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A.I.D. Project Impact Evaluation Report No.2

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**Kitale Maize: The Limits of Success**

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May 1980

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KITALE MAIZE  
THE LIMITS OF SUCCESS

PROJECT IMPACT EVALUATION NO. 2

by

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In October 1979, the Administrator of the Agency for International Development requested that, in preparation for an Agency-wide ex-post evaluation system, between twenty and thirty projects be evaluated during the subsequent year, focusing on the impact of these projects in several representative sectors of the Agency's program. These impact evaluations are to be performed by Agency personnel and result in a series of studies which, by virtue of their comparability in scope, will ensure cumulative findings of use to the Agency and the larger development community. This study of the impact of the Kitale Maize research in Kenya was undertaken November - December 1979 as part of this effort. A final evaluation report will summarize and analyze the results of all the studies in each sector, and relate them to program, policy and design requirements.

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## EXECUTIVE SUMMARY

AID first became involved with hybrid maize research in Kenya in 1963, through the Organization of African Unity and the East African Community. By 1970, the yield of the original hybrids had been successfully improved by 25 percent under research station conditions. The breeding program was continuously followed with similarly positive results until the EAC broke up in 1977. Other aspects of the AID program were less rewarding. Research to improve maize protein quality and to develop varieties for low rainfall areas did not succeed. Nor did the attempt to train Kenyans and integrate them into the research operation succeed. When the last American scientist left almost 15 years after the first AID project began, the effort was not sustained by Kenya.

In 1964, the first hybrid maize seeds were released for commercial production. Hybrids produced a remarkable 40 percent increase in yield over local seed and proved appropriate to the environment of the high potential areas of Kenya, with their fertile soils, abundant rainfall, and moderate temperatures.

It was assumed that African farmers would continue to use the old variety rather than the new hybrid -- it was less prone to disease and it could be re-used year after year whereas hybrid seed had to be re-purchased each year. But the hybrid was clearly superior in yield, enjoyed the status of a crop used by large farmers, and small farmers soon demanded it. By 1977, the majority of smallholders in high potential Central, Rift Valley and Western Provinces grew hybrid maize and their production far surpassed large farmer output.

An aggressive private firm, the Kenya Seed Company, reproduced the seed, distributed it, and promoted it throughout the country via a network of private shopkeepers. Extension agents demonstrated the use of improved cultivation techniques. The government-supported official prices and marketing system provided incentives, particularly for large farmers, to adopt and profit by the hybrid technology.

Innovations are usually unfair in the sense they reward those who have the means to benefit from them. Consequently, it is not surprising that hybrid maize was of greater value to those farmers with sufficient land, labor and capital to fully utilize the innovation. More surprising is the large number of smallholders who did gain access to the hybrid maize technology and who have improved their food security as a result. The overall impact of the increased maize production attributable to the use of hybrid seed is that Kenya has continued to be more or less self-sufficient in maize, the country's staple food. As a result, Kenya has not had to face the food policy decisions which have confronted other developing countries, despite a very high rate of population growth. Without hybrid maize, population pressure would likely have led to a demand for more land for food crops and a reduction in less essential export crops. Hybrid maize helped to keep the price of food down in the cities, thus muting the pay demands of urban workers and keeping Kenya attractive for foreign investment.

There is a question, however, whether the government saw the increased production of maize as more of a problem than an opportunity. The government continued a pricing and marketing system more suited to dealing with the problems of scarcity than those of abundance. The Maize and Produce Marketing Board responded to an obvious need for increased storage capacity, for example, with too little, too late. Nor did the government take adequate measures to ensure the continued success of hybrids by guarding the flow of critical inputs, including sufficient credit and chemical fertilizers and being supportive of the research facilities which made the hybrids possible. The loss of the incremental benefits, which the AID project demonstrated were possible by improving hybrid seed year to year, cannot be calculated -- but based upon the benefits derived from the program in early years, the loss is substantial.

Smallholders have not yet exerted policy influence on the government (as did the European-dominated large farm sector prior to Independence) by forming effective organizations of their own. If government policy toward maize is to become more effective, it will require not only better long range planning but wider popular participation, especially among smallholders, in its formulation.

From the experience of hybrid maize in Kenya and from the observations of Kenyan maize growers and consumers, an AID evaluation team drew seven key lessons:

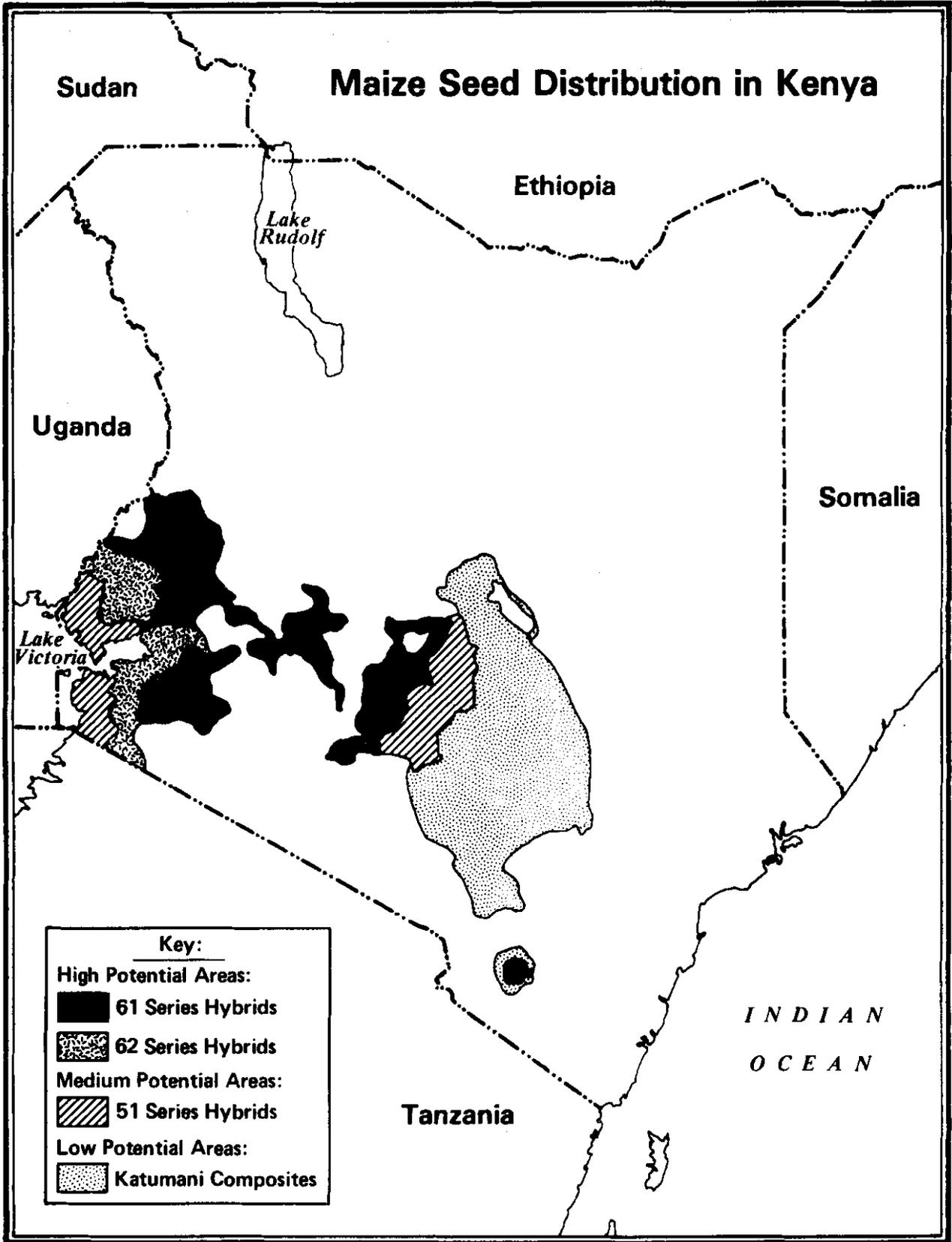
1. Simplicity and viability were the decisive factors in the success of hybrid maize.
2. The private sector was crucial in the rapid diffusion of hybrid maize.
3. Perfect equity cannot be expected even from the most successful technology.
4. The long-term continuity of foreign experts was basic to the success of the breeding program.
5. Foreign advisors and finance do not automatically create institutional capacity to perform agricultural research.
6. Pragmatism and skepticism should surround AID support for regionalism.
7. Too many lessons should not be drawn from a unique experience in one African country.

