (In Kenya we are now trying improved bean varieties from the Latin American center of origin instead of looking only to Europe or the United States for introductions.).

Breeding methods were adapted to this special situation so that more rapid progress has been made than would have been expected from conventional methods appropriate to different situations in temperate countries. Flexibility of the system was considered most important. The system used permits the production of hybrids, improved synthetic or composite varieties. We did not know if peasant subsistence farmers could be persuaded of the benefits of paying the necessarily high price each year for first generation hybrid seed. If much second generation seed was grown, yields would be decreased instead of increased. The extension service of agricultural officers, in the special effort described later, have in fact convinced farmers of the

value of hybrid seed. The difficulties have been overcome and our fears proved groundless; so that work is now concentrated on the development of hybrids. However, the breeding of the synthetics and composites is not wasted work because they were deliberately planned as improvements of source material from which to extract better hybrids for the future. Also, varietal hybrid crosses between improved composites and synthetics can be achieved further than conventional hybrids and, in our special situation, modern refined recurrent selection methods in the composites are raising the yield levels of the hybrid crosses between them at a much greater rate of increase per year than by conventional inbreeding. Orthodox hybrids have been as successful as in other countries but the new types of hybrids, possible under our special circumstances, are rapidly replacing them because of the greater yield increases obtained.

Table I illustrates the improvements made by this breeding system at Kitale for late maturity maize. Kitale Synthetic II and Kitale Synthetic III were produced from Kitale Station open-pollinated maize by one and two cycles respectively of recurrent selection for general combining ability. The superiority of Kitale III over Kitale II is also carried through into the varietal cross. Hybrid 611B containing Kitale III is superior to hybrid 611 containing Kitale II. Inbred lines F and G were developed from the elite lines used to form Kitale II and are clearly superior to the earlier inbred lines D and E.

Composites from local varieties and from material introduced in 1959 were available for yield trials for the first time in 1966. The results are shown in Table II. Kitale Composite A is the advanced generation of Kitale II x Ecuador 573. Kitale Composite D was developed from several sources of elite

Kenya varieties whereas Kitale Composite C was developed from Ec.573 and additional selected Central American varieties. Composite D includes all entries in both B and C. Composite E includes all entries in D plus additional accessions that had other desirable characteristics. The superiority of composites D and E over the others clearly demonstrates the importance of using a wide range of divergent material to form the breeding composites. The next stage will be to compare the variety crosses of these new composites with current hybrids. Intensive recurrent selection has already been started in composites A, B, C and E.

There is very good reason to think that these developments, not so easily obtained in other countries, will soon lead to hybrids with even greater yield increases.

Similar progess is now being obtained at Kakamega and Katumani in breeding early and medium maturity maize, using the ideas and methods from Kitale, in programs entirely financed by Kenya without any outside assistance.

2. Determining the Agronomic Requirements

Prior to the current maize improvement program, the average yield of maise in Kenya was estimated to be about 1,000 kg/ha. In a series of district maize variety trials, which have been carried out for several years under good husbandry conditions, the local farmer's maize included at each location yielded an average of 4,040 kg/ha in 1964, 3,280 kg/ha in 1965 and 4,750 kg/ha in 1966. In fertiliser trials carried out under good husbandry conditions with local and improved types of maize, the yields of the control plots without fertilisers were several times greater than the national average yields. Since the low maize yields in Kenya apparently are not due

primarily to the genotype of the local maize, nor to severe nutrient deficiencies, the poor standards of basic husbandry seem to be a major factor. In order to verify this and determine objectively the relative importance of husbandry factors, maize varieties, and fertiliser requirements and the interactions of these factors, a series of multifactorial experiments were laid down in 1966 at 6 locations in Western Kenya. Two levels of six of the main agronomic factors influencing yields were included in a 2^6 factorial design, with the high level representing currently recommended good husbandry, and the low level representing a defined level of bad husbandry as often seen under normal farming conditions. The details of the six factors and the treatment levels are shown in Table 3 along with the average yields which were obtained, and also the approximate differences in costs between obtaining the high and low levels of each factor. Under these conditions the time of planting and the type of maize clearly have biggest effects on yields. The plant population and standard of weeding are next in importance, whereas the fertilisers are relatively least important.

There were big interactions between the time of planting, the type of maize and the plant populations, so that in order to obtain the highest yields from the hybrid, it was essential that these factors were at the correct level. When this was done, 8030 kg/ha were obtained.

