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OF
THE NEW CEREAL VARIETIES

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GLOBAL CROP PAPER
CORN

THE NEW CEREAL VARIETIES

Global Crop Paper--Corn

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Summary

Success in improving corn production has been achieved when all factors in the Cereal Welfare Formula presented by Mr. E. Rice have been available. These factors are: (1) plant breeding research, (2) agronomic research, (3) seed production, (4) distribution of seed, fertilizer, and pesticides, (5) education and training of local research and extension staff, (6) a vigorous extension program, (7) adequate credit facilities, (8) a transportation network, (9) a marketing organization with fair prices, (10) storage facilities, and (11) official government support and strong participation.

A full scale systems approach has not been used with corn as yet; but the development of a management system including these factors should be most useful. The analysis of factors presently available and the identification of those factors limiting improvement could greatly increase the efficiency of future corn improvement programs by AID.

Many of these factors can be provided most efficiently by the private sector. Encouragement and stimulation of the private sector would be most desirable.

Thailand has 90% of the corn hectarage in improved varieties with average yields in excess of 2.5 tons/ha. The development of variety-cross hybrids responsive to fertilizer, seed production and distribution of these hybrid varieties by a commercial company, and the expansion of credit to increase the use of fertilizer should result in even greater corn improvement.

All large scale farms in Kenya (approximately half are now owned by Kenyans) are now using hybrid varieties and improved cultural practices with average yields of 2.8 tons/ha. In some areas as many as one fourth of the small-scale farmers are using the package program for corn improvement. The expansion of credit facilities and more vigorous efforts by the extension service are required to extend this program to additional farmers.

In Mexico the corn improvement has reached the large-scale farmer but not the small scale-farmers who are in the vast majority. Seed production and distri-

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bution by the private sector, increased extension activity, and credit are required to improve corn production on these small farms.

The first hybrids had not been selected for response to improved cultural practices and fertilizer in Brazil, but the Breeding Research Program has changed their policy and has developed varieties with greater responses. Fertilizer was not in wide scale use because of lack of credit to the farmers and the smaller profit ratio due to unresponsive hybrids and high transportation costs. These factors are being corrected and this was reflected in the 1968 production when the effect of a severe drought on total production is taken into account.

El Salvador is probably also on the verge of large increases in production if credit can be provided for the increased use of fertilizer. An extensive AID sponsored demonstration program by the extension service has resulted in 30% of the hectarage being planted to hybrid varieties in 1968; but with a very small increase in the use of fertilizer. All factors except credit seem to be present.

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S. A. Eberhart 1/

I. The Crop

1. Although improvement in corn production has not made the headlines as has the improvement of other cereals, progress is being made and the potential increases in average yields are probably even greater than with the small grain cereals. Corn is the basic food crop of Central and South America and much of Africa; and hence, it deserves considerable attention. Reliable estimates of the area devoted to corn production and average yields with the unimproved and improved varieties are very difficult to obtain. Some very crude estimates are given in Table 1. The estimates from the large scale farms in Kenya are probably the most reliable figures available. Although average yields have doubled with the adoption of the package improvement program including hybrid varieties, improved agronomic practices and fertilizer, there is still the potential for a further doubling of the yields with more attention to the same factors as pointed out later on in the paper.

2. With the maize improvement in Kenya, a rather large surplus has been developed in the last two years. In order to be able to sell this surplus on the world market, the Kenya government has been forced to reduce the price of maize for growers from $58.10 to $43.50 per ton in 1968 and $38.60 in 1969. This has encouraged the large-scale farmers to devote only the better areas to corn and go to alternative crops--mainly pastures with increased livestock production. Although the small-scale farmers have been producing at a somewhat lower yield level with the unimproved varieties, there is evidence to indicate that they have also been able to double their yields with the package deal for corn improvement. The increased acreage planted to hybrids by the small scale farmers is shown in Table 2. This leveled off somewhat in 1968 because of the reduction in price as well as credit and distribution problems. Although only 10% of the Kenya hectarage is in hybrids, much of the total area is marginal land unsuited to corn. In many of the areas where the hybrids are adapted, 25% of the corn acreage is planted to

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Table 1. Estimates of current maize production and production prior to the availability of improved varieties in the countries under review.

Country	Unimproved Varieties		Improved Varieties		Hybrid Varieties		Total
	ha (thousands)	Yield	ha (thousands)	Yield	ha (thousands)	Yield	ha (thousands)
Kenya							
Large Scale							
1958-63	0	--	60	1.36	0	--	60
1967-68	0	--	2	1.36	48	2.82	50
Small Scale							
1958-63	1000	1.10	0	--	0	--	1,000
1967-68	914	1.10	36‡		50	2.20?	1,000
Mexico							
1949-53	4129	.76	100	?	100	?	4,329
1964-68	4243	.76	2800	1.36?	727	2.72?	7,770
Thailand							
1950	35	.76	0		0	--	35
1966-68	50	1.40	448	2.69	0	--	498
Brazil							
1945-49	4413	1.29	0	--	0	--	4,413
1966-68	4597	1.29	0	--	4500	1.45	9,097
El Salvador							
1950-60	223	.88	-	--	0	--	
1968	138	.88	-	--	60	2.26	198

* Yields are given in Metric Tons per hectare

‡ This is a very early drought escaping variety (Katumani A) in a subsistence area where hybrids are not feasible.

Table 2. Hectares of maize hybrids grown in East Africa

	Kenya					
	Large Scale Farms (ha)	Small Scale Farms (ha)	Total (ha)	Tanzania (ha)	Uganda (ha)	Ethiopia (ha)
1963	156	4	160			
1964	11,400	700	12,000	4	8	---
1965	22,200	8,100	30,300	2,150	25	---
1966	25,500	15,300	40,800	50	12	---
1967	55,500	46,700	102,200	100	20	160
1968	40,600	52,300	92,900	6,050	270	270
1969 (est)	36,400	54,700	91,100	11,700	?	1,800

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

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

hybrids with the associated improved cultural practices. Table 2a shows the influence of this on the corn handled by the Maize and Produce Board.

3. Whereas Kenya has been able to move the package program for corn improvement into the small scale areas very successfully, Mexico has not succeeded in extending the use of hybrid seed and the associated improved practices to the farmers other than the large-scale operators. This accounts for roughly 10% of the total hectares planted to corn. Stakman, et al. in Campaigns Against Hunger state that approximately 36% of the corn area is planted to improved varieties and synthetics in addition to the 10% in hybrids. I have assumed that the remaining farmers have not changed their average yield and that the average yield of the improved varieties is approximately half the yield of the hybrids. Using these assumptions and the total production, I have estimated the average yields of 1.36 tons/ha and 2.72 tons/ha for the improved and the hybrid varieties.

4. Corn has only recently become a commercial crop in Thailand with the development of the market for livestock feed in Japan. Even though hybrid varieties have not been available there, very great improvement has been obtained in corn production by their small-scale farmers. An improved variety of the type preferred by the Japanese market was selected from among several introduced from Guatemala and elsewhere. Coming from a similar ecological area, this material was resistant to the diseases and pests and gave 20-40% increases in yield. Some fertilizer has been used, but most of the improvement has come through improved agronomic practices as it has in Kenya and Mexico. The development of variety-cross hybrids and the increased use of fertilizer could probably give an additional 50% to 100% increase in yield.

5. Some estimates of the total current potential production are shown for the countries under review in Table 3. Where the package of corn improvement practices has been used, it has been possible to obtain averages of nearly 3 tons/ha. Hence, these potential production figures have been based on this figure.

6. Although 1,000,000 hectares of corn are grown annually in Kenya, it is felt that with improved production per acre this could be reduced to about 600,000 hectares and the remainder devoted to livestock production and alternative crops. Even this could produce nearly four times the present surplus. These figures indicate that if an extensive effort is made to increase corn production, provi-

Table 2a. Source of Maize purchased by Maize and Produce Board.

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

Table 3. Estimates of total current and potential production for countries under review.

Country	Current Production			Potential Production			Surplus	
	Hectares (thousands)	Yield (tons/ha)	Total tons (thousands)	Hectares (thousands)	Yield (tons/ha)	Total tons (thousands)	Current (thousands of tons)	Potential (thousands of tons)
Kenya	1,000	1.15	1,150	600	3.0	1,800	245	900
Mexico	7,770	1.16	9,013	7,770	3.0	23,310	954	22,000
Thailand	498	2.56	1,275	600	3.0	1,800	1,175	1,700
Brazil	9,097	1.37	12,460	10,000	3.0	30,000	815	18,355
El Salvador	198	1.21	257	200	3.0	600	(-20)	120

sions must be made for the use of the surplus crop or else some of the areas must be directed to the production of alternative crops.

7. The extent to which corn improvement has progressed in the five countries under review varies considerably. Even though Mexico and Brazil have not been as successful in obtaining the improved yields with small-scale farmers as Kenya and Thailand have, the production exceeds food requirements and results in a surplus.

8. Although a full scale systems approach was not used for the corn improvement in Kenya, the necessary factors were made available as required. The basic research had been conducted by the Ministry of Agriculture with the assistance of the British Ministry of Overseas Development and the Rockefeller Foundation and more recently by the AID-ARS Major Cereals in Africa Project so that improved hybrid varieties were available from the breeding program. The agronomic research had provided the information necessary to obtain maximum economic yields from these varieties. The private enterprise sector was very strong so that the hybrid seed was produced and distributed to the farmers at a very low cost, adequate supplies of fertilizer were made available to all farmers with a small fertilizer subsidy from the Kenya government and an effective extension service used demonstration plots grown by progressive farmers within walking distance of most farmers in the major corn producing areas. The Maize Produce and Marketing Board provided a ready market at a subsidized price that made it profitable to increase production and assured the farmer in being able to sell his crop and repay his loan or recover expenses incurred with additional fertilizer and pesticide. The effect of this maize improvement program on the nation's economy can be seen in Table 4 in which the area under hybrid maize is shown as well as the volumn of maize handled annually by the Maize and Produce Board. Kenya has moved from a country with cyclic surpluses and deficiencies of corn to one of a large stable surplus. Although the large-scale European farmers provided the nucleus to get this expansion started, the small-scale farmers are joining in the improvement program in increasing numbers every year.

9. AID has contributed extensively to this corn improvement through the education and extension institutions. Although the leadership in the research program has been provided by expatriot personnel, the bulk of the research has been conducted by local Kenya personnel trained either at the Egerton Agriculture

Table 4. Maize handled by the Maize and Produce Board annually (thousands of metric tons)

Year	Hybrid Maize Grown (ha) (Thousands)	Purchases (tons) (Thousands)	Export (tons) (Thousands)	Import (tons) (Thousands)
1959/60		150.8	9.1	-
1960/61		144.2	0.2	17.0
1961/62		149.3	9.1	64.8
1962/63		203.0	87.0	-
1963/64	0.1	97.5	53.1	-
1964/65	12.1	106.4	-	13.5
1965/66	30.3	134.0	-	191.8
1966/67	40.8	228.0	63.1	-
1967/68	102.2	325.6	271.4	-
1968/69 (est)	(92.9)	(318.0)	(218.0)	-

College or overseas on scholarships provided by AID and other organizations. The extension service has benefited greatly from the overseas and local training programs for their staff members provided with AID assistance.

10. Thailand has also made very great progress in corn improvement in the short time in which this program has been in operation; and all factors necessary for corn improvement appear to have been present. A large number of varieties and hybrids were introduced and tested and a superior variety from a similar ecological area in Guatemala was selected for seed increase. Agronomic research was conducted and suitable recommendations developed and presented by the extension service. The private sector was active in seed production and distribution, provision of credit, distribution of fertilizer and pesticides, and marketing and transportation. Approximately 90% of the corn hectarage is planted to the improved variety with recommended cultural practices (except fertilizer).

11. The Thailand Corn Report gives four causes for events which have contributed to the increase in corn production in Thailand: "(1) The introduction and rapid spread of Guatemalan corn varieties, (2) the construction of the Friendship Highway with the subsequent opening of the upper regions of the central plain and the northeast, (3) the relatively successful control of malaria, and (4) the availability of the Japanese market for the export of corn at prices which allow production incentives." Probably a fifth factor should be added to these. The presence of a private enterprise sector which made the necessary inputs readily available to the small farmer, which provided a large amount of credit to the farmer and also provided a ready market for his crop at a price that gave him a great incentive to increase production. AID was involved in some manner in all of these aspects. AID is also participating in the several training centers and universities in Thailand as well as providing funds for overseas training of research and extension staff workers. The Thailand report states "it can best be said that the United States inputs into the corn program at the time were the right catalystic agents."

12. At the present time only about 5% of the corn crop in Thailand is fertilized. The TVA study states that conservative estimates give an expected increase of 50% over present yields for approximately 30% of the acreage if proper fertilization practices are followed. This indicates an overall 15% increase in yield on existing acreages is easily obtainable which would mean a crop of approximately 1.4

to 1.5 million metric tons. The development of hybrid varieties would give even greater responses to fertilizer and attention to factors such as early planting and plant populations would probably result in an even greater increase in yield.

13. Although the work in corn improvement has been going on for more than 20 years and has enabled Mexico to produce a surplus above the food requirements of the country, the number of Mexican farmers that have achieved increased production and are benefiting from the extensive breeding and agronomic research programs conducted by the Ministry of Agriculture and CIMMYT is extremely small. Two major factors seem to be inadequate--the extension program for small-scale farmers and a private enterprise sector in seed production and the distribution of seed, fertilizer, and pesticides.