FOREWORD

Corn is not usually the first thing that springs to peoples' minds when they think of Kenya. But beyond the tourist hotels and the game parks is a poor country where 90% of the people depend on maize for their staple food. The importance of efforts to increase corn production is significant given the dire predictions of large foodgrain shortages facing the world in the 1980s.

There have been a number of evaluations of Kenya hybrid maize in the past. It was the subject of comprehensive treatment in 1969-70 as a part of AID's first Spring Review of the new cereal varieties and again in 1972, 1975, and 1978 when special teams were sent from the U.S. to examine progress under the succession of AID-financed projects which related to breeding maize. Yet, in all of these years no one within the Agency had taken a serious look at the impact of this new technology on people in Kenya. With the advantage of hindsight perhaps it would be possible to answer important questions concerning agricultural research, its applications, its impact on people, as well as AID's assistance in helping people feed themselves. Why and how did hybrid maize spread so quickly in Kenya? Did it reach the poor majority and, if so, what difference did it make in their lives? How did it change the institutions, policies and economy of the country? What are the lessons for the future that can be learned from the Kenya experience and can they be replicated in other countries? These questions, and others which soon arose, more than justified the exercise. The members of the team hope that the following answers have done justice to the importance of the questions.

Many people in Kenya and here helped the effort. In Kitale, Messrs. Kusewa, Hazelden and Motanya set aside entire days to assist the team. In Nairobi the USAID Mission rendered valuable administrative support. Wilbur Scarborough helped guide the team for two weeks, while Harold Jones generously offered his experience and insights. Mrs. Ester Mbajah and Miss Annah Ngumbi gave outstanding clerical assistance. Back in Washington Twig Johnson backstopped the team from the Studies Division. Finally, we are grateful to numerous Kenyan farmers for their common sense views which they shared with us.



## INTRODUCTION

1964 was a good year for Kenya. Besides being Kenya's first full year of independence, 1964 saw the release of a hybrid maize labelled H611 for commercial production. There are two parts to the story of hybrid maize in Kenya. The first involves the research and development of the seed. The second is the spread and impact of the seed to the small farmers of the country. AID figures most prominently in the research and development component, but an evaluation of AID's effort must include the telling of both parts of the story.

The people of Kenya rely on agriculture. Even though agriculture has declined from some 40% of the Gross Domestic Product in 1964 to just over 25% today, over 90% of the population derive their livelihood from agriculture. The major change in agriculture since independence has been the decline in large scale farming and the increasing importance of smallholder production.\* This has not only been the result of the subdivision and Africanization of most of the large European farms, but it also reflects an absolute growth in production among smallholders to over 50% of the value of total marketed production -- up from some 20% in 1960.

Maize is the primary staple food grown by smallholders. It accounts for over half of their land devoted to food crops and nearly all smallholders grow some variety of maize to eat and to market. Maize is such an important food that there is little attempt to substitute other staples even as the price of maize rises in the market; indeed, there is great resistance to changing the maize diet even when other foods are available. For example, a successful rice production scheme in Mwea, central Kenya, resulted in the farmers' selling as much of their rice as possible in order to buy maize for their own consumption.

## MAIZE RESEARCH AND AID

AID has been for some 15 years involved in research to improve hybrid technology. The commercial introduction of hybrid maize in 1964 was a result of a lot of work and a little luck. The work started in the mid-1950's at the urging of large-scale European farmers. The

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\*The Government of Kenya defines smallholders as those who own eight hectares of land or less; however, 75% of all smallholders actually own less than two hectares. For the purpose of this impact evaluation the team has used the two hectare demarcation as our definition of the rural poor majority. The focus of our inquiries about hybrid maize in Kenya is on this group.

government, with Rockefeller Foundation support, hired Michael Harrison as a maize breeder to work at Kitale Research Station. His early work with local varieties had resulted in only mixed success in increasing yields. Then following his AID and Rockefeller-sponsored trip to Mexico to collect new maize breeding lines, Harrison's luck changed. In experiments involving some 200 lines, he crossed an Ecuadorian line with the best local variety, Kitale Synthetic II. The resulting hybrid, H611, produced a remarkable 40% increase in yield and proved appropriate to the high potential areas of Kenya, with their fertile soils, abundant rainfall and moderate temperatures.

At the time it was assumed that the African small farmers would continue to use the local synthetic rather than the new hybrid seeds. The synthetic had a wider genetic base than the hybrid, reducing the chance of crop failure; moreover, it was an open pollinated variety, meaning farmers did not have to buy new seed each year as they did with hybrid seed. However, because the hybrid was superior in yield and enjoyed the status of a large farm crop, small farmers demanded and purchased the hybrid seed. It was so popular that small farmer hybrid maize production soon surpassed large farmer output.

AID first became involved with hybrid maize in Kenya in 1963. Over the next 15 years AID committed an estimated \$1.5 million in pursuit of two primary objectives--one to develop a breeding methodology to make regular improvements in hybrid maize; and the other to create the institutional capacity in East Africa for maize research. The first was a success, the second a failure.