These results confirm that Kenya's low average yields are probably due to all factors being at the low levels. Yields can be improved greatly, at a negligible cost, by concentrating on such simple points as (1) good land preparation, (2) early planting, (3) the use of hybrid seed, and (4) planting at the correct population. More expensive inputs such as fertilisers cannot

give profitable returns when used under conditions of poor husbandry; and it is wrong to advise farmers, especially small farmers who are short of capital, to spend money on fertilisers before they have raised their husbandry standards to levels at which fertilisers can be profitable.

In addition to this evaluation of husbandry factors, other agronomic investigations are carried out to determine the optimum levels of individual factors, such as the best plant populations for the new hybrids, the rates of fertilisers which should be applied on various different soil types, and the best types of improved maize for the various different ecological zones. These experiments, which are conducted at good husbandry levels, are laid down over a wide range of altitudes, and on as many different soil types as possible.

From the results of these investigations, recommendations are prepared on varieties and cultural practices. These recommendations also take into account practical points which have been noted from farmers in the course of the annual maize tours, which are made during the growing season to various parts of the country. The recommendations are presented to maize growers in several ways. Every year, just before planting time, the latest recommendations are published in the "Kenya Weekly News" and, in Swahili, in "Ukulima was Kisasa". These publications are widely read by literate farmers. Reprints of these articles are circulated to extension staff in all districts, who digest the information and pass it on to their junior staff. Summaries of these recommendations are printed in leaflets in English and Swahili by the Kenya Seed Company, who insert one leaflet into every packet of seed sold for hand-planting to the smaller farmers.

To ensure that extension staff are up-to-date with the latest information, seminars are held before planting time in the main maize-growing areas, and at these meetings there is a direct exchange of information between the extension staff and the research workers. During the annual maize tours, the research workers visit farmers' fields accompanied by the local extension staff, and observe how the various recommendations are working under farming conditions. Another way in which the research work is publicised is by holding annual field days on the research stations. During recent years the attendances at such events have frequently exceeded 1,000 visitors. Although the maize research team is very interested in following-up the results of this work, the main extension effort must naturally come from the field extension officers of the Agricultural Department.

3. The Extension Program

Effective breeding and agronomic research will not benefit the developing countries unless the local farmers buy the improved seed and grow it with the recommended cultural practices. Farmers throughout the world tend to be conservative. If they have always grown a crop in the same manner as their fathers and grandfathers have done, they feel they know how to grow it and do not need advice. This sociological problem seems to be one of the major obstacles to improving crop production.

Prior to 1964, Kenya had no better success than most other countries in overcoming this problem. Kitale II had been available since 1960 except in certain areas but had little impact on the maize industry even though research stations obtained good yields with it.

Success came only with the release of a new type of maize - Hybrid maize. Farmers were advised not to grow this new crop unless they were good farmers willing to give it the required attention including all recommended cultural practices. If they were good farmers willing to carry out these practices, however, they could get very high yields of maize.

Farming, ignorance and poverty are closely associated in the minds of some people, especially in countries of peasant subsistence farmers. It has helped to overcome this difficulty to some extent to hold out hybrid maize as a reward and privilege to progressive farmers willing to adopt modern and scientific methods. They were told that hybrid maize has the potential of high yield but that hybrid must be planted early, the land must be properly prepared for hybrid, hybrid needs full stands, hybrid needs weeding, and so on. It is little use preaching these things about maize--though they are equally true of all maize--but farmers will listen when these things are said about hybrids because hybrids are new and they do not know how hybrids are planted. It is a big psychological advantage we have used in our extension work.

In order to illustrate these facts, demonstration plots were organised by the extension field staff on local farmer's fields. Farmers are usually sceptical of results obtained on government stations. They say that if government gave them tractors and if they had as much money to waste as research stations they would never be hungry. On the other hand, if they see that one of their neighbours can produce good maize on his farm, they will try to do a better job than he did. In addition, many small scale farmers cannot read the technical journals and research reports and they are likely

to forget information presented as lectures. But such farmers will readily learn by seeing and doing.

Lack of education and a low cash income of peasant subsistence farmers do not necessarily mean that agricultural extension methods will not work. What it does mean is that completely different methods are needed under these special circumstances.