14. Stakman, et al. in Campaigns Against Hunger (p. 70 and 71) give the following statement, "Hybrid corn, however, which has been available for 18 years, has come to occupy only 14% of Mexico's corn acreage, and this is a real disappointment when compared with the progress in the United States. There, in a similar 18 year period, from 1933 to 1951, hybrid corn expanded to 80 percent of the total acreage, including even the smallest farms. But in the United States progress was stimulated by the competition of private enterprise. For various reasons the Mexican government preferred to maintain complete control of production and distribution of improved seed, and private enterprise was excluded. One consequence has been that, once hybrid corn became established on the larger farms managed by the more progressive farmers, expansion slowed down. Hybrid seed is not yet reaching the small farmer in Mexico in substantial amounts, and it probably never will until private enterprise is allowed a part in its promotion."

15. Since the writing of this book, the Mexican government has not enforced the policy of a government monopoly in seed production as strongly and private companies are managing to enter this field at the present time. If they are permitted to continue to provide this service it is expected that they may be able to greatly assist in the further expansion of production in Mexico.

16. On page 207, Stakman, et al. also pointed out that it was fairly easy to reach a small class of relatively affluent farmers which operate the larger highly mechanized farms with good land much of which is under irrigation. They also indicated that more effective extension efforts are required to increase maize production on the small farms.

17. "At the other extreme is the great majority of the farmers-impoverished, illiterate, isolated, suspicious of strangers. Their farms generally are small, the soil poor and often worn out by centuries of mismanagement, the farming methods laborious, primitive, and traditional. These farmers seldom travel any distance away from home, so extension workers have to go to them. Because their resources are so limited, they cannot afford to experiment with new methods; failure of the experiment could mean no food at all. They and their families usually consume most of the crops produced, selling only a small surplus, should there be one, in order to buy the few necessities they cannot produce themselves."

18. "Extension work with these farmers is much more expensive than with the prosperous ones because it must be intensive and thus requires more extension agents per unit of farm area. Because most of these farmers cannot read, an agent must visit them. Because they do not travel far, demonstrations must be made in their own neightborhoods; that is, there must be many demonstrations for relatively small groups. Because they have had little or no schooling and are firmly bound by tradition, it may take a long time to persuade them to try new methods and materials. Because their resources are limited and they usually live in the more isolated communities, supplying them with the goods and services required by new practices tends to be both difficult and expensive. And because each farm is small and produces but little, the net increase to the national agricultural product will likewise be small even after all the above conditions have been met. In a country with limited resources, therefore, efforts to improve agriuclture should not begin with this class of farmers, but neither should they cease until these farmers have been serviced effectively. The record shows that many individual small farmers have been helped by skilled extension agents to make notable improvements. Such work can and should be done, but it takes both time and money."

19. The rate of progress in corn improvement in Brazil has also been slower than one might hope for. The following information has been extracted from the Brazil report: "Work on the production of hybrid corn in Brazil began in the 1950's. By 1955 hybrid corn seed was being offered to farmers on a commercial scale, and by 1968 approximately 40% of the corn planted in the more important areas (Central and Southern Brazil) was either hybrid or synthetic varieties. However, this increase in the use of hybrid seed has not resulted in noticeable

improvement in national levels of yield per hectare."

20. "By far the most effective means of the distribution of hybrid seed corn in Brazil has been the promotion campaigns of the private company, Sementes Agroceres S.A. Programs of government distribution generally have been discontinuous and seldom have been of sufficient magnitude to meet potential needs. In some cases, government produced seed was offered to farmers at prices lower than those prevailing for common corn. Usually the farmer regarded the low price of corn as being correspondingly low quality and used it for purposes other than planting."

21. "When yields of hybrid corn and common varieties are compared under farm conditions in the semiarid northeast Brazil the better hybrids usually average about 10% greater than common corn. In contrast, in areas of moderate fertility in southern and central Brazil, hybrid corn usually produces about 20 to 30% more than common varieties. Rainfall is usually adequate for corn production in these areas. In cases where adequate fertilizer applications and appropriate cultural practices are used in central Brazil, the better hybrids often yield twice common corn varieties. Corn yields above 100 bushels/acre (6.3 tons/ha) occur routinely in experimental fields using hybrid seed."

22. The potential for increased yield levels from the use of corn hybrids has not been realized on a large scale in Brazil primarily due to the lack of adequate soil fertility. In other words, the improved varieties were introduced without the package deal involving the improved cultural practices such as early planting, proper plant population, and fertilizer.

23. The early hybrids were developed to increase yields under local conditions and were not particularly responsive to fertilizer. The policy of the research department has changed so that the newer hybrids have been selected for a response to improved environmental conditions.

24. "In Brazil AID strategy has been to assist in developing, carrying out, and financing a balanced total agricultural program. As such it participated actively in most aspects of the program. These included: (1) University and sub-university training of agricultural people, (2) participant training of administrators at all levels (3) a large scale research program aimed at solving key limiting factors to production expansion including crop varieties, fertility, nutrition, management, pest control, and marketing, (4) improvement in methods for getting farmers to

adopt new practices, (5) development of improved practices affecting production, marketing farm supplies, seeds, etc., and (6) credit expansion to meet development needs. The program was aimed at establishing the development needs, determining local capacity and filling in where there were major missing elements of any kind."

25. The expanded use of corn hybrids that has occurred in Brazil has been accomplished primarily by the private enterprise section. With increased availability of fertilizer from a new plant at Santos (built with AID assistance) and other sources it is expected that large quantities will be used on corn with the resulting increase in production if the extension service and private sector will promote the package deal. Lack of credit has also limited any expansion in the use of fertilizer, but a program to expand credit is underway. 1968 production equalled production in 1966 and 1967 despite a severe drought in 1968.

26. All factors leading to the improved corn production in El Salvador were present by 1964 except that extension activities and credit facilities needed strengthening. A mass fertilizer demonstration program under the direction of Dr. B. J. Birdsall was sponsored by AID in 1965-67. Demonstration plots of .04 hectares were used in which hybrid seed and all recommended cultural practices were used. The method was essentially the same as that used in Kenya, except that the inputs were given to the farmer rather than requiring him to purchase them at commercial rates. It is still too early to assess the effectiveness of this program, but the sale of hybrid seed has increased rapidly with 1000 tons being sold in 1968 compared to 100 tons in 1963. This is sufficient seed to plant approximately 30% of the hectarage in El Salvador. The national average yield has been going up slowly, but there was no sharp increase following this extensive program. Although the use of hybrid seed has increased, the use of fertilizer does not appear to be increasing accordingly. Credit is probably the biggest factor involved in this and now appears to be the limiting factor for further large increases in production.

II. Corn Improvement in Developing Countries (Management)

27. In all instances where great increases in average corn yields have been obtained with the use of new hybrid or synthetic varieties, the largest contributing factor to these increases in yield have been the improved agronomic practices and not the improved variety itself. Research workers in all countries have long realized that it is the agronomic practices that are so extremely important, but it has been impossible to get these practices adopted without the stimulus of an improved variety. The reluctance of the small scale farmers to adopt these improved practices had lead to the conclusion that corn improvement was not pos-

sible for these small-scale farmers. Kenya and Thailand have shown that this conclusion is false for corn, and several other countries have produced similar demonstrations with the dwarf wheat and rice varieties. Where these improvements have been obtained, the psychology used to get the package program adopted and the price incentive seem to be the most important aspects. Each part of the package program produces only a very small improvement; and if the farmer can not easily see the results of the improved practice, he is reluctant to adopt it. Hence, attempts to obtain improvement with only one aspect such as an improved variety is probably a waste of time and funds. But when all the desirable practices are combined in a package program, the sum of the parts plus the interaction that often results, produces such great improvement that a farmer can not help but be impressed if he is given the opportunity to see the results on his own farm or on a comparable neighbor's farm. This package program inevitably includes fertilizer, improved seed, and pesticides which involve the expenditure of funds. Hence, there must be an adequate profit margin to induce him to spend funds to increase production.

28. The inputs included in the formula for cereal welfare by Mr. E. Rice are all necessary for this package deal. I would like to consider each aspect of these inputs as they affect maize improvement. I have assembled tables and figures from several sources and unfortunately the units of measurement are not the same. For the most part metric units have been used where 1 quintal (q) = 100 kg = 0.1 ton. Lbs/acre and kg/ha are very similar (1 kg/ha = .892 lbs/acre) for readers not familiar with the metric system.

RESEARCH

29. A more useful breakdown from a research worker's point of view would be Plant Breeding Research and Agronomic Research. A sound research program includes both basic and adaptive projects. But the research itself falls into the category of breeding or agronomic practices, each of which requires a different staff and project orientation.

Breeding Research

30. Breeding research is the foundation of corn improvement. Although agronomic practices will usually give greater increases, it is usually not possible to get the small-scale farmer to change his agronomic practices unless you have some sort of lever. An effective extension program properly oriented can convince him that, like a new crop, this new variety can not be handled in the traditional fashion.

31. Synthetic varieties and variety crosses produced from very divergent source materials have a wide range of adaptation and can often be used over wide areas within similar ecological zones. The factors that seem to determine adaptation in corn are altitude, length of rainfall season, daylength, and diseases and pests. Corn breeding centers should be operating in each of the main ecological zones in Africa, Asia, and South America. Formerly the Rockefeller Foundation and now CIMMYT has a major International Program of Maize Improvement centered in Mexico City with additional programs in Colombia, Thailand, Nigeria, and Kenya. Any expansion in maize breeding should be in close cooperation with CIMMYT utilizing their experience and resources.

32. The AID-ARS major Cereals in Africa Project is an example where it has been necessary to supplement CIMMYT's activities. Although improved varieties and hybrids had been developed in Kenya prior to the initiation of this project, the AID-ARS research has increased the efficiency of the previous program and extended the results throughout Eastern Africa.

33. The traditional inbreeding and hybridization method of corn improvement in the U.S. made large initial gains, but has made very little progress in more recent years. Basic quantitative genetic studies in the U.S. have shown that the development of corn populations (varieties) and population improvement through recurrent selection must be the basis of modern breeding programs. The project in Kenya has been most useful in obtaining information on how to increase the efficiency of recurrent selections and which methods are most effective under different conditions. This information has been disseminated throughout Eastern Africa and to Nigeria; and the breeders working in the national programs are making use of this information with a great increase in the effectiveness of their breeding programs. Since corn is a major food crop in East Africa, most of the countries have national breeding programs with varying levels of experience and size of projects. Kenya was chosen as the location of the AID-ARS research activities because of the strong maize breeding program of the Kenya government assisted by the Rockefeller Foundation and the British Ministry of Overseas Development. The contribution by AID has not only strengthened Kenya's program; but as mentioned above, has had a big influence on the programs of surrounding countries. As Kenya has been able to provide her own maize breeders, the former Kenya

maize breeder, Mr. Harrison, has now been employed by CIMMYT as the Regional Maize Coordinator. The success of the regional program has been due to the close cooperation of the AID-ARS and CIMMYT personnel.

34. A few of the results from the Kenya and Mexican breeding programs will illustrate that large improvement can be made in corn varieties. In most developing countries the improvement has been even greater than in Kenya where the large scale European farmers had done considerable variety improvement on their own farms by mass selection prior to the initiation of the breeding program by the Kenya government in 1955. The results of the yields from the national maize variety trials in 1966 and 1967 are shown in Table 5. Kitale II was the first synthetic variety developed and in previous trials has proved to be 7 to 8% superior to the best farmers strains in use in European farming areas. H622 and H632 are a double cross and a three-way cross hybrid developed by the traditional inbreeding and hybridization method and they show the usual 25-30% superiority over the parental varieties. The variety cross hybrids H611B and H613B show similar or even greater superiority. As evidenced from the experience in the U.S. and Rhodesia, it would be very difficult by traditional breeding methods to produce further improvement over H622 and H632 by selecting new double crosses or three-way crosses from the same breeding material. However, a variety-cross hybrid can be used to make available to the farmers the improvement in the parental varieties obtained by recurrent selection. The first variety-cross hybrid, H611, is the cross of Kitale II and Ec. 573. Ec. 573 is a race collection from Ecuador from the race Montano. Ec. 573 was improved by 1 cycle of selection in the AID-ARS breeding method evaluation program to produce Ec. 573 (E1) C1 and Kitale III was the next cycle of selection by Mr. Harrison. Kitale III x Ec. 573 (E1) C1 (H611B) shows a 10% superiority over the original 611. Figure 1 illustrates the improvement that was made in the AID-ARS reciprocal recurrent selection program. Since Ec. 573 was an unadapted variety, very great improvement was made in the first cycle of selection, but less improvement is expected in subsequent cycles. However, quantitative genetic theory indicates that similar improvement can be made for a rather large number of cycles. Hence, an effective breeding program will produce even greater genetic superiority of synthetics and hybrids over the unimproved varieties previously available to the local farmers.