There was never an AID project called "Kitale Maize". There were, in fact, parts of some dozen projects that had an impact on the phenomenon called "Kitale Maize". These began with agreements between AID, the Organization for African Unity and East African Community (EAC) to finance basic research in maize at Kitale (and other grains elsewhere in Africa) under the Major Cereal Crops in Africa project. Building on what Michael Harrison already had done, the first AID-financed breeder began work in 1964 to make annual improvements in the hybrid maize lines. By 1970 the breeding program had improved yields by 25%, under research station conditions. At the same time, AID posted field trial officers to Tanzania and Uganda to evaluate hybrid maize under commercial farming conditions in those countries. Spinoffs from the Kitale program included a USAID Kenya project designed to diffuse hybrids in densely populated Vihiga District and a seed multiplication project in Tanzania.

In 1972 the East African Community Food Crop Research project formalized the attempt to breed hybrids for the low altitude, low rainfall conditions found in most of East Africa. By 1975 the project was redesigned to establish a regional Protein Quality

Laboratory for research on high-protein maize and to emphasize work on breeding disease resistant maize. Breeding for marginal rainfall areas continued and was central to a new 1978 project, Dryland Cropping Systems Research, which came out of an evaluation in the same year.

The themes of training and institution building began to be woven into two new projects. In 1969 AID sought to build within the East African Agriculture and Forestry Organization (EAAFRO) a capacity for maize breeding and for linking this research to neighboring countries. The projects were Animal and Crop Production and Major Cereals and Legume Improvement. Research conferences were held in five East African countries and regular varietal trials of hybrid maize were undertaken throughout the region. 1972 saw an attempt to strengthen the institution building objective with an AID offer to train 15 to 20 African scientists. The deterioration of the EAC and the withdrawal of U.S. assistance to Uganda in 1972 hampered the achievement of the objective. The offer of U.S. training for African scientists was renewed in 1975 along with a substantial increase in U.S. technicians. However, the collapse of the EAC in 1977 and the termination of the breeding program at Kitale coincided; the third and last AID-financed maize breeder went home; and the project shifted from regional auspices to the USAID Mission in Kenya.

After some 15 years of AID involvement in maize breeding, these are the results of the scientific effort; 1) most of the breeding program for the high potential areas was a success. Under the direction of American scientists the original hybrid lines were regularly improved; 2) the research to improve maize protein quality has not worked out. The scientific research did not match the earlier hopes that maize would become a valuable source of protein for third world people; and 3) the efforts to develop varieties in low rainfall areas has not been successful. As one scientist remarked, "The perfect maize for semi-arid areas is sorghum."

Nor did AID's effort of much of this 15 year period to create a regional maize research capacity succeed. The breakup of the EAC destroyed the original concept of a regional institution. But even when regionalism was flourishing, the individual states preferred to keep their own scientists working on national programs.

Yet the national research programs were not more successful in building their own research staffs. The Kenya Government failed to improve salaries and benefits for its maize breeders and so reduced the incentives for trained Kenyans to stay with the national program, AID played a fairly ineffective role -- while in periodic evaluations it criticized the failure of projects to train Africans, AID continued

the training rationale to justify support for maize research under new projects. When in 1977 the last American breeder, L. L. Darrah departed, his African colleagues did not carry forward the breeding program. Today in Kenya, as elsewhere in East Africa, indigenous maize breeding capacity remains very limited.

THE SPREAD OF HYBRID MAIZE SEED

The reasons for the spread of hybrid maize seed are both simple and complex. Simply put, hybrid maize seed produced more of an already accepted product. While farmers demanded the seed because of its increased yield, consumers liked the taste, color and texture of the hybrid product. Beyond those simple conditions, Kenya had the means to spread the seed. The research station kept turning out varieties adapted to the different regional climates, A private firm, the Kenya Seed Company, reproduced, distributed and promoted the seed throughout the country. Shopkeepers made money from it, farmers recommended it to their neighbors, and extension agents demonstrated how to use it. All of these groups took advantage of Kenya's well-developed transportation and marketing systems. As a result, by 1977, the hybrid seed spread from large to small farmers and to every region of Kenya as shown below.

Percentage of Smallholders Growing Local  
and Hybrid Maize by Province

<u>Province</u>	<u>Local Maize</u>	<u>Hybrid Maize</u>
Central	95 %	67 %
Coast	94	19
Eastern	99	30
Nyanza	80	36
Rift Valley	59	92
Western	74	73
All Kenya	86	50

(Note: The totals for each Province exceed 100% because most farmers grow both local and hybrid maize.)

Source: Integrated Rural Survey

Other reasons why the seed spread are more complicated. For the poor majority of smallholders, increasing production is not the overriding goal. Their primary objective is to minimize the risk of crop failure. With this in mind, production is then maximized. New methods of production must clearly be demonstrated before these farmers will adopt them. Where soil and climate are less than ideal, local varieties with a wide genetic base will produce some harvest while hybrid seed, less adapted to local conditions is more likely to fail completely.

Poorer smallholders adopted hybrid maize later, and less completely, than their wealthier neighbors because of the risk involved. Those smallholders adopting hybrids had cash crops six times greater in value than those not adopting. These cash crops gave farmers money to purchase inputs needed for hybrids (i.e., fertilizers) and they provided a cash buffer to offset the risk of innovation. Larger smallholders adopted earlier and to a greater extent than smaller ones. In short, smallholders who adopted hybrid seed tended to have more land, grow more cash crops and earn higher cash incomes than those who did not. They were the better-off of the poor majority.

The government's extension service generally got mixed reviews in aiding the spread of hybrids. In the early years, extension agents were active and enthusiastic promoters of hybrids, setting up as many as 5,000 maize demonstration plots in one year. More recently, enthusiasm and effectiveness seem to have waned, perhaps because farmers came to believe they knew more about growing hybrid maize than did the agents. Many of the poorer farmers felt that the extension service consistently recommended practices beyond their means. A related example of this problem was found in a survey of farmers around the research station at Embu, central Kenya. The farmers who lived near the research station actually had lower rates of adoption of hybrid maize than those who lived 20 to 100 miles away. The nearby farmers apparently knew what kinds of inputs the station used to grow hybrid maize (fertilizers, insecticides, machines, etc.), and understandably figured that such methods were too expensive.

#### THE IMPACT OF HYBRID MAIZE SEED

The spread of hybrid maize had various effects on the economy, government and poor majority of Kenya. The larger smallholders benefited the most; the poorer smallholder benefited the least; all benefited to some extent. Government policy was the arena perhaps least changed by the spread of hybrids. The research effort was

not maintained, the marketing system remained oriented to problems of shortages, and the government continued to pursue an inadequate pricing policy towards maize.