Since the small scale farmers have a long tradition in growing maize and other crops, the demonstration plots must be used to educate them out of the traditional approach, not by criticising their present methods but by demonstrating the superiority of improved methods. The demonstration plot should be strategically situated so that it is accessible and conspicuous to as many farmers as possible and it should be typical of neighbouring farms. The farmer on whose land it is sited must command local respect but his public status should not be elevated by wealth or politics. (These people have the same disadvantages as research stations.) He should understand fully what is involved in his participation as a demonstration farmer.

In Kenya, a package deal was offered to farmers selected to participate. If the farmer agreed to buy hybrid seed, insecticide, and fertiliser and to carry out the recommended cultural practices on a one-acre plot, the agricultural instructor would advise him at all stages and see that everything was done correctly. A fertiliser company provided the fertiliser at a reduced cost for the first demonstrations. At planting time the agricultural instructor and the demonstration farmer invited the local farmers in for a field day to see how the land was prepared and planted. The importance of proper land preparation, early planting, proper plant populations and weed control were

stressed as these factors cost the farmer very little yet give large increases in yield. At harvest time the neighbours were again invited for another field day to see what had been produced. The farmer was encouraged to feel that it was his demonstration and not a Department of Agriculture demonstration. The farmer himself was urged to do the talking if necessary by asking him questions how he measured the correct rate of fertiliser, etc., although the agricultural instructor may have discussed with him previously major points to be covered. Comparisons of 3,500 to 5,000 kg/ha on the demonstration plots with 800 - 1,500 kg/ha on surrounding farms are so striking that many farmers are compelled to order hybrid seed the following year and to grow it under improved cultural conditions with similar results. These demonstration plots were increased as rapidly as it was possible to do in Kenya while maintaining adequate supervision. The goal was a demonstration within walking distance of every small scale farmer, and in 1965 no less than 5,000 were grown. The impact has been fantastically good, most heartening and greatly exceeding expectations. Similar methods are now being used in demonstration plots for cotton and may soon be extended to other crops.

4. Seed Production and Distribution

In developed countries there are adequate numbers of seed producing and distributing firms to ensure that the results of the breeding programs are made quickly and easily available to farmers. However, in developing countries this situation hardly ever exists and in many cases seed is produced and distributed only by Government agencies and stations. This method is often inefficient and expensive as has been shown by very unfortunate experience in many different countries in the world. Kenya is fortunate because

when hybrid seed production was started in 1963, it was undertaken by a commercial seed firm, the Kenya Seed Company, Limited, based at Kitale. This firm, an established producer of tropical pasture and sunflower seeds, was able to add hybrid maize seed production to its existing enterprises without going through a difficult organisational stage. Under an agreement with the Kenya Government, this Company was given the sole right for production and distribution of hybrid seed in Kenya and in return the Government retained a measure of control over the price and other policy matters.

Hybrid seed production is relatively easy in Kenya compared with other developing countries because it can be done on large scale commercial farms in the Trans Nzoia district where the seed factory is situated. The Seed Company makes individual contracts with a fairly large number of individual farmers. Only certified hybrid seed can be sold and seed is inspected by Government inspectors and must meet standards laid down in new seed legislation drawn up specially for the purpose, with standards equal to or higher than the International Crop Improvement Association. The growers harvest the seed after it has dried in the field, then sort, shell and deliver the seed to the Kenya Seed Company where it is cleaned, graded and bagged. During all stages of production from planting to bagging, the technical staff of the Seed Company exercise constant supervision over all the processes and checks are made by the inspectors. The staff of the Seed Company include two former maize breeders.

The amount of hybrid maize seed grown has increased very rapidly indeed since 1963 as shown in Table 4. To cope with this expansion, the Seed Company has had to increase its technical staff and to invest substantial

amounts in proper cleaning, storage and processing equipment and in buildings.

In other countries, in Latin America and Asia, seed production and distribution has been the weakest link in similar efforts with hybrid seed. The technical complexity and the size of operation needed are very great. In Kenya we are convinced that Government is not the right type of organization for the task--lacking financial flexibility, incentive and drive--and we realise that the scale and rapidity of expansion, also the high quality of the hybrid seed, has depended on our commercial seed company.

It has also proved rather difficult to build up an efficient distribution network, since the seed is required in some very remote areas of the country. The large commercial retail organisations including fertiliser companies and farmers' cooperatives which act as agents for the company, generally have branches and depots only in the main towns and villages, and, therefore, the small farmers may sometimes have to travel large distances to collect their seed and also their fertilisers. The seed is packaged in 20 lb bags sufficient to plant 1 acre to simplify distribution problems.