Table 5. Yields of the National Maize Variety Trials in Kenya (q/ha)

Variety	1966 (27)	1967 (22)	Mean (49)	% of Kit. II
Kitale II	46.2	53.0	49.6	100
H622	58.1	68.9	63.5	128
H632	61.2	68.4	64.8	131
H611B	61.9	69.7	65.8	133
H613B	67.0	71.1	69.0	139

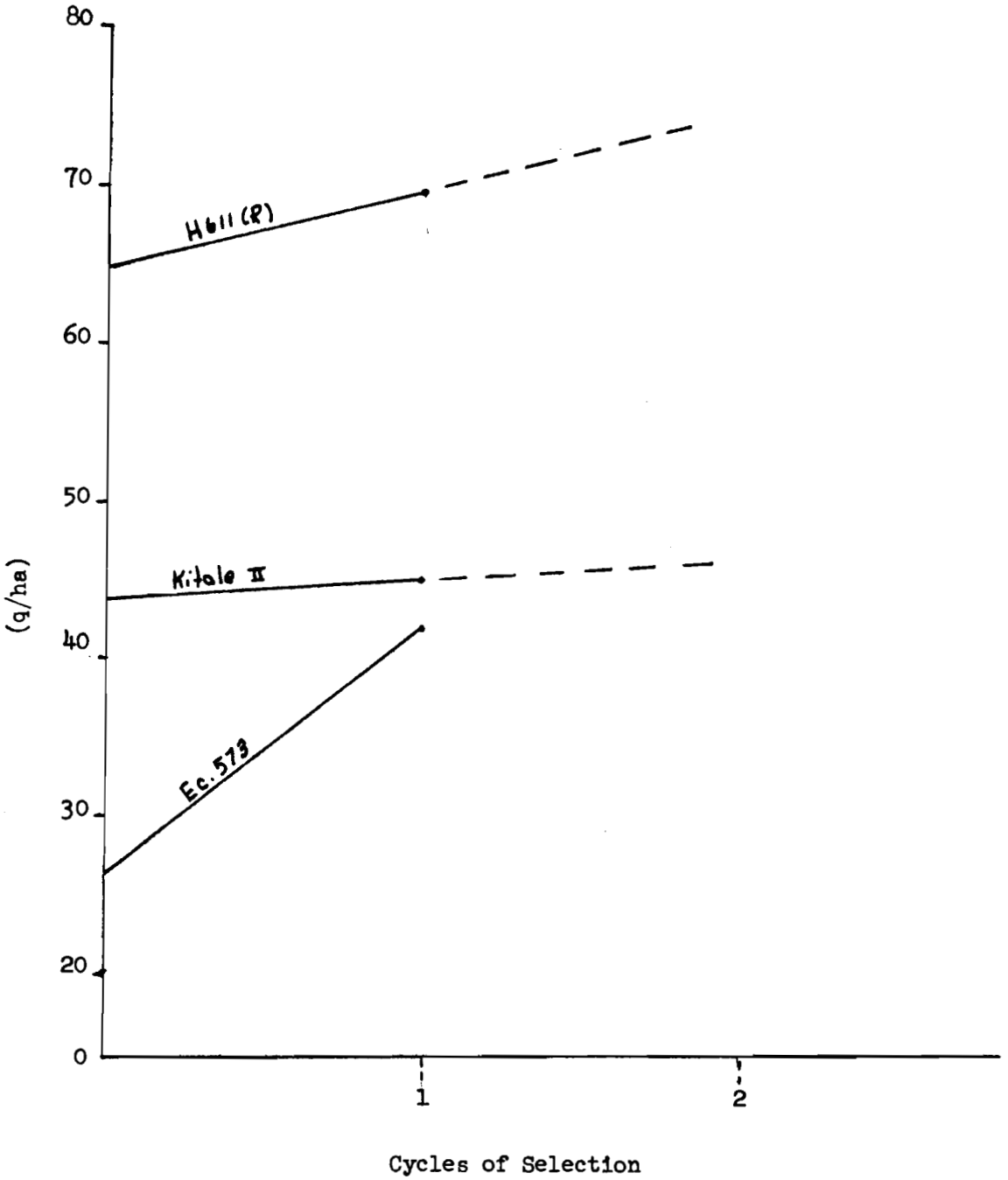


Figure 1. Improvement in Kitale II, Ec. 573 and H611 by 1 cycle of recurrent selection under average conditions at 6100 feet.

Similar progress has been made in V520C (Tuxpeno) in Mexico by mass selection as shown in Figure 2. But this improved variety has not been utilized in variety cross hybrids as yet. Thailand introduced an improved variety, Tiquisate Golden Flint, developed at the Tropical Research Center in Antigua, Guatemala from a variety cross--Cuban Yellow Flint x Guatemalan Dent. Further improvement in yield and percentage flint kernels are being achieved by recurrent selection in the Thailand Research Program. The possible use of this material and other material in variety-cross hybrids is also being investigated.

35. Figures 3 and 4 illustrate the value of the basic investigations by the AID-ARS program. Under conditions that exist at Kitale in which 3 seasons can be obtained in 2 years with dry season irrigation, S_1 testing is considerably more effective than full-sib testing. However, in conditions that exist at Mwanza, Tanzania, where they can get 2 seasons each year with irrigation, full-sib selection becomes much more effective than S_1 testing.

36. The Comprehensive Breeding System proposed by Eberhart, Harrison, and Ogada (Der Zuchter 37: 169-174. 1967) gives flexibility in that both improved synthetic varieties and hybrids can be produced from the same breeding program. There is considerable debate whether or not improved synthetic varieties or hybrid varieties should be used in corn improvement programs. In Kenya and in most countries where maize has been the traditional food crop, very little improvement has been obtained in corn production until the hybrids have been brought in as a lever to stimulate improvement. In contrast to this Thailand is now getting very good average yields from the introduced Guatemalan Flint varieties. But corn was not a basic food crop in Thailand, and, consequently, there was not the problem of changing the traditional methods of production. Hence, as acreage of Guatemalan Flint varieties was expanded to meet the new market for livestock feed in Japan, the farmers could be encouraged to use improved cultural practices in new areas. But there is now a major breeding program in Thailand under the direction of Dr. Ernest Sprauge of CYMMIT and staff of several local Thailand research workers. The development of hybrids with a greater response to improved cultural practices can result in even greater increases in average production, if these are used as a lever to stimulate the further use of fertilizer and higher plant populations.

37. When the seed is efficiently produced by a private company, the additional cost per acre of hybrid seed over unimproved or improved seed from a neighboring farm is very small compared to the total cost of production with fertilizers.

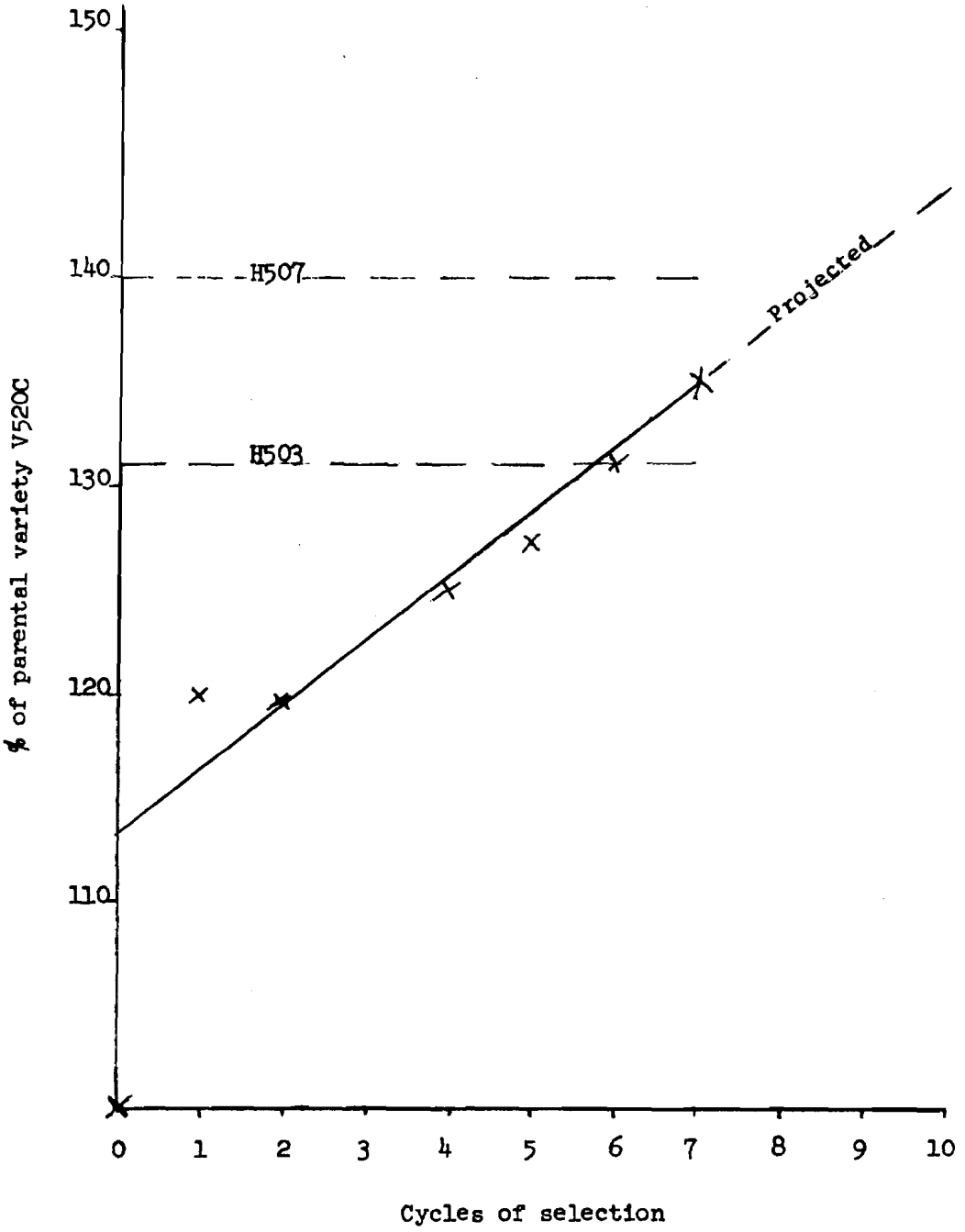


Figure 2 . Improvement of V520C through 7 cycles of mass selection from evaluations with 20 replications in 1965, 1966, and 1967.

Extracted from the 1967-68 CIMMYT Report

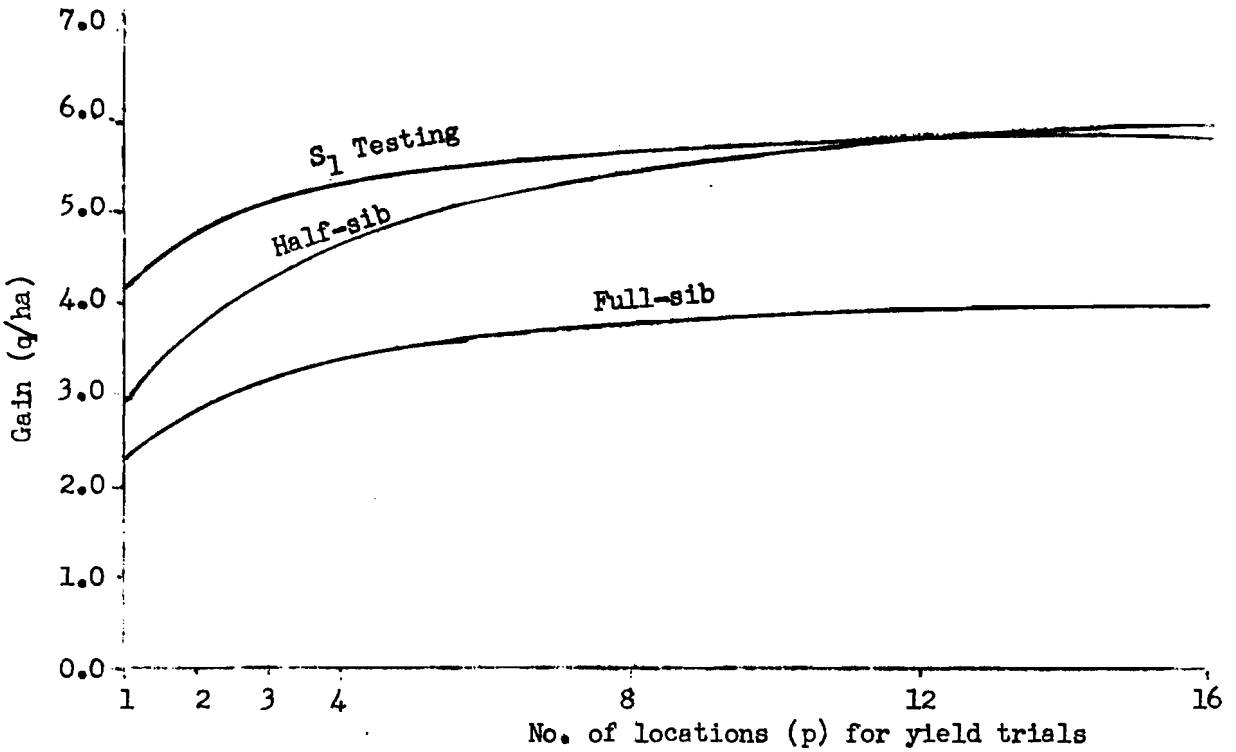


Figure 3. Expected annual gain from selection in KCA with 3 seasons in 2 years.