### Growth

During the period of very rapid diffusion of hybrid maize and prior to the 1973-74 price explosion in fuels and fertilizers, the Kenyan economy achieved an impressive rate of growth. From 1964 to 1972 the economy grew at 6.5% annually with a per capita increase of nearly 50% for the period. While the share of agriculture in gross domestic product fell, the value of production increased by 67%. At the same time the area planted to hybrid maize increased 22 times, raising the yield attributed to the new maize seed by nearly one million tons. The impact of this increase was summed up by an agronomist in 1973: "Without these 11 million extra bags, it is more than likely that Kenya would have had severe food shortages in the past decade."\*

The spread of hybrid maize thus paralleled the growth of the economy as a whole in the 1964-72 period and has remained a bright spot in the dull economic picture of 1973-79.

Hybrid maize affected individual farmers' economic decisions. A new word was added to their vocabulary, "hybrid", that described a new plant completely different from the maize the farmer had previously grown. Hybrid maize seed was promoted as part of a package of improved practices and inputs, although technically, a simple substitution of the appropriate hybrid seed for local seed results in increased production. By applying improved plant husbandry practices, for example, it was demonstrated that a 217% increase in output per hectare could be achieved. While the same husbandry innovations used with local seed were estimated to return a 175% increase in yields, the research and extension services argued that it was easier to convince farmers to use new practices with new seeds than to change farmers' techniques with old seeds. They seem to have been right. Farmers did change their farming practices with the advent of the new hybrid maize seed. Surveys show that most hybrid-using farmers have not adopted the whole package of husbandry recommendations but have certainly incorporated some -- presumably with increases in yields.

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\*Allan, Uhuru na Hybrids, p. 2.

Furthermore, the small farmer's orientation to the market has been accelerated by the spread of hybrid maize. The importance of the commercial climate for maize production was vividly illustrated in 1979, when a reduction in the official purchase price for maize and the cancellation of the major large-farm credit program happened simultaneously. The commercial farmers were expected to react strongly -- and they did. Maize hectareage, as estimated from seed sales, declined dramatically. What had not been anticipated, however, was the reaction of smallholders to the uncertain price situation. In the past, when the official purchase price at harvest was \$120 per ton, many smallholders were only able to sell for \$60 in the open market. This year's official reduction in the maize purchase price caused hybrid seed sales to smallholders to drop by nearly 15%. Many farmers were interviewed who had little confidence in future market conditions. They reported that they were still growing maize for home consumption but that they were not going to grow such substantial surpluses as they had in years past.

Another strong impression given the team was that smallholders are now able to use more of their limited land for cash crops without reducing the food supply needed for household consumption. Survey data indicate that smallholders who grow hybrid maize produce no more than those who grow local maize, about 750 Kg. per holding on the average. Given the yield superiority of hybrid, this means that smallholders can meet all or part of their home consumption requirements while withdrawing land from maize production. This land can be planted to more profitable crops like vegetables, coffee and pyrethrum. The increased commercial activity of smallholders in these cash crops is, thus, partly attributable to the use of hybrid maize seed.

For the economy as a whole, Kenya has been more or less self sufficient in maize for some time even though in any given year there may be a small surplus or deficit. This performance, which in large measure may be attributed to the successful diffusion of hybrid maize, sets Kenya apart from its neighbors who must import substantial quantities of food each year.

### Equity

Small farmers benefited from this new technology despite the odds. Innovations generally reward those who have the means to benefit from them. By releasing constraints on productive resources, technology allows land, capital or labor to be more fully utilized. Those people who have more access to these resources will gain greater benefits than those who have limited access. Consequently, it should not be surprising that hybrid maize was of relatively greater value to those farmers with sufficient land, labor and capital to utilize fully the innovation. More surprising may be that large numbers of smallholders,

including a substantial number of the poor majority, did have access to the hybrid maize technology and that they have gained improved food security as a result.

Hybrid maize was of greater benefit to people who lived in agriculturally favored regions. Originally designed for the requirements of the high potential areas, chiefly Rift Valley and Western Provinces, the adoption of hybrid maize allowed smallholders there to outpace smallholders elsewhere. As shown by the table below, provinces with high hybrid maize production also consumed more maize than provinces with low hybrid maize production.

Average Hybrid and Local Maize Production and Consumption Among Kenyan Smallholders, 1974-75

<u>Province</u>	<u>Hybrid (Kgs)</u>	<u>Local (Kgs)</u>	<u>Value of Home Produced Maize Consumed as % of total consumption</u>
Central	250	540	11.74 %
Coast	280	420	12.55
Eastern	50	470	10.76
Nyanza	630	1,730	20.60
Rift Valley	1,970	480	24.49
Western	1,280	160	17.55

Source: Integrated Rural Survey, 1974-75

Beyond these regional differences, there was a clear relationship between production of hybrid maize and size of holdings: the larger the farm the more likely the smallholder was to grow hybrid maize. In addition, it was the larger farmers who adopted hybrid maize first. This was not thought to be particularly worrisome, so long as small farmers followed suit within a reasonable period of time. A delay in adoption only becomes a serious problem if the early adopters are able to prevent the later adoption of the technology by others, through land accumulation, cornering credit or inputs, or other means. There is no evidence that this happened in Kenya.

Nevertheless after 15 years of hybrid maize in Kenya, it seems reasonable to conclude that there are real constraints on the poor majority's ability to participate fully in the increased yield potential of the hybrid seed. Here again the condition of those smallholders who cultivate two hectares or less are being addressed. Visits by team members to East Bunyore in Western Province and Embu in Eastern Province revealed that the same factors that prevented small farmers from adopting hybrid maize technology in the early

1970s are preventing them from adopting it today; fear of crop failure and an inability to mobilize cash for the timely purchase of inputs, particularly chemical fertilizers. The risk factor and the lack of cash frequently means that small farmers do not get the full benefits of hybrid maize. They are unable to follow recommended farming practices such as early planting. They often cannot afford adequate amounts of fertilizer and insecticides. They attempt to reuse the hybrid seed rather than buy new stock. And they prefer to use costly chemicals on cash crops rather than on a food crop like maize. As a result, the smallest farmers' benefits from hybrid maize production are probably less than the figures on hybrid seed adoption would indicate.

**Production of Hybrid and Local Maize  
Among Smallholders by Size of Holding**

<u>Size of Holding (Ha.)</u>	<u>% of Holdings in Local Maize</u>	<u>% of Holdings in Hybrid Maize</u>
Below .5	88.8 %	44.1 %
.6 to .9	85.7	43.6
1 to 1.9	89.8	44.3
2 to 2.9	88.9	51.6
3 to 3.9	82.7	62.2
4 to 4.9	91.4	47.4
5 to 7.9	68.9	74.8
8 plus	67.3	78.5

**Source: Integrated Rural Survey, 1974-75**

Team visits to densely populated smallholder areas confirm these impressions. Few farmers were planting hybrid seed. Some were returning to traditional varieties, others were attempting to use second generation hybrid seed despite their obvious lower yields. Whether this is a temporary phenomenon, reflecting recent unstable government price policy and uncertain market conditions, remains to be seen.