As the hybrid seed became more popular it was clear that the seed and also fertilisers should be distributed from as many centres as possible. Due to increased demand, the retail organisation and the local co-operatives are showing more interest in establishing additional distribution centres as they now realise that more business can be done in this way.

Since more and more farmers are planting the hybrid seed together with fertilisers and other improved husbandry standards, more surplus maize is expected to be produced by the small farmers. Efficient marketing arrangements for the surplus will need to be made so that the farmers can reap the benefits

in cash of their improved farming methods. Studies are now being made of increased use for livestock feeding and the possibility of a maize products factory.

Conclusion

Farmers are now obtaining 2 or 3-fold yield increases from hybrid seed. The breeders only claim about 30% increase due to genetical advantage; the rest is due to better cultural practices. A very conservative estimate is that the 300,000 acres planted this year will produce an increase worth about seven million dollars, or about fifty times the total research cost. It is much cheaper than growing this maize in the United States and shipping it to Kenya, apart from factors concerned with self-sufficiency and the degradation of dependance on hand-outs.

In Kenya maize growing has improved greatly in the last few years due to a co-ordinated program incorporating the breeding of better types of maize and the release of hybrid varieties, the determination of their agronomic requirements, the production and distribution of the improved seed on a commercial scale and the demonstration by field staff of how the better methods and improved seed can result in greatly increased yields on the farmer's own land.

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Table 1 - MEAN YIELDS OF KENYA VARIETIES FROM 15 LOCATIONS IN 1965 AND 20 LOCATIONS IN 1966

VARIETY	PEDIGREE	YEAR OF RELEASE	MEAN YIELDS 100 kg/ha	%
Kitale Station		--	--	93*
Kitale Synthetic II		1960	43.2	100
Kitale Synthetic III		1965	--	107*
Hybrid 611	(Kitale II x Ec.573)	1964	--	120*
Hybrid 611B	(Kitale III x Ex.573)	1966	56.8	131
Hybrid 621	(A x G) (Dx E)	1964	--	124*
Hybrid 632	(A x G) F	1965	56.5	131
Hybrid 612	(A x G) x Ec.573	1965	56.8	131
Hybrid 613B	(F x G) x Ec. 573	1966	--	143**
L.S.D. .05			3.5	

* Data available for 1965 only.

** Data available for 1966 only.

Table 2 - MEAN YIELDS OF KENYA COMPOSITE VARIETIES AND VARIETY CROSSES FROM 10 LOCATIONS IN 1966

VARIETY	MEAN YIELD	
	100 kg/ha	%
Kitale Synthetic II	50.9	100
Ecuador 573	38.7	76
Kitale Composite A	51.2	101
B	54.1	106
C	53.5	105
D	59.7	117
E	57.5	113
Kitale II x Ec573	62.7	123
Kitale Composite B x Kitale Composite C	59.8	117
L.S.D. (.05)	5.8	

Table 3 - AVERAGE YIELDS FROM 6 MULTIFACTORIAL HUSBANDRY TRIALS 1966

10^2 kg/ha

Factor	Treatment	Yields	Differences	Cost Differences between treatment levels (per ha)
1. Time of planting	Early in rains	52.6	18.5	Nil
	28 days later	34.1		
2. Plants per hectare	36,000	49.3	11.8	$ 2.80
	18,000	37.5		
3. Type of maize	Hybrid 613A	52.7	18.6	$ 4.18
	Local maize	34.1		
4. Standard of weeding	Clean weeding	48.2	9.6	$ 6.96
	One late weeding	38.6		
5. P_2O_5 at planting (kg/ha)	56	44.6	2.4	$11.14
	0	42.2		
6. N top-crossing (kg/ha)	79	44.8	2.7	$27.84
	0	42.1		

Table 4 - ACREAGES OF HYBRID SEED PRODUCTION AND COMMERCIAL HYBRID MAIZE GROWN IN KENYA

Year	Seed Production	Commercial Hybrids		
		Large scale farms	Small scale farms	Total
1963	321	390	10	400
1964	526	33,500	1,500	35,000
1965	1,057	52,000	18,000	70,000
1966	3,145	50,000	50,000	100,000
1967	1,635	100,000	200,000	300,000