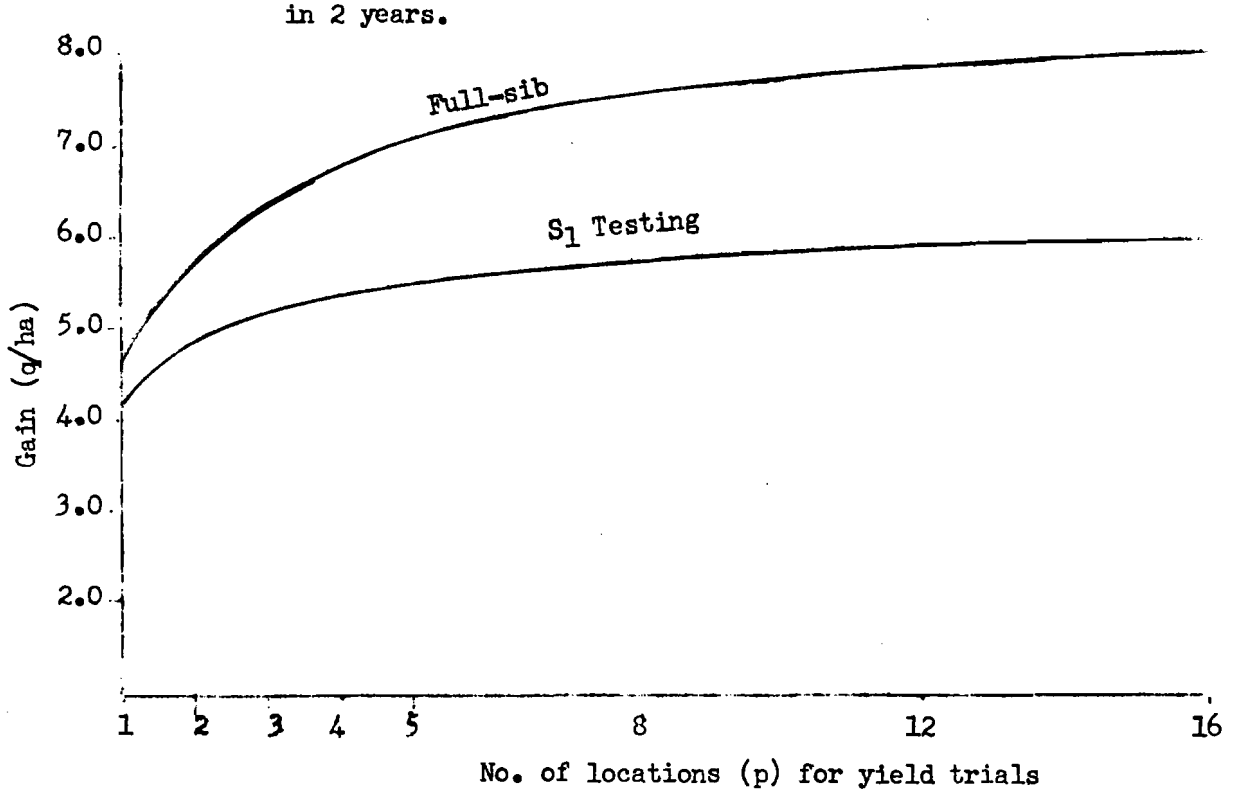


Figure 4. Expected annual gain in KCA with 2 seasons per year.

If the farmer has to spend money for seed, he feels that this is a valuable crop which requires considerable attention: i.e., the hybrid must go on his best land and have fertilizer, it must be early planted with the proper plant populations, clean weeded, etc. On the other hand, if he gets his seed from his own field or from his neighbors (even though it is an synthetic variety with considerable potential when grown under the same agronomic conditions) there is nothing special about it because it costs little or nothing extra and he soon reverts to the traditional methods of production. This tendency to revert to the traditional methods can be overcome to a certain extent if the improved synthetic variety has distinctive morphological characters such as dwarfness of the wheat and rice varieties or as the Katamani corn synthetics in Kenya. These Katamani synthetics were much shorter and earlier and were very distinctive from the previously grown local varieties. Hence, the extension service was able to establish this as a "new crop" that required different agronomic practices than the old varieties even though seed was saved from the previous crop.

38. Once hybrids have been introduced and they are being utilized, it is very simple to get new improvements in the hybrids to the people. When there is an effective breeding program producing genetically superior variety-cross hybrids every one or two years this aspect becomes very important. Also hybrids make it very much easier to produce materials with improved nutritive value such as high lysine corn which will be available with the opaque-2 and floury-2 hybrids. This is also true with the disease resistant varieties which are developed to combat the spread of new diseases.

39. The development and introduction of high lysine corn varieties is an extremely important program for Africa and South America where corn is the basic food crop. As soon as these new hybrids have been developed they can be used as the lever to get the improved cultural practices adopted. These varieties will provide good promotional material for launching a corn improvement campaign. Care must be exercised, however, to make sure that the taste and texture are acceptable and that these new varieties are truly adapted.

40. As part of the regional maize corn improvement program, the CYMMIT regional coordinator and the AID-ARS maize geneticist obtained the cooperation of all corn research workers and established the Eastern African variety trials in 1966. It has been expanded even further in 1967, 1968, and 1969. The results from the

1967 trial are shown in Table 6. Below 6,000 feet, the Kenyan hybrid H632 and the Zambian entry SR52 (a single cross developed by Rhodesia) have given uniformly superior performance and have greatly out yielded all local farmer's varieties. SR52 is sold only in Rhodesia and Zambia, but the Kenya Seed Company has been expanding their sales effort greatly and have been selling H632 in Ethopia, Tanzania, Uganda and even more recently have investigated the possibility of selling seed in the Eastern Congo. Above 6,000 feet the Kenya variety cross hybrid 613B will give the best yields and is recommended wherever the rainfall season is long enough. H511 was developed by the AID-ARS maize geneticist at Kitale for areas having a shorter growing season than the H632 or H613B require. This medium-maturity variety cross hybrid was released in Central Kenya only 3 years after initiation of the project. Yields in the East African variety trial were very good for the most part, indicating that other factors such as late planting, low plant populations and levels of fertility were not limiting the expression of the potential of the improved variety. The one exception to this is perhaps Uganda where additional agronomic research and more careful attention to the yield trials is required to get the maximum potential from the improved varieties.

41. A similar regional trial has been established in West Africa by Dr. J. Craig at Ibadan with the AID-ARS Major Cereals in Africa project. Results from 4 locations in 1967 are given in Table 7. No hybrids are currently available in Western Africa and the yield levels at all locations are extremely poor indicating that other agronomic practices are also limiting yields. Considerable agronomic research is required to identify these limiting factors and to find economic methods of removing these limitations. The AID-ARS team at Samaru, Nigeria is making considerable progress in this area.

42. Similar trials are being conducted in Central America under CIMMYT coordination. Results from 15 locations in 6 countries in 1965-66 are given in Table 8. Yield levels are moderately high with considerable superiority over the local unimproved variety for all maturity groups.

Agronomic Research

43. Most administrative and research personnel without experience in developing countries assume that the only requirements for increased corn production are an improved variety and fertilizer. The error in this assumption has been demonstrated by the investigations conducted by Mr. A. Y. Allan on several farms near Kitale,

Table 6. Yields (q/ha) from the Eastern African Variety Trial in 1967.*

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

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

Table 7. Yields (lbs/acre) of 1967 West African uniform maize trial entries at 4 locations.

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

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

Table 8 . Results of regional trials grown at 15 locations in 6 Central American countries.

Variety	Origin	Yield Tons/ha	Days to flower[1]	% of tester[2]
Late				
Hibrido semi-cristalino	Mexico	4.17	59	103
H-507 (Check)	Mexico	4.04	61	100
H-1 Experimental	Venezuela	3.96	57	98
Tuxpeno Synthetic	Honduras-Mex.	3.52	60	87
Diacol 154	Colombia	3.52	58	83
Poey T-66 (yellow)	Poey Seed Co.	3.62	59	87
Intermediate				
Composite E.S.1	El Salvador	3.30	56	96
H-5	El Salvador	4.60	55	134
H-4 (Check)	El Salvador	3.44	56	100
Yellow Composite	El Salvador	3.52	55	102
H-3 Experimental	Honduras	4.08	56	119
Nicarillo (yellow)	Nicaragua	3.62	56	105
Composite E.S.2	El Salvador	3.33	54	97
Early				
H-3	El Salvador	3.40	53	107
H-1 (Check)	Nicaragua	3.19	50	100
Early Composite	Honduras	2.98	52	94
Synthetic 2	Nicaragua	2.41	49	76
Local Variety	each country	2.28	--	73

1 Averages for first planting cycle (spring) for 1965-1966.

2 Averages within the three groups of varieties--late, intermediate and early.

Extracted from the 1966-67 CIMMYT report.

Kenya. This was a 2^6 factorial trial involving: (1) hybrid variety versus local variety (2) early versus late planting, (3) good stand versus poor stand, (4) clean weeding versus 1 late weeding, (5) 56 kg/ha of P_2O_5 versus none, and (6) 78 kg/ha of nitrogen versus none. The results are given in Figure 5. Even though the low levels were chosen to simulate the farmer's conditions, the yield obtained in the six trials in 1966 averaged 1.97 tons/ha compared to the national average of approximately 1.1. The use of hybrid seed, nitrogen, and phosphorous fertilizer only resulted in an increase of 1.3 tons/ha giving a net profit of $16.13 per hectare. In contrast, early planting with the proper plant population and clean weeding (even with the unimproved variety) resulted in a yield increase of 2.92 tons/ha and an additional profit of $117.00 per hectare. The big interaction factor is seen in that, once good agronomic practices have been adopted, the use of hybrid seed and fertilizer gives 3.14 tons increase in yield compared to 1.30 with unimproved agricultural practices. The hard work required for early planting, good stands and clean weeding gives 2.92 tons/ha increase in yield for the unimproved variety and no fertilizer, but 4.76 tons/ha with a hybrid variety and fertilizer.

44. The futility of using nitrogen fertilizer without early planting is shown in Figure 6. If planting is delayed 6 weeks after the beginning of the rain (as was often done in Kenya), there is no yield increase from the nitrogen. In contrast there is a very great response to nitrogen with the early planting. Figure 7 shows effect of time of planting on yields of the unimproved variety Muratha at Embu in seasons of high and low rainfall. Figure 8 shows the response obtained from 511 to increasing plant populations compared to no response in the Muratha variety. Figure 9 illustrates the increased response to nitrogen from the hybrid variety (SR52) over an unimproved variety in yield trials conducted in Zambia. Figure 10 shows a similar response to plant populations. Figure 11 shows the greater response obtained from hybrid compared to a local variety over a wide range of environmental conditions in Tanzania. Superiority of H622 is much greater when the average varieties in the trial are yielding 60 quintals compared to the superiority at 16 quintals per hectare.

45. To further illustrate the importance of agronomic-entomological research as part of the package deal, the results obtained by the AID-ARS entomologist and soil scientists at Serere, Uganda, with sorghum are shown in Figure 12. With a high level for infestation, there was only a small uneconomic response to nit-

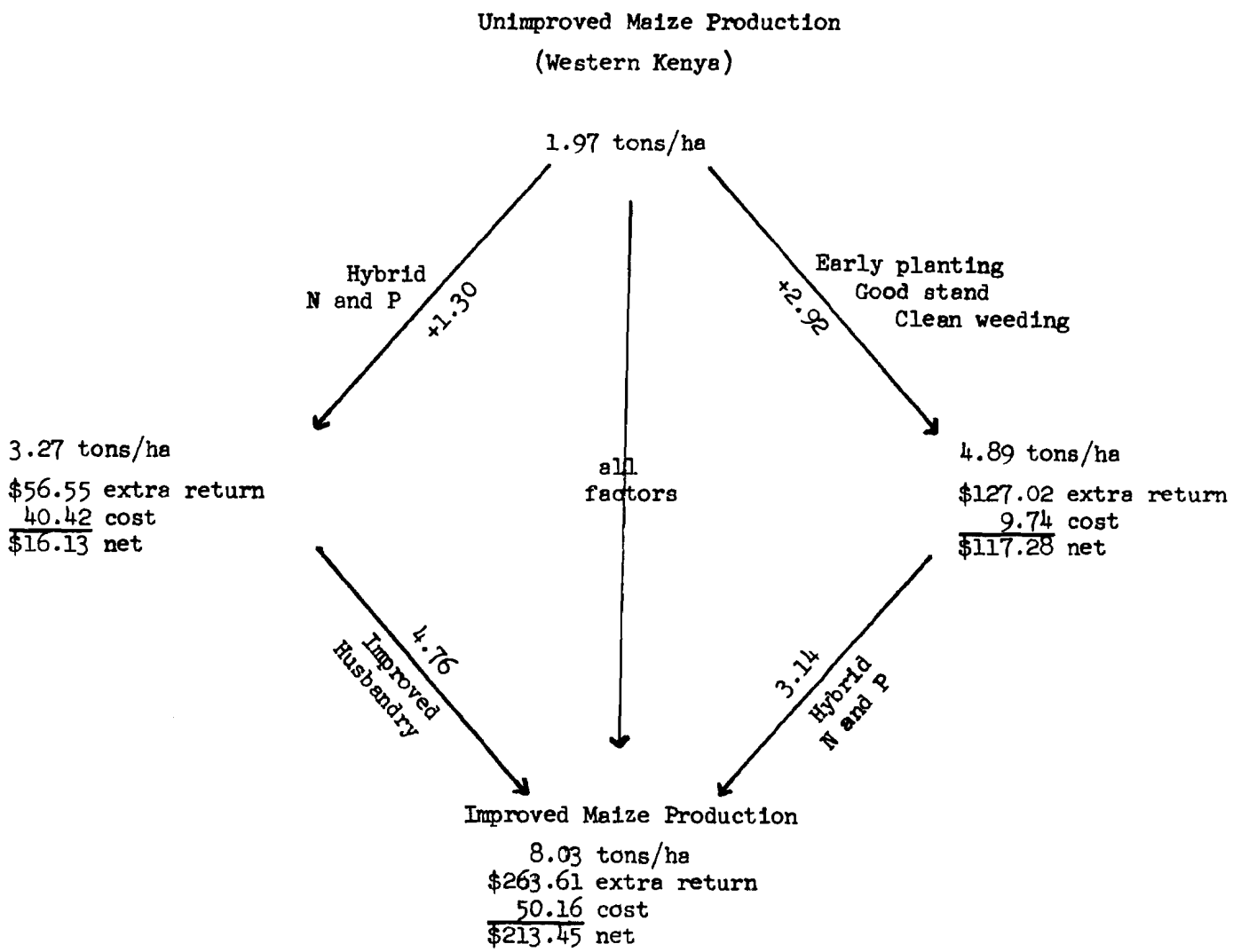


Figure 5. Extracted from a 2^6 District Husbandry trial grown at 6 locations near Kitale in 1966.