**Government Policy**

The development of hybrid maize technology was the result of government actions in research. The success of this technology has meant that Kenya has not faced the food policy decisions which have confronted other developing countries. In large part because of hybrid maize, Kenya could continue to feed itself despite a very high and apparently accelerating rate of population growth. This enabled it to pursue a

course of rapid industrialization. Hybrids also allowed Kenya to earn foreign exchange by exporting cash crops like coffee and tea. It helped to keep the price of food down in the cities, thus muting the pay demands of urban workers and keeping Kenya attractive for foreign investment. Increased maize production helped dampen possible demands for income redistribution and the hard policy options that would have been forced on the government. In short, hybrid maize bought time.

The success of hybrid maize did, however, confront the government with policy questions concerning pricing, marketing, storage and research. In general, the government viewed the increased production of maize more as a problem than as an opportunity. It continued an antiquated pricing and marketing system more suited to dealing with the problems of scarcity than those of abundance. The difference between what farmers received and what consumers paid increased. The government's official marketing arm, The Maize and Produce Board (MPB), incurred ever-increasing deficits through inefficient and reportedly corrupt operations. The MPB responded to the clear need for increased storage capacity with too little, too late. The government has given little support to establishing secondary industries based on maize. Nor did it take adequate measures to ensure the continued success of hybrids by guarding the flow of critical inputs, such as sufficient credit and chemical fertilizers, and the research facilities which made the hybrids possible.

This last point deserves special attention since AID's involvement was, after all, directed to the support of agricultural research. The government started out with a policy of high priority and support for maize research. Now the signs of de-emphasis are everywhere: new positions for maize breeders have not been created, nor have salaries stayed competitive with similar positions in private industry and the university. Some 16 years of AID support of maize breeding, albeit on a regional level, produced only three Ph.D. level Kenyan breeders -- none of whom is now working in the country's maize research program. The comprehensive breeding improvement program installed by U.S. technicians is no longer operating. The loss of annual incremental benefits, improved yields, greater disease resistance, and better plant characteristics have been and will be substantial.

Crisis policy-making mirrored the centralization of government control over agriculture and a decline in influence of the agriculture sector. Influence over policy by farmer organizations, such as the Kenya National Farmers Union and the Kenya Farmers Association, has diminished. Even the influence of the MPB may have weakened. Their decline has paralleled that of the European-dominated large farm sector which created and sustained them. Smallholders have not filled the gap with effective organizations or pressure groups of their own. Even Parliament seems ineffective in determining policy toward maize. If government policy toward

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maize is to become more appropriate, it will require not only better long range planning but wider popular participation from smallholders as well.

These problems have not gone unnoticed. The government currently is investigating the moribund state of maize research and, it is hoped, recommendations and action will be forthcoming to correct the observed deficiencies. In the meantime, due to these erratic policies, especially over marketing and pricing, Kenya will likely have to import maize in 1980.

#### LESSONS LEARNED

1. Simplicity and viability were the decisive technical factors in the success of hybrid maize. Simplicity meant that farmers could substitute hybrid for local seed with no change in agricultural practices, even though improved husbandry was recommended. It also meant that hybrid maize easily replaced local maize in the market and in the diet; no change in consumer preferences was required. Viability meant that the hybrid maize yield increase (some 30 to 40%) could be readily perceived by farmers. The large benefits from adopting hybrid seed and improved husbandry practices also allowed for inefficiencies elsewhere in the agricultural system, e.g., marketing, without diminishing the appeal of the new technology.
2. The private sector was crucial in the rapid diffusion of hybrid maize. The key was the ability of the seed producer (the Kenya Seed Company) and the seed distributors (the vast network of small shopkeepers) to make a profit without excessive government interference. Conversely, the government's continuing regulation of maize marketing has probably hindered the realization of the full potential of hybrid maize -- probably in terms of production, almost certainly in terms of smallholder equity.
3. Equity cannot be expected even from the most successful technology. While smallholders owning two hectares or less had access to the hybrid seed and large numbers adopted it, the benefits to them were relatively less than those gained by farmers with more land and more financial resources. At the same time larger smallholders did increase maize production and the nation as a whole increased its food security. While perfect equity was not achieved, neither were there any significant unfavorable consequences such as the alienation of the poorest farmers from the land, increased sharecropping or a radical skewing of income. This may set Kenya apart from other countries, e.g., Pakistan and India, where the "miracle seeds" have been introduced and, it appears, inequalities between wealthy and poor farmers have been accentuated.

4. The long-term continuity of foreign experts was basic to the success of the breeding program. Three American maize breeders spent a total of 14 years at Kitale and this continuity ensured constant improvement in the research.
5. Foreign advisors and finance do not automatically create an institutional capacity to perform agricultural research. Often the solution is the problem: successive generations of projects with foreign advisors and donor finance to keep the research going. Neither recipient governments nor AID seem to have any option when confronted by the failure to achieve the institution building goal and the deterioration of a breeding program but to once again employ foreign assistance. Both parties overlook the basic causes of failure: non-competitive salaries, alternative employment opportunities, and the dominance of foreigners in the research. The lesson for recipient governments is that its own team of administrator-scientists must be in charge of the research agenda and be responsible for its execution. The lesson for AID is that prerequisites for project assistance ought to include attractive terms of service for national scientists and technicians and a strong host government financial commitment to research operations.
6. Pragmatism and skepticism should surround AID support for regionalism. Even in the heyday of the East African Community no partner country was sufficiently committed to the creation of a regional research institution that they would assign their scarce scientific and technical talent to it. AID should support the development of national agricultural research institutions with strong linkages to neighboring national institutions and to international centers. This is preferable to supporting regional institutions which are intended to substitute for national capabilities.
7. Too many lessons should not be drawn from the Kenyan experience. In most important aspects Kenya's experience with hybrid maize seed is not replicable, at least in Africa. The initial boost given by large-scale commercial farmers, the significant long term presence of foreign advisors, the aggressive private seed company, and a well-developed transportation infrastructure all mark Kenya's success as unique.

#### CONCLUSIONS

The bottom line of the success of hybrid maize is that it allowed Kenya to feed itself and to industrialize rapidly at the same time in the face of a very rapid increase in population. Kenya has had to spend relatively little of its foreign exchange on food imports. Hybrid maize made it possible for the country to earn foreign

exchange from the export of cash crops by reducing the demand for land for food crops. Hybrid maize helped moderate food prices, thus muting pay demands of workers. In short, hybrid maize helped Kenya avoid many of the problems must other African countries face.