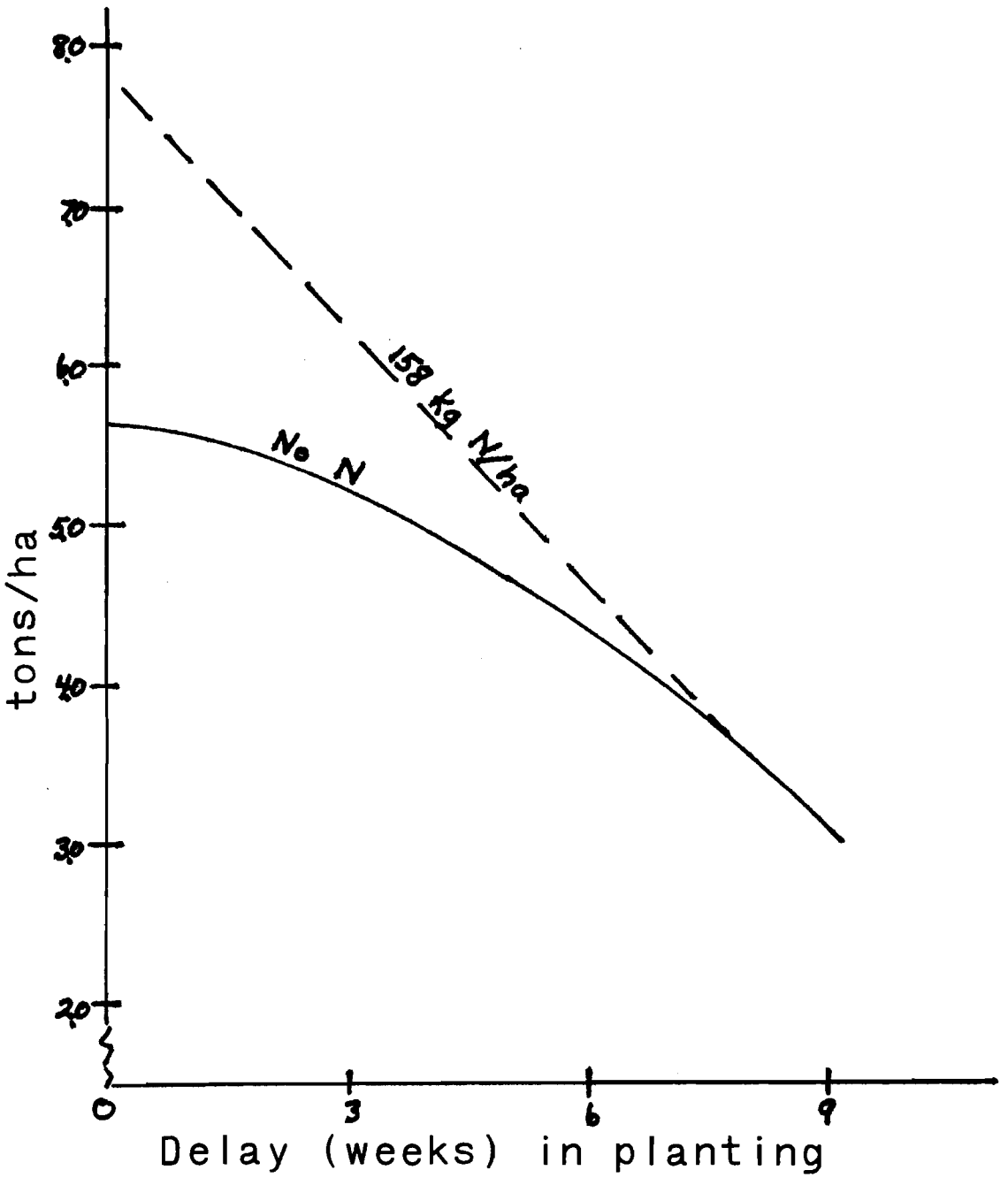


Fig.6 Response to delay in planting of Kenya Hybrids in 1966 (2) and in 1967 (4) near Kitale.

(34)

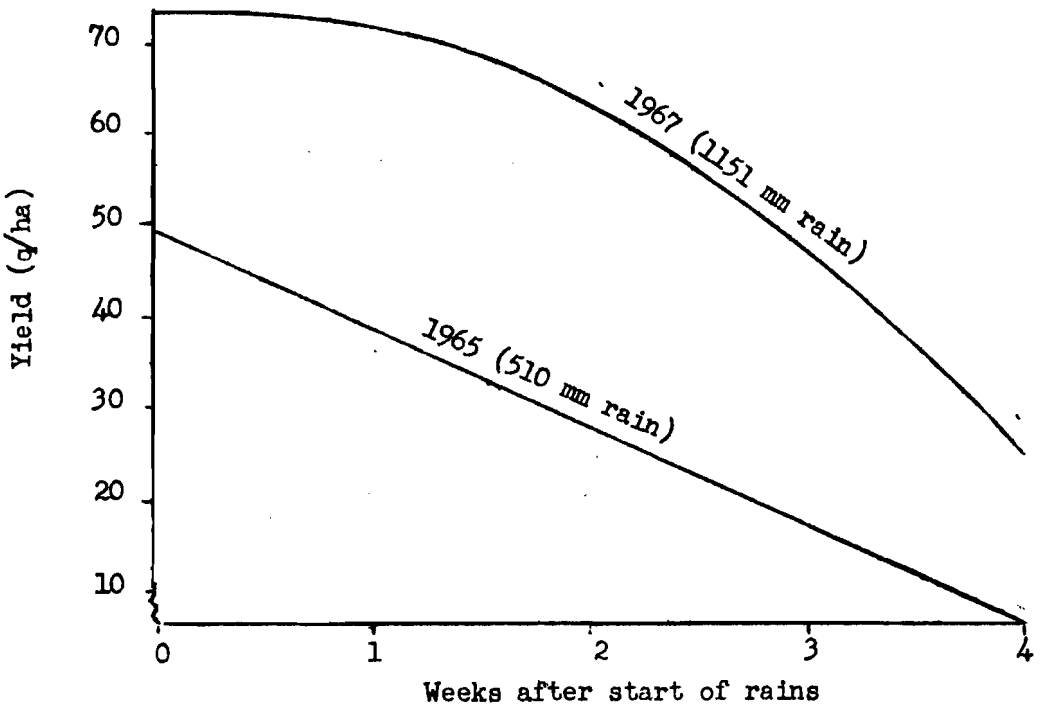


Figure 7. Effect of time of planting on yields of Muratha at Embu

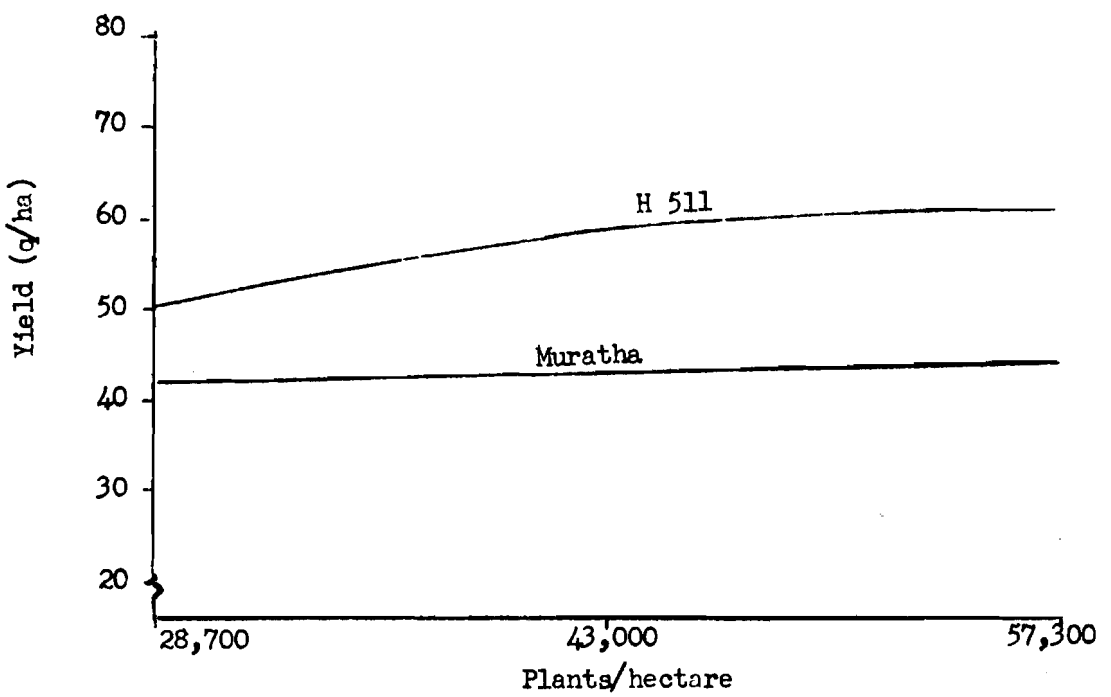


Figure 8. Response of Muratha and H 511 to increasing plant populations at 6 locations in Central Province in 1967.

(48)

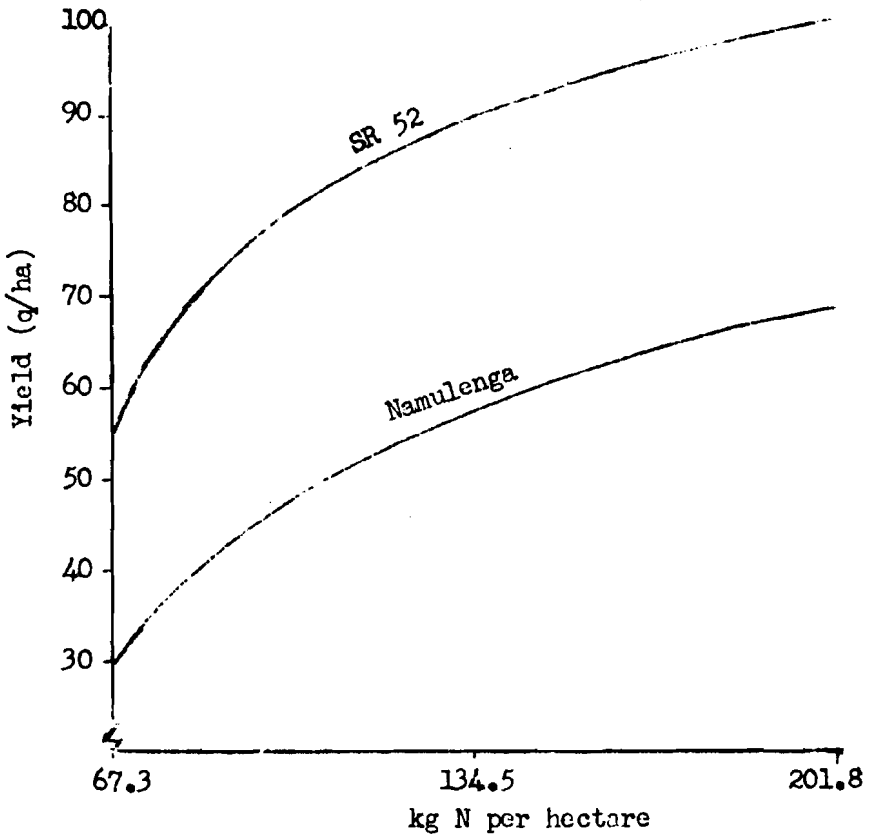


Figure 9 . Response of varieties to N at Lundazi, Zambia in 1966/67

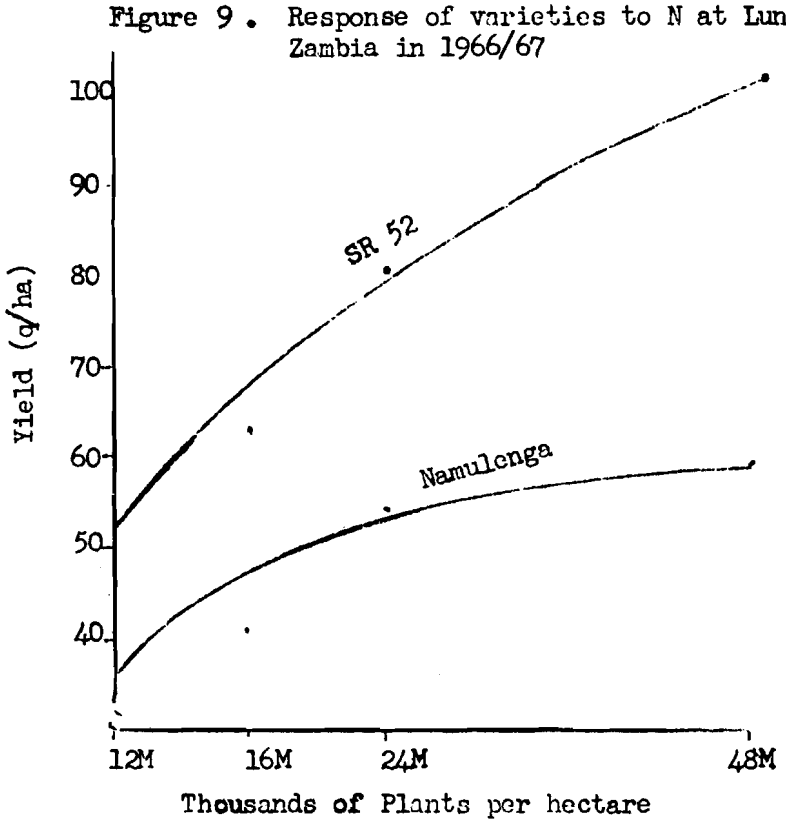


Figure 10. Response of varieties to plant population at Lundazi, Zambia in 1966/67