There were limits to the success. An indigenous, on-going maize research capacity has not been created in Kenya. A substantial number of the country's poor majority have probably not been able to participate directly, or on a sustained basis, in achieving the increased yields which hybrid maize allows. And the policies and institutions of the government have not changed sufficiently to allow the full economic benefits of the technology to filter through the existing marketing system to smallholders. Yet, it is an undeniable fact that the majority of all smallholders and a large number of the poor majority of smallholders have had access to, and benefited from the hybrid maize technology. On this basis hybrid maize is rightly regarded as a development success story both by the Government of Kenya and practitioners of the development art alike.

AID played a secondary role in the success of hybrid maize. While supporting the research effort with U.S. Department of Agriculture maize breeders, the Agency had nothing to do with original genetic breakthrough and very little to do with the successful diffusion of the hybrid seed. AID shares responsibility for the successful diffusion of the seed to neighboring countries in Eastern Africa. The results of the training and institution building aspects of the AID-financed projects have been notable by their absence. But if AID can claim only partial credit for the success of hybrids in Kenya, it perhaps has even less responsibility for the limits of that success.

## APPENDICES

APPENDIX A

A.I.D.'S ROLE

- 1 -

A.I.D.'s ROLE

The purpose of this appendix is to summarize A.I.D.'s role in supporting research on hybrid maize in Kenya. This summary is limited by the fact that the documentation of the early years is fragmentary at best. However, if we consider A.I.D.'s role in only one piece of the hybrid maize phenomenon--research at Kitale, Kenya--it will be seen that what began in 1963 has continued, almost without interruption, to the present day and is planned to continue until 1983. While this kind of continuity is somewhat unusual, especially after the fairly abrupt change in government philosophy occasioned by the "new legislation of 1973, it will also be seen that agricultural research at Kitale has been justified under the auspices of a number of projects each of which had a slightly different purpose.

A.I.D. was involved in Kenyan agriculture as early as 1957 with the arrival of the first U.S. technician, a soils chemist who was followed by a land classification specialist, a soils physicist and a soils mineralogist. In 1962 A.I.D. supplied a team of experts in extension and later assisted in the construction and development of fourteen farmer training centers throughout the country. By 1963 a rural youth advisor had helped to establish the farm youth program known as 4-K and later A.I.D. extended technical assistance to the cooperative movement. 1/

A.I.D.'s interest in Kenyan maize originated in Washington as part of a world-wide research project on the major cereal grains. In Africa, A.I.D.'s interest centered on the staple food crops: maize, sorghum and millet. It is not clear whether these research interests were the result of a formal request from any African Government. In any event A.I.D. signed an agreement with the Scientific and Research Committee of the Organization of African Unity in 1964 to conduct research work in both West and East Africa under a project entitled Major Cereal Crops in Africa (No. 946-11-990-419). In addition, a separate agreement was executed with the East African Common Services Organization (commonly referred to as the EAC for East African Community) to utilize existing research staff and facilities to achieve the following objectives:

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- a. to review the world collections of sorghum, millet and maize seeds for varieties that were resistant to disease, insects and other pests;
- b. to determine the soil management factors which contribute to maximum crop production;
- c. to develop high yielding, disease resistant varieties of these crops for different areas;
- d. to assist seed breeders in the multiplication and distribution of these high-yielding varieties;
- e. to arrange for uniform trials of promising varieties and hybrids in different parts of East Africa; and
- f. to facilitate the exchange of planting materials and information.<sup>2/</sup>

To implement these research programs A.I.D. signed an agreement with the Agriculture Research Service (ARS) of the U.S. Department of Agriculture (USDA). ARS agreed to provide one maize breeder for assignment at the Government of Kenya's research station at Kitale and an agronomist, sorghum breeder and entomologist for assignment to Serere, Uganda.<sup>3/</sup> However, the maize breeder was not to be a part of the Kenya Government's research program. Within the East African Community the charter of the subsidiary East African Agriculture and Forestry Research Organization (EAAFRO) permitted each country to retain responsibility for any crop of its choice. Kenya had decided to retain responsibility for maize research within its national program. In fact beginning in 1955 Kenya had initiated work under the guidance of the grass breeder M. N. Harrison. Subsequent to an A.I.D. and Rockefeller Foundation study tour to the U.S. and Mexico in 1959 his work resulted in a very significant yield increase from the cross between maize varieties from Equador and Kenya in 1961. This hybrid was put into commercial production as H611 in 1964. Kenya augmented this breeding program with the services of Mr. A. Y. Allan who, under a grant from the Rockefeller Foundation, began research work on appropriate agronomic practices to enhance the yields of the new hybrid maize. Kenya then requested A.I.D. assistance directly; this was not possible but EAAFRO made special arrangements with Kenya to support the maize research component of the Major Cereals project. The ARS maize

breeder S. A. Eberhart arrived in July, 1964, to begin work on the development and evaluation of breeding methods to improve the hybrid maize lines. Local labor, materials and supplies to support Eberhart's work--ostensibly separate from the Kenya Government's work--were provided by Kenya at the Kitale Station and were reimbursed by A.I.D. through EAAFRRO to Kenya. Although the personnel at Kitale were sponsored by different organizations, e.g., Kenya, the U.K., Rockefeller and A.I.D., the evidence suggests that they worked very well together. For example, details of the comprehensive maize breeding program were jointly authored by Eberhart, Harrison and F. Ogada in Der Zuchter in 1967.<sup>4/</sup>

There was considerable activity in East Africa with ARS staff visiting Zaire, Ethiopia, Malawi, Tanzania and Uganda. Further contact with research workers was engendered through the Eastern African Cereal Research Conferences held in Kenya (1965 and 1967), Uganda (1967), Zambia and Malawi (1969) and Ethiopia (1971). In addition, regional maize variety trials were conducted and included the participation of Ethiopia, Kenya, Madagascar, Malawi, Nigeria, Tanzania, Uganda, Zaire and Zambia. The project provided foundation seed stocks of parents of recommended hybrids and composites to seed-producing facilities in partner states. The A.I.D.-financed buildings and cold storage facility at Kitale provided the means to maintain the germ plasm. Finally, under the comprehensive breeding program dramatic progress was made in improving the yields of the original commercially released hybrids. By 1970 improved versions of the original hybrids were recording yield gains of 26 percent for H 611C and 24 percent for H 613C.<sup>5/</sup>

In 1969, A.I.D. reassigned responsibility for the Major Cereals project from its central Office of Agriculture to the Africa Bureau and divided the Western and Eastern parts into separate projects. In East Africa A.I.D. support for agriculture research was further divided into two projects, Animal and Crop Production (No. 618-11-110-644) and Major Cereals and Legume Improvement (No. 618-11-130-652). Under the former project the one element which had consequences for maize breeding was the recruitment, by ARS, of a plant pathologist to head the East African Plant Quarantine Service. Under the latter project the maize breeding

activities at Kitale were continued. In addition, two A.I.D. field trial officers were posted to Tanzania (1970) and Uganda (1971) to evaluate regional research findings.<sup>6/</sup> Launching these two projects closed the period when EAAFRO was simply a mechanism of convenience to support an AID/ARS determined research agenda. Thus, A.I.D.'s purpose changed from doing research per se to the explicit goal of creating a research capacity within EAAFRO to carry out appropriate research and to diffuse the research findings in the region. Agreements were signed with EAAFRO reserving funds for U.S. academic training for EAAFRO staff and, for the first time, EAAFRO agreed to finance the local costs of ARS operations at Kitale and elsewhere.<sup>7/</sup>