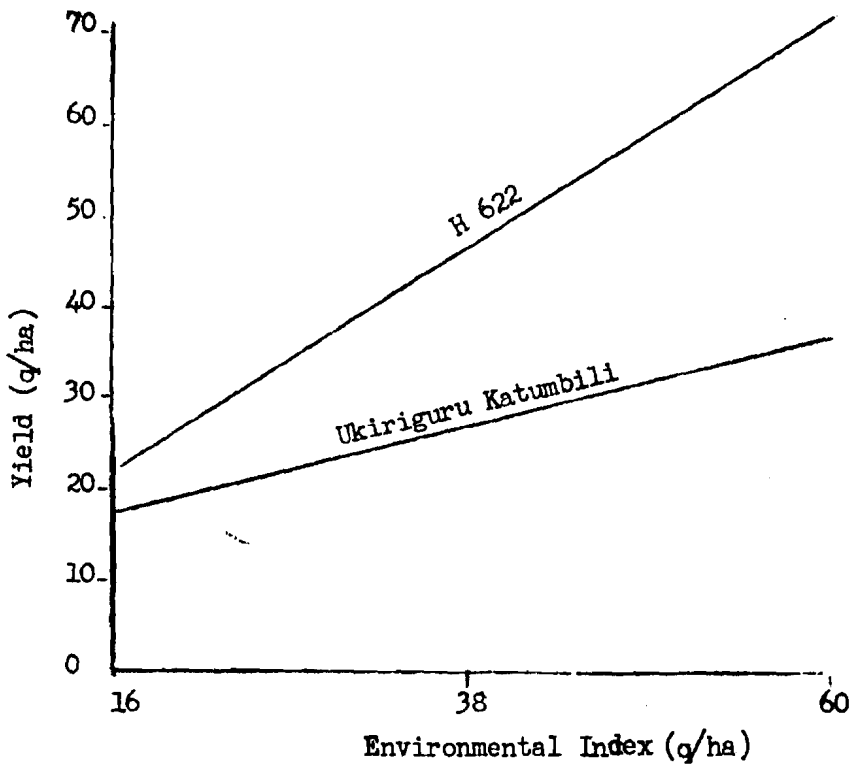
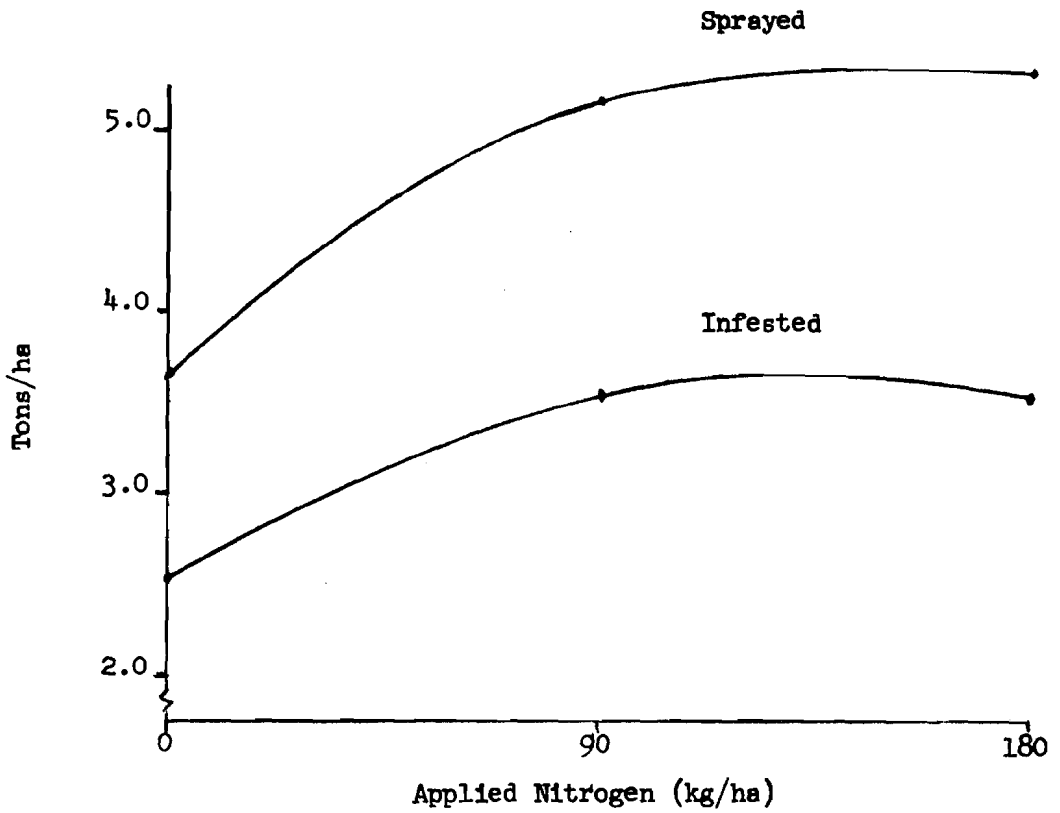


Figure 11. Response of H 622 and Katumbili to varying environmental conditions in Tanzania in 1965/66*

* A. Bolton. E.A. Agric. Jour. (Inpress)



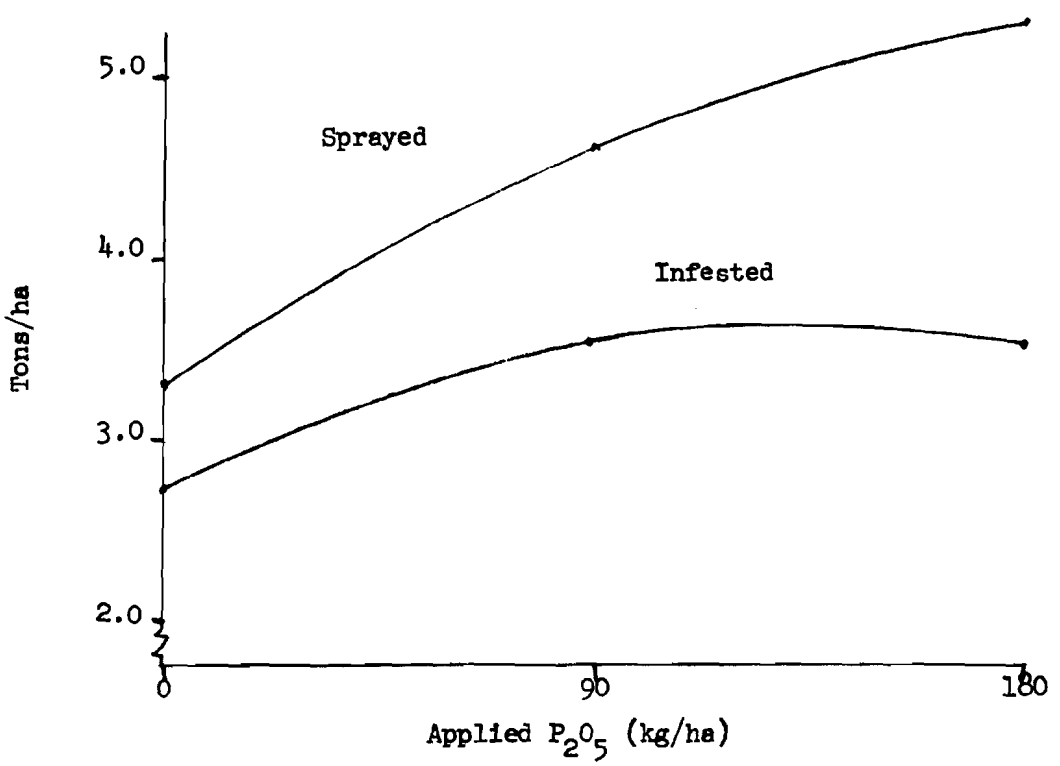


Figure 12. Response of a sorghum variety to fertilizer in the presence and absence of stalk borers (Chilo partellus) at Serere, Uganda in 1968. Results from trials conducted by K. Starkes and G. Schumaker.

rogen or phosphorous. In contrast, when the borers were controlled there was a very large response. If a program of cereal improvement were launched in this area with a package deal of a new introduced variety (without borer resistance), fertilizer, plant populations, etc; and in that particular year there was a heavy infestation of stalk borers, there would be a very disasterous result. At Kano, Nigeria, a fertilizer factorial trial was a complete failure in 1967. In 1968 when lime was included, a response of 580% was obtained from nitrogen and 140% from potassium; but the maximum yield was still only 1.9 tons/ha. A sound research program and adequate national and regional evaluation programs are essential to solve such problems and to develope the recommendations for the package program.

46. The agronomic research investigations at Kitale have now proceeded to the stage that all of the cultural factors affecting yield have been identified and corrected and now attention is given to determining the optimum level of fertilizer. Only three elements have shown to be essential: nitrogen, phosphorous, and sulfur. In the past, the sulfur has been supplied as part of the single superphosphate and ammonium-sulphate-nitrate. However, in 1968 commercial companies had greatly expanded operations in Kenya and were selling mixed fertilizers composed of di-ammonium phosphate with calcium-ammonium-nitrate applied as a top dressing. Since sulfur is not included in these fertilizers there have been some crop failures on newly plowed land in Kenya in 1968 even though generous levels of N and P_2O_5 were used. However, the agronomist promptly identified the source of the trouble and gave recommendations to prevent this from happening again in 1969 and even in time to save some fields in 1968.

47. On the clay soils on 10 farmer's fields near Mt. Elgon, the natural levels of phosphorous seem to be adequate for extremely high yields. Hence, the recommendation is only to replace phosphorous used by the corn crop. The response to varying rates of nitrogen from 0 to 220 lbs/acre are shown in Figure 13. The optimum economic rates are shown when nitrogen costs are $.126 and $.098 per lb. Kenya had been subsidizing phosphate fertilizers previously but with the recent reduction in price of corn for the farmers to 25/- per bag ($38.60/ton) the government has increased the fertilizer subsidy. The cost of ammonium sulphate-nitrate to the farmer is reduced from $74.73/ton to $67.45 by a 9.7% subsidy. Single superphosphate is reduced from $54.25 to $38.84 with a 28.4% subsidy. An economic response to both N and P with an NP interaction was obtained on 18

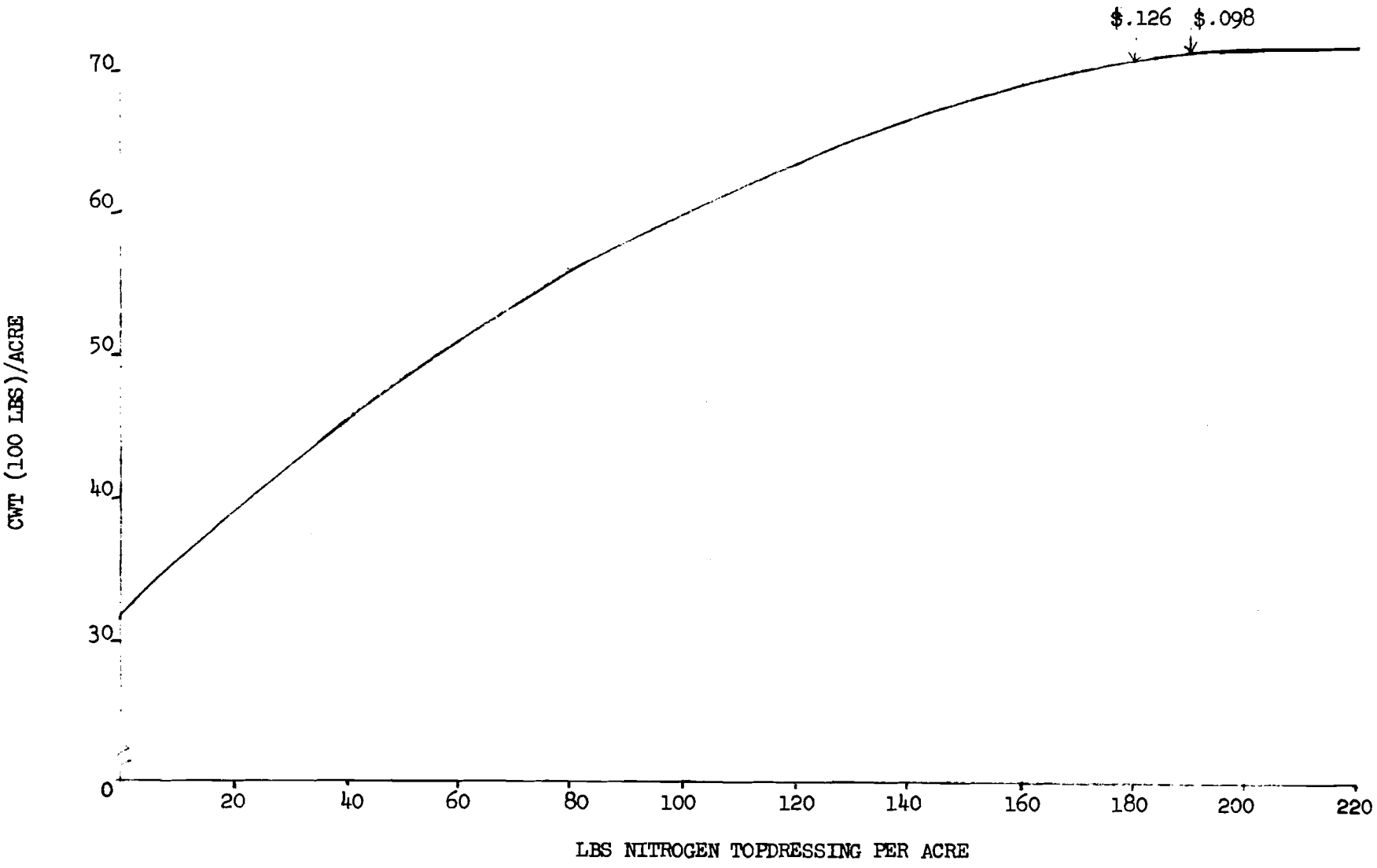


FIG. 13. NITROGEN RESPONSE ON 10 CLAY SOILS, ON OR NEAR MT. ELGON, KITALE, KENYA, 1968.

farmer's fields in other parts of Trans Nzoia with sandy red soils. The response surface is shown in Figure 14 and Table 9 gives information on economic levels and potential profit. These results suggest that although average yields in the Trans Nzoia are only 2.8 tons/ha, these could easily be doubled with careful attention to cultural practices (as was done in these trials) and more generous applications of fertilizer.

48. Extensive trials of a similar nature have been conducted in Mexico by CIMMYT. Excellent responses to nitrogen were obtained for sites with adequate rainfall as shown in Figure 15. Yields without nitrogen gave lower yields than in Kenya but maximum yields were not as high.

Research-Extension Liaison

49. In many countries the coordination between research and extension activities is not as close as might be desired. This is sometimes caused by the fact that they are in completely different ministries or in different agencies within a ministry. The AID-ARS Major Cereals Project is planning to assist in this area by assigning agronomists in certain countries with responsibilities in this area. Often the research organization has adequate facilities for the development of improved varieties, but lacks the means to obtain evaluations in the major corn growing areas in the country. This agronomist would be responsible for making arrangements with the Ministry of Agriculture for facilities to conduct these trials. He would be responsible for preparing the trials and summarizing the results. This would include the evaluation of the improved varieties and determining optimum cultural practices to obtain maximum economic yields from these improved varieties. Once these results become available he would be expected to present the information to the extension personnel, to assist in making the recommendations for the "package program" that would be used in the demonstration plots, and to assist the extension service in any way possible.

OTHER PHYSICAL INPUTS

Seed, Fertilizers and Pesticides

50. Once the basic research has progressed far enought to have available an improved hybrid corn variety and information on agronomic research as to the economic levels of each factor that are required to obtain efficient production, the availability of seed, fertilizer, and pesticides becomes most important. I have trans-

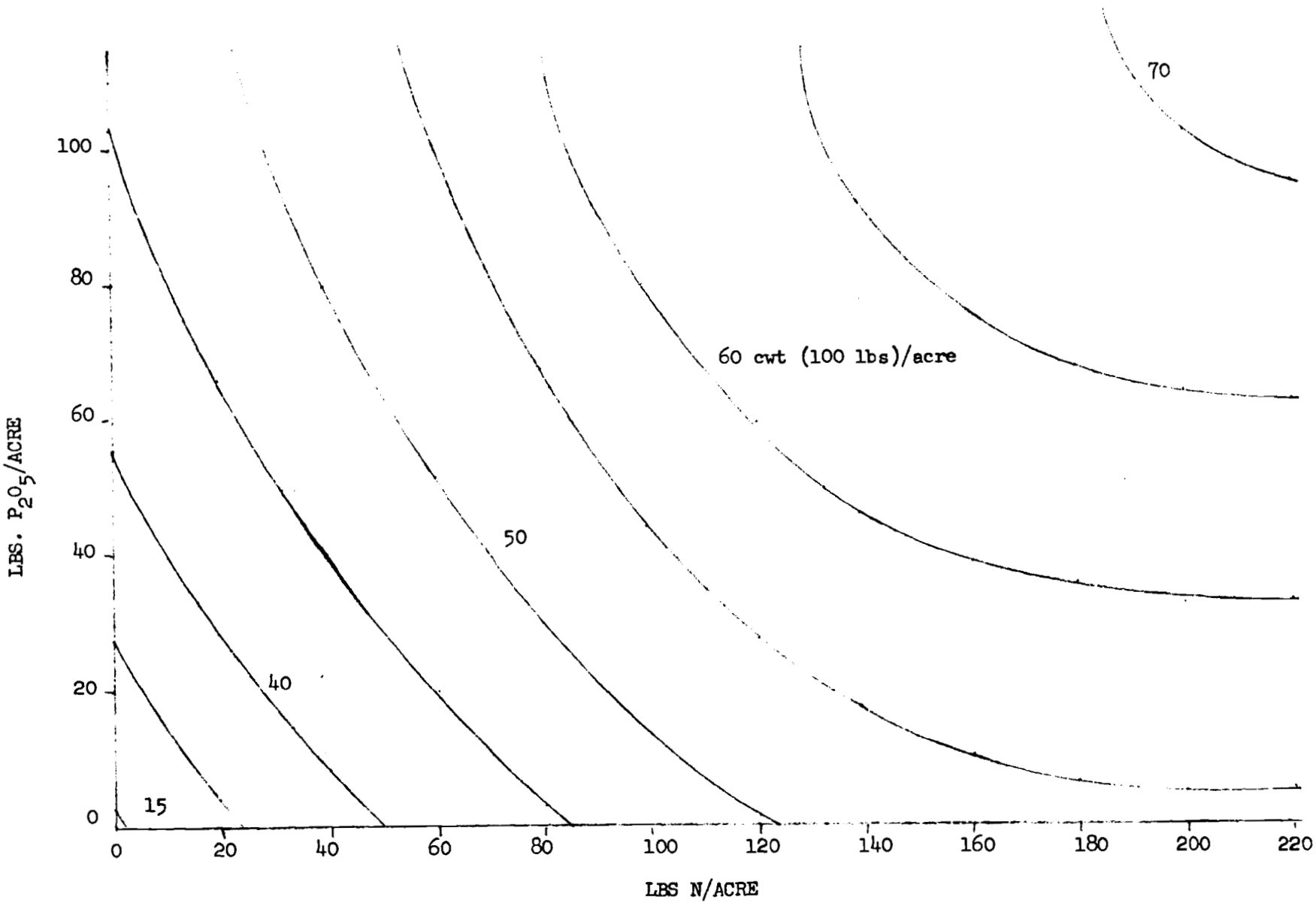


FIG. 14 NITROGEN AND PHOSPHATE RESPONSES ON 18 SANDY CLAY SOILS IN THE TRANS NZOIA, KITALE, KENYA, in 1968.

TABLE 9. FERTILIZER RESPONSES ON 10 CLAY SOILS, ON OR NEAR MT. ELGON

Money available for nitrogen per acre.		Recommended N		Predicted yield increase		Increase in gross return per acre.		Increased profit per acre.		% Profit from nitrogen usage
Shs	Dollars	Lbs/acre	Kg/ha	Bags/acre	Tons/ha	Shs	Dollars	Shs	Dollars	
a) N costs/70 ($.098) per lb. and corn sells for 25/-per bag ($38.60/ton or $.98/bu)										
50/ -	($7.00)	71	80	11	2.47	275	$38.50	225	$31.50	450
100/ -	($14.00)	142	159	17	3.81	425	$59.50	325	$45.50	325
Economic optimum 134	($18.77)	191	214	20	4.48	500	$70.00	366	$51.24	273
b) Nitrogen costs/80 ($.112) per lb.										
50/ -	($7.14)	63	71	10	2.24	250	$35.00	200	$28.00	400
100/-	($14.29)	125	140	16	3.58	400	$56.00	300	$42.00	300
Economic optimum 131	($18.35)	187	210	20	4.48	500	$70.00	369	$51.66	282
c) Nitrogen costs/90 ($.126) per lb.										
50/ -	($7.14)	56	63	9	2.02	225	$31.50	175	$24.50	350
100/-	($14.29)	111	124	15	3.36	375	$52.50	275	$38.50	275
Economic optimum 127	($17.79)	182	204	19	4.26	475	$66.50	248	$48.72	274

$1.00 = 7/14 Shs; 1 ton/ha = 4.464 bags/acre; 1 kg/ha = .893 lbs/acre

N.B. There were no significant phosphate responses on these soils and therefore it is recommended that phosphate be applied at rates adequate to replace the phosphate removed in the crop. Suggested rates are 20 lbs/acre P_2O_5 where the expected yield is below 20 bags/acre, and up to 40 lbs P_2O_5 per acre at higher yield levels. Phosphate costs are not included in the following table; the phosphate cost is regarded as an "overhead" cost here.

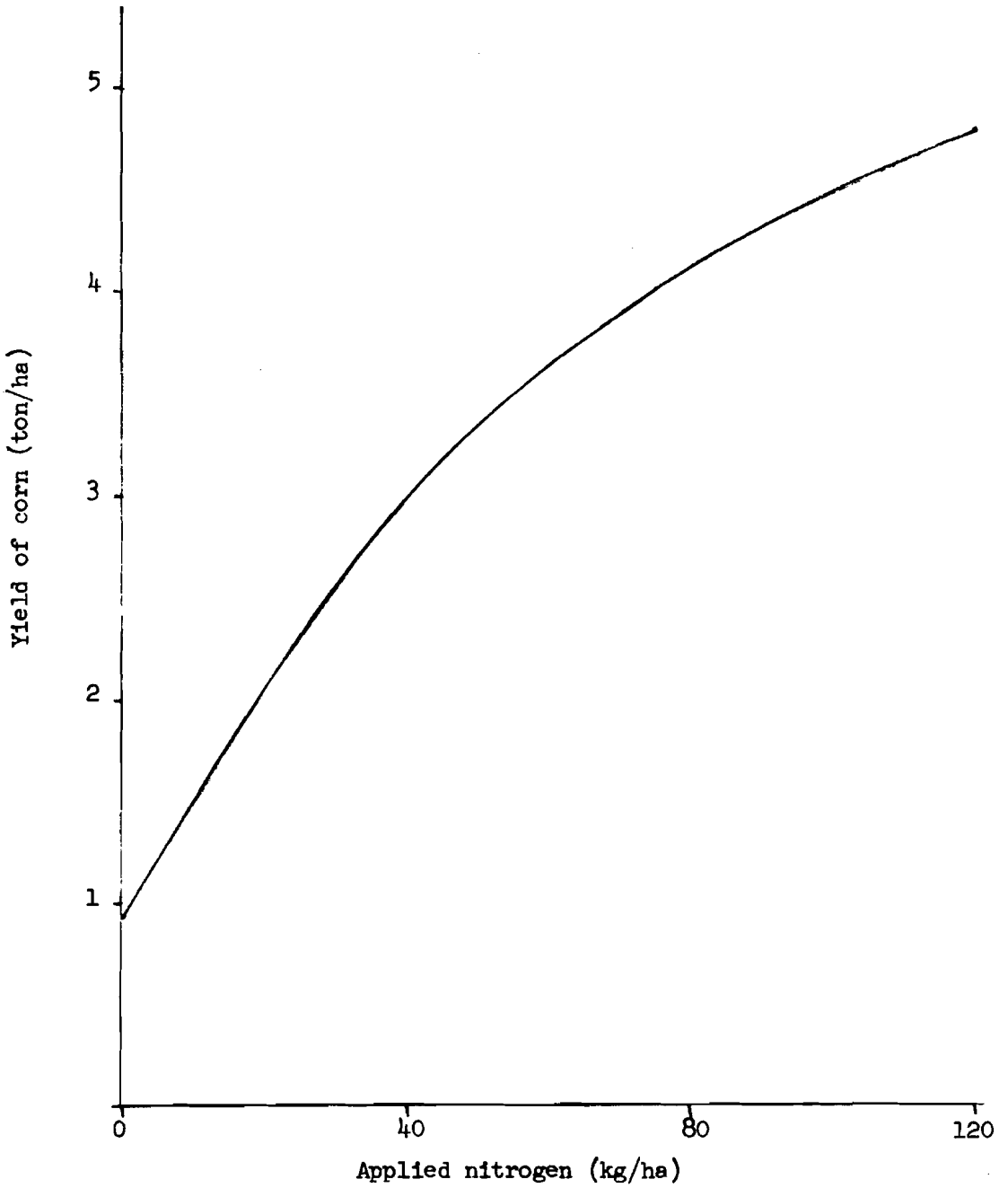


Figure 15. Response to N from 76 fertilizer trials in Central Mexico when the response was not limited by drought during 1962-1965. Extracted from the 1967-68 CIMMYT Report.

ferred seed to this section from "Institutions" for Corn as private enterprise is required for hybrid seed production.

51. All of these inputs have been provided by commercial companies in Kenya in a most efficient manner. In Mexico and Brazil, seed production has been under governmental control with very little success. The production of hybrid seed in Kenya has been with a private company from the beginning. The Kenya Seed Company had been established previously by a group of local large-scale European farmers to make available the improved grass seed being produced by the Grasslands Research Station. This company subsequently expanded to include sunflower seed (grading and exporting) so that it was a simple matter to expand the operation further in 1963 to include hybrid corn seed. With the rapid development of the hybrid corn industry in Kenya, seed corn is now the largest department. Even though they were granted a monopoly by the Kenya government to encourage them to produce the hybrid corn seed initially, profits are held at a moderate level by a joint price policy. Their efficiency of operation is sufficiently great so that they are able to distribute hybrid seed at probably the lowest price available any place in the world ($228.30/ton or $5.80/bu.). The seed is all grown by large-scale farmers (European and Kenyan) on contract under the seed certification program controlled by the Kenya government. Marketing is done through the Kenya Farmer's Association and Dalgetys, Inc. in Kenya and more recently with Tanzania Farmer's Association in Tanzania and through the Ethiopian Building Supplies and Technical Company in Ethiopia. These same companies also sell and distribute fertilizer and pesticides throughout these countries in addition to several additional international fertilizer companies that have established branch sales organizations in Kenya. They have arrangements with small shop keepers in the rural areas to stock and sell the seed and fertilizer.

52. Thailand has chosen to use a synthetic variety in their corn improvement program and have been successful in organizing an efficient seed production and certification program. Each year Breeder's Seed from their mass selection breeding programs in the Research Department is made available to qualified private seed producers. Those fields meeting the certification standards are certified by the government and the growers are permitted to sell this certified seed through private or government channels at 110% of the regular commercial

price.