On the basis of an in-depth evaluation by an A.I.D. Washington team, A.I.D. designed a new project in 1972, East African Community Food Crop Research (No. 618-11-110-657) to combine the principal elements of the terminating Major Cereals and Legume Improvement Project and the Animal and Crop Production project and to add some new elements as well. Briefly, the new project proposed to accomplish the following objectives:

- a. to maintain sorghum and millet research;
- b. to continue research on maize breeding improvement research at Kitale;
- c. to initiate an effort to develop maize suitable for low altitude conditions in Eastern Africa;
- d. to mount a new program for legume research;
- e. to initiate a new rice research program; and
- f. to introduce a new regional dimension into wheat research, which was already fairly advanced in Kenya with Canadian assistance.

A.I.D. envisaged expanding the number of A.I.D.-financed technicians from nine (1971) to a total of about nineteen by 1974. Further, since there were no African entomologists or soil scientists employed by EAAFRO, A.I.D. foresaw the need to provide more than 50 years of academic training so

that by the end of the project, then planned for 1980, there would be a staff of at least 15 to 20 African scientists employed by the EAC, about equally divided between the Ph.D. and Master degree levels. However, the A.I.D. project proposal recognized the difficulty of reaching this objective:

"To accomplish this change requires not only the recruiting and training of the requisite scientific personnel but also the creation of attractive terms of service both in terms of pay and in terms of opportunity for rewarding professional accomplishment. The latter further requires adequate working facilities and supporting staff as well as decision making procedures which take account of the professional judgement of the staff in determining research priorities. The lack of each of these requisites has in the past contributed to the very slow development of EAAFRO as an effective research organization."<sup>8/</sup>

The new A.I.D. project proposal also revealed the difficulties of recruiting U.S. technicians who were both highly qualified and attuned to the need to upgrade the skills of their regional counterparts. Under the earlier projects USDA had provided eight of the eleven technicians while a private contractor, the Institute for International Education, provided the remainder. While IIE had done a good job recruiting personnel the A.I.D. regional office doubted that IIE would be able to mount a team of up to nineteen technicians and provide the required scientific backstopping. Another option, the use of a U.S. university, was put aside on the grounds that even a well established Faculty of Agriculture would be forced to recruit outside of its own staff to fill such a large and diversified team. While A.I.D. recognized that USDA had access to the largest pool of technicians with the required scientific skills, the regional office expressed the following reservation:

"Despite our predeliction for the choice of USDA... we would not recommend that choice unless USDA is willing to accept the new prime purpose of the project to develop the institutional capability of EAAFRO to conduct food crop research. This means that training Africans to do and make decisions about research

temporarily take (sic) precedence over research results. It also means that USDA technicians must live with, and when necessary seek remedial action within, EAAFR0-EAC channels rather than obviating (sic) the obstacles by [the] uncontrolled use of AID funds. It will be a difficult adjustment from past USDA practices and attitudes in their conduct of research in East Africa. But if USDA is not willing to make that adjustment then the AID and EAC purpose in the project would be better served by the choice of a new implementing agency."9/

The new project was overtaken by political developments, namely the cessation of U.S. economic assistance to Uganda in 1972. One major part of the project, sorghum and millet research, was curtailed. Furthermore, since the East African Community did not meet after 1972 no approval could be obtained for the new elements of the project. What remained was the continuation of the maize breeding methodology research at Kitale and three scientists for food technology, plant quarantine and field trials. When it became obvious that these activities were poorly coordinated A.I.D. conducted another in-depth evaluation in February, 1975. The A.I.D. -financed team of U.S. university and USDA experts recommended that the project be redesigned to include the following elements: establishing a regional Protein Quality Laboratory (PQL); continuing work on maize breeding methodology; accelerating work on disease resistance in maize; developing cropping systems for marginal rainfall areas; undertaking sugar cane research; and continuing the work of the plant quarantine station.<sup>10/</sup> The purpose of the protein quality breeding program was to enhance the lysine component in maize protein by incorporating the Opaque-2 (high lysine) gene in high yielding maize varieties and hybrids. The PQL was to perform chemical analyses and supply Opaque-2 germ plasm to the maize breeders at Kitale. The disease resistance work on maize was to be performed at Muguga, where the initial focus was to be on virus diseases, particularly maize streak. Finally, the Plant Quarantine Station, also at Muguga, was to continue to protect Kenya and East Africa from the introduction of plant diseases and pests from outside the region. The recommended

sub-projects included very ambitious objectives. For example, disease resistant maize germ plasm was to be available to national maize breeders by December, 1978; Opaque-2 was to be incorporated into the East Africa maize breeding program; and the basic research for maize in marginal rainfall areas was to be completed by December, 1976.<sup>11/</sup> To accomplish these objectives the project was to provide 45 years of U.S. technical expertise, 30 undergraduate scholarships in East African universities; and about 35 years of advanced academic training in the U.S. for EAAFRO staff.<sup>12/</sup>

Meanwhile in Kenya the USAID Mission had assisted the Government of Kenya to extend the new hybrid maize seed to densely populated Vihiga District as one part of an integrated Rural Development project (no. 615-11-810-147). Among other things A.I.D. claimed that increases in maize production of up to 300 percent were possible due to the availability of the needed production credit, improved husbandry and hybrid seed.<sup>13/</sup> In Tanzania A.I.D. had initiated a Seed Multiplication project (No. 621-11-130-092) in 1970 to establish four seed farms, one in each of the major environmental zones, which would multiply seed for several staple food crops, including maize.<sup>14/</sup>

With the collapse of the East African Community in July, 1977, the breeding methodology program at Kitale terminated and the Food Crops Research project shifted from A.I.D. regional auspices to the USAID Mission in Kenya. L. L. Darrah, the third and last ARS maize breeder, departed Kenya at this time. In 1978 an A.I.D.-financed team of USDA experts evaluated the project once again. Some elements of the defunct project were then incorporated in a new project entitled Dryland Cropping Systems Research (No. 615-0180) along with a particular emphasis on dryland agriculture in the Machakos and Kitui areas of Kenya. The components of the new project include the stationing of scientists and technicians (for maize breeding, agrometeorology, agronomy, plant pathology, soil physics and agricultural economics) at the Kenya Agriculture Research Stations at Kitale and Muguga and a significant training program for Kenya research staff (e.g., about 14 Kenyans to be trained to the M.Sc. level and 4 to the Ph.D. level in U.S. institutions). The project, which will collaborate with an FAO

project in marginal rainfall areas, is expected to be completed in FY 1983.<sup>15/</sup> In late 1978, L. L. Darrah returned to Kenya to review the state of maize research. At Kitale, he found that the three Ph.D. and one M.Sc. level staff had departed for better opportunities and that the remaining staff lacked the historical and scientific knowledge required to carry out the comprehensive breeding program. The facilities and equipment at Kitale were also deteriorating.<sup>16/</sup>