53. With the small-scale farmer one of the biggest problems that must be solved before he will adopt the package deal for corn improvement is to have the inputs easily available to him and also to have a readily available market for surpluses. The seed and fertilizer is often transported from the small shop to the farmer's home by means of bicycle, wheelbarrow, tractor with a farm trailer, and even on the wife's back. Hence, the source of supply must be relatively close to the farmer's field.

54. It is easy to devise a system on paper whereby these services are provided by the extension service equally as well as by private enterprise. However, in practice one seldom finds the government employees willing to give such projects the attention required for their success. On the other hand, the profits for the commercial companies and their salesmen depend on the volume of fertilizer and seed sold especially where there is competition between two or three companies. Salesmen and promotional personnel employed by these companies may be much more effective in instructing the farmers as to the cultural practices required to get improved production with the new varieties and fertilizers than the extension staff employed by the government. Some of the best extension staff and research personnel have already been hired by these commercial companies as salesmen with extension responsibilities in Kenya.

55. Tanzania has been working for several years now trying to get a government seed production institution established with little success. In contrast, the Kenya Seed Company is making very rapid advances in their sales of hybrid seed throughout Kenya and more recently in Tanzania. They are now planning to hire an additional staff member to aid in the expansion of sales in Tanzania.

56. The private sector has also been responsible for making available the bulk of the cash inputs for the corn improvement program in Thailand. Fertilizer and insecticides are available through the local distributors. The larger distributors are, in addition, carrying on training programs for dealers and have developed through these dealers a type of extension service for the distribution of their products. Seed is generally available in village merchant stores, from the Ministry of Agriculture, or is saved from previous crops.

57. In many of the developing countries private enterprise sometimes requires assistance in order to get established initially. The granting of long-term loans

and financial guarantees to companies under certain circumstances might be a much more economical and efficient use of funds than giving grants to governments in order to develop seed institutions in the Ministries of Agriculture to undertake seed production and distributions. Kenya Seed Company and Zambia Seed Producers Association are big assets to Eastern Africa and can expand greatly in the future in the absence of tax or import restrictions on the part of other East Africa countries. Influence by AID to discourage such restrictions could be most helpful. The companies handling the commercial fertilizer are also big assets. Phosphorous fertilizers are manufactured locally by a private company in Uganda. Several companies have fertilizer sales organizations in Kenya, Tanzania, and Zambia and to a limited extent in Ethiopia. These operations can easily be expanded as the market develops for additional fertilizer. With the world surplus of nitrogen at the present time, it is much more economical for these countries to import the nitrogen fertilizer (perhaps with some subsidy to the farmers) than it is for them to try to set up local fertilizer plants as Kenya has only recently discovered to their financial embarassment.

58. In West Africa, the situation is completely different. There were not the large-scale European farmers present to create the demand to enable the fertilizer and machinery companies to establish sales and distribution networks. Also at the present time, there are no seed companies in West Africa that could extend their operation to include the production of hybrid corn or other crops. Up until now research has not been available to develop such improved corn varieties nor to determine their agronomic requirements. However, the AID-ARS Cereal Improvement Program (and in the near future the Tropical Research Institute in Ibadan) will soon change this situation. This deficiency in the private enterprise sector must be corrected before there is hope for cereal improvement in West Africa.

59. Most disease and insect pests of corn can best be controlled by developing resistant varieties when an efficient breeding program is being conducted by the research department. In some cases insecticides are required as a "stop gap" measure until resistant varieties can be developed. DDT is being used currently in Kenya to control stalk borers (Busseola fusca) and is distributed by the private sector along with the seed and fertilizer. In both Kenya and Brazil, governmental programs to control army worms and grasshoppers on a national or international basis are required occasionally. In El Salvador dusting with 5% Sevin or Dipterex

was included in the package deal as well as a 12" x 12" open weave cloth bag to apply the insecticide.

Machinery

60. The small-scale farmer is benefiting from the package program without any change in farm machinery in many instances. But the use of tractor plowing to speed up land preparation would be useful to gain the full benefits from early planting. The number of tractors is increasing in these small-scale farming areas in Kenya and Thailand mainly in the private sector. Farmers are buying them and often recover the cost through custom work. Shop keepers are also entering this contracting business. Tractor imports in Thailand were 3700 in 1966 and 9400 in 1968. In Brazil the number of farm tractors has increased from 62,000 in 1962 to 100,000 in 1968. The shelling operation is largely mechanized in Thailand and is gradually increasing in Kenya.

Water

61. Although great increases in yield can be obtained from corn with irrigation in many areas, this is a rather expensive way to obtain increased production at the present time. There is much land suitable to corn production in which the yields can be doubled or even quadrupled with nothing more than the use of the package program involving improved varieties, appropriate agronomic practices, and fertilizer. Irrigation should have much lower priorities until these other areas are exploited. In many of the areas currently growing corn in which there are drought periods or uncertainty in rainfall, sorghum and millet should probably be substituted. At the present time there are problems with these latter crops as far as birds, pests, and acceptability of the food products by the local people. Research to solve these problems and thus to increase the use of sorghum and millet would be a much more economic proposition than irrigation with corn in many of these areas. The AID-ARS Cereal Improvement Program is currently investigating these problems for Eastern Africa with the research project centered at Serere, Uganda and at Samaru, Nigeria in Western Africa.

62. Where irrigation can be developed simply and economically; or if it must be developed for political reasons, very high yields of corn can usually be obtained. However, this provides a specific ecological situation and both breeding and agronomic research will be required to develop the improved hybrids and agronomic practices necessary to get maximum economic yields under these conditions.

INSTITUTIONS

Extension

63. The factor probably most limiting maize improvement in Eastern Africa at the present time is the extension program. Sufficient research has been undertaken by the national research organizations and coordinated by the AID-ARS Cereal Improvement Program, that these aspects of the package program are available to most of the major maize growing areas. The Kenya Seed Company and commercial fertilizer organizations are operating in most of the countries and can expand their facilities to provide the fertilizer and to distribute both the fertilizers, seed, and pesticide if a demand is created by the extension staff. This is particularly true in Tanzania and Zambia where adequate marketing organization exists with guaranteed prices so that the profit incentive is available to the farmer.

64. The success of the maize programs in Kenya and El Salvador is due to a large extent to the effective program mounted by the extension service. AID had a big part to play in the programs both through the assistance to the agricultural colleges and the provision of study opportunities in the United States for members of the extension staff. Egerton College, Njoro, Kenya, (which has received assistance from the West Virginia University AID Contract) has provided a very large number of capable extension officers and assistant agricultural research officers involved in the maize work in Kenya. As mentioned previously many of these are also being hired by the commercial companies where they are still providing a valuable service to Kenyan agriculture. Other members of the extension staff have been provided short courses in the U.S. in which they are given a chance to see how extension is functioning here. The present Director of Agriculture in Kenya, Mr. P. S. Mirie, was given such a course several years ago. The demonstration plots which have contributed so much to the success of hybrid corn in Kenya were initiated and expanded by him as he moved up to the Provincial Agricultural Officer and then finally the Director of Agriculture under which the Extension Service operates.

65. Mr. Mirie realized that the small farmer is not convinced by demonstration plots and trials grown on government stations. Most of these stations are mechanized and have government funds available to them. In contrast, the same demonstration plots conducted on typical farmer's fields by the farmer himself, but

with supervision by the extension personnel, can be very effective in getting the message to the farmer and to his neighbors that they can obtain similar results on their own farms if they will adopt the package program. It is much better to expand such a program slowly to see that all demonstration plots are done properly rather than to try to launch too extensive a program and thereby fail in the supervision of some of these plots. The goal of Kenya was to have a one acre demonstration plot with all practices done on a farmer's field within walking distance of every farmer. In 1966 two thousand of these demonstration plots were grown with varying levels of success. Once this program was under way and the leading progressive farmers in each area had obtained the information, their fields often provided a better demonstration than those under government supervision where sometimes there was delay in planting due to late arrival of seed or fertilizer or the fact that the extension officer was busy with some other task and did not give proper supervision. The expansion of the area devoted to hybrid corn in Table 2 suggest that most of the progressive farmers in Kenya have now adopted the package program and further expansion will require a more extensive effort on the part of the extension staff. Such a program is being launched in 1969 with the cooperation of FAO.

66. Zambia has been obtaining very high yields on the large-scale European farms with hybrid varieties for several years now. But prior to independence, no effort was made to extend this to the small scale farmers. During the past two or three years an extensive effort has been put forth by the extension staff to get the small-scale farmers to adopt these practices as well.

67. Malawi has also been working very strongly in this area. Although hybrid varieties have been developed by the breeding research program, the seed production has not been developed to make these available to the farmers. Hence, they have felt it desirable to proceed with improved synthetic varieties. With an open-pollinated crop such as corn, this can only be done effectively if the whole district adopts the variety and improved agronomic practices at the same time. Otherwise improved varieties are soon contaminated and the genetic superiority lost. If this effort is successful, it will be extended throughout Malawi. On the other hand the Zambia Seed Producers Association or the Kenya Seed Company could probably very easily produce the hybrid seed required by Malawi and the use of hybrid seed might increase the efficiency of the maize improvement program in Malawi.

Credit

68. When inputs are required such as fertilizer, hybrid seed, and pesticides that incur an expenditure of cash by the small-scale farmer, one of the big problems becomes credit. Family relationships are extremely close within many of the developing countries in Africa and Asia. If a certain proportion of the population is employed by the government, industry, etc., it is surprising how much of this money becomes available to the relative back on the farm for the procurement of these inputs. When these sources of funds are not available, it becomes rather difficult to provide credit for a crop such as corn in which such a small proportion is sold through controlled markets. For cash crops such as cotton and coffee there is usually a single marketing organization to which the farmer must sell his crop, and it is easy to collect the money that has been loaned when the crop is sold. In contrast, if the crop can be sold to neighbors or through other channels not under control, it sometimes becomes very difficult to regain money from the loans. This credit has been provided very effectively in Western Kenya to those farmers belonging to coffee cooperatives because the cooperative could advance enough money for seed and fertilizer for corn as well as expenses for coffee and the money could easily be collected when the coffee was sold. Similarly there are two pilot projects underway in the Eastern Congo--one in which tobacco is the cash crop and corn is the food crop, and the other in which cotton is the cash crop. In both of these projects it should be very easy to provide credit for the corn as well as the cash crop and tnen to deduct these loans from the sale of the cash crop.

69. In Thailand in spite of various plans to organize agriculture credit both through government sources and to encourage private lending through loan guarantees, the bulk of the credit to the corn farmer comes through traditional sources. Kasetsart University studies indicate that corn merchants and relatives are principle sources of credit. The detailed breakdown follows: corn merchants 43%, relatives 23%, grocers 14%, cooperatives 7%, neighbors 6%, banks 4%, others 3%.

70. Credit was apparently limiting corn improvement in Brazil until this service was provided in 1967-68. With 40% of the hectarage already planted to hybrid corn, availability of credit and fertilizer should result in greatly increased production. Since all factors except credit seem to be available in El Salvador, returns from the provision of this service should be very great. At the present time, credit for farmers with less than 6 hectares is almost impossible to obtain

in Kenya. Providing credit might be much more effective than increasing extension activities alone.

MARKETING

71. Another aspect that is extremely important in getting the small-scale farmer to adopt the improved package is the profit motive. Before a farmer will be willing to spend money for seed and fertilizer, he must be assured that at harvest time he can sell his crop at a fair price to either repay his loan or have money available to buy seed and fertilizer for the following year. When a stable market does not exist, it would probably be a waste of time to attempt corn improvement. This is the situation in Uganda at the present time for corn, sorghum, and millet. The market is strictly a supply and demand situation which fluctuates greatly from season to season within a year and from year to year. It is difficult to see how any improvement is going to occur until this situation has been corrected.

72. Not only must a market with a fair price be available, but this must be accessible to the farmer. This becomes especially important to the small-scale farmer as he has very few transportation facilities of his own. There must be collection centers close enough so that he can reach them by primative transportation. Another aspect, of course, which is important is for the government to develop farm-to-market roads to assist this process. This will be one of the biggest problems in Ethiopia as the road network is extremely poor.

73. The major transportation facilities also become extremely important once the program has become successful enough to produce an exportable surplus. In Kenya, the transportation system is so inefficient that it costs nearly as much to transport corn from the maize corn growing centers to the port and to load it on the ship ($23.10/ton) as the farmer receives for his crop initially ($38.60). A recent study has indicated that the current transportation and handling cost of $23.10 could be reduced by $9.00/ton with an efficient bulk handling system. Providing long-term loans for local storage facilities and for the updating of transportation facilities could be a real contribution by AID in many of these countries. Assistance by providing storage and transportation experts to give advice on the most efficient systems would be another most worthwhile service. The establishment of strategic storage in Kenya through the use of the "Cyprus Bins" was a very worthwhile project. On the other hand, one can seriously question

whether such structures are the most efficient when year to year storage is considered in addition to the longer term strategic storage.

LAND TENURE

74. A very important aspect of the profit incentive is the land tenure system. When a farmer owns his land, he will benefit from long-term land improvement programs and he will receive the profits from the corn improvement obtained by the package deal. In countries with tribal ownership if no assurance of continued use of a farm is given, corn improvement will be difficult. This is also true of countries such as Ethiopia on the large land holdings where the tenant does not profit by increased production.

UTILIZATION

75. As more and more developing countries give attention to food production with the success that can be achieved as demonstrated by Kenya and Thailand, attention must be given to the second generation problems created by these surpluses. The increased use of cereals for livestock feed is probably one of the best uses that can be made of these surpluses. However, in many of these developing countries a complete program for livestock improvement must be conducted similarly to the cereal improvement program. The other area is food processing and finding additional ways to utilize corn products within the developing countries. These can include commercial food preparations as well as corn starch and corn oil.