While the diffusion of hybrid maize has had a profound impact on Kenya its impact has not been limited to only one country. The A.I.D.-planned and financed project activities discussed above have contributed to the diffusion of hybrid maize in East Africa and beyond. This diffusion is most clearly reflected in the estimates of hybrid and composite seed exports made by the Kenya Seed Company. On the basis of these export sales it is possible to make a very rough estimate of the area under hybrid or improved maize seed cultivation, i.e., one metric ton of seed will plant approximately 42 hectares of land to the recommended high plant density.

Estimated Area Planted to Hybrid Maize in 1978/79 from  
Kenya Seed Company Export Sales

<u>Country</u>	<u>Estimated Area (Ha.)</u>
Tanzania	42,000
Uganda	16,800
Ethiopia	26,500
Cameroon	210
Zaire	13,600
Mozambique	2,100
Sudan	2,100

In addition, hybrid maize based on the original Kitale cross is grown in Zambia, Malawi, Rhodesia and South Africa. The management of the Kenya Seed Company anticipates further export sales of seed to Rwanda, Burundi, Somalia and Eastern Zaire.

In the following section we have summarized the fiscal data for each of the A.I.D. assisted projects which relate to hybrid maize in Eastern Africa. However, it should be understood that most of these projects included financing

for activities other than breeding maize and diffusing the technology; therefore, the sum of the obligations recorded here is much greater than the amount of money committed to hybrid maize technology per se.

<u>Country</u>	<u>Project Title</u>	<u>Project Number</u>	<u>Years of Obligation</u>		<u>A.I.D. (\$000)</u>
			<u>Initial</u>	<u>Final</u>	
Worldwide	Major Cereal Dev.*	946-11-990-419	6/63	12/73	213
Regional	Seed Seminars-Nairobi	968-11-130-611	1963	Unk.	Not Avail.
E. Africa	Animal & Crop Production	618-0644	5/69	6/74	338
E. Africa	Major Cereals & Legume Improv.	618-0652	5/70	6/74	1,068
E. Africa	E. Africa Food Crop Research	618-0657	6/72	Still Active	1,953
Kenya	Crop & Live-stock Extension	615-0101	6/60	12/73	2,471
Kenya	Ag Coops & Credit	615-11-140-103	8/63	12/69	357
Kenya	Marginal, Semi-Arid Lands	615-0164	1/75	1/75	1,134
Kenya	Ag System Support Proj.	615-0169	8/78	Still Active	5,573 grant 20,000 loan
Kenya	Marginal Land Development	615-0172	1979	Still Active	1,330 grant 10,000 loan
Kenya	Food Crops Res.**	615-0180	1979	Still Active	1,300
Kenya	Rural Devel.	615-11-810-147	1971	1976	1,886
Tanzania	Seed Multipli-cation	621-0092	1970	Still Active	6,300

\*Also known as Major Cereal Crops in Africa, No. 698-11-130-176.

\*\*Also known as Dryland Cropping Systems Research.

Notes

- 1/ International Cooperation Administration, "Aid Level Submission", October 30, 1959, p. 10, concerning the Agricultural Investigation, Development and Training project (No. 615-11-008) and USAID Kenya. "Corn in Kenya, Spring Review - New Grain Varieties", May, 1969, pp. 26-27.
- 2/ A.I.D., "East African Regional Program", December, 1964, pp. 116-118.
- 3/ A.I.D., "East African Community Food Crop Research" project, No. 618-11-110-657, October 21, 1971, p.5.
- 4/ Litzeberger, S.C., et. al., "East African Major Cereals Project Evaluation", September, 1972, p.5.
- 5/ Ibid., pp. 7-8.
- 6/ Ibid., p.6.
- 7/ Project 657, op. cit., p.6.
- 8/ Ibid., p.3.
- 9/ Ibid., p.9.
- 10/ RDOEA/Arusha, "Revision of the Non-Capital Project Paper, East African Food Crop Research", No. 618-110-10-657, April, 1975, pp. 1-4.
- 11/ Ibid., logical framework, p.36ff.
- 12/ Ibid., p.3.
- 13/ A.I.D., FY 1976 Congressional Presentation, May, 1976, p.57.
- 14/ Ibid., p. 93.
- 15/ USAIDKenya, "Dryland Cropping Systems Research". Project Paper No. 615-0180 and FY 1980 Congressional Presentation, p.332 where the project is renamed "Food Crops Research" with the same number.
- 16/ L. L. Darrah, "Report of a Technical Consultation in Kenya", USDA, October, 1978.

**APPENDIX B**

**A. I. D. - SUPPORTED MAIZE RESEARCH IN KENYA AND THE SMALL FARMER MANDATE**

## A.I.D.-Supported Maize Research in Kenya and the Small Farmer Mandate

The series of projects subsumed under the title "Kitale Maize" originated a decade before the US Congress directed A.I.D. to address the needs of small farmers in the developing world. Thus it is hardly surprising that the first projects were not aimed explicitly at small farmers. Nevertheless, the program did have a favorable impact on certain categories of small-scale Kenyan producers--which illustrates how tenuous the relationship may be between project design goals and actual impact achieved. The project-by-project review which follows attempts to assess how well the Kenya projects responded to small farmer needs, and also attempts to identify areas in which the projects could have done better. Before entering this discussion one preliminary issue must be raised: what is a "small farmer" in the context of Kenya?

The definition of a smallholder forwarded by the Kenya Central Bureau of Statistics (and accepted by the USAID) is any farmer with eight hectares of land or less. This may seem reasonable, insofar as many Kenyan farmers have two hectares of land or less. Clearly, production recommendations for smallholders with two hectares of land will be different than recommendations suited to those with much larger amounts of land. It is not difficult to see how the "eight hectare" definition could lead to research and recommendations inappropriate to the "poor majority," i.e. those with less than two hectares of land. There is no scope here to resolve this definitional problem in the context of Kenya, but one point should be remembered. A project that appears to respond to the small farmer mandate when the definition includes those with eight hectares or less may seem completely irrelevant to small farmers when the definition is refined to include only those with two hectares or less. Questions of small farmer relevance are extremely sensitive to such definitional variation, and care should be taken to insure that those who are asked to answer the questions do so with a realistic and relevant assessment of what small farmers are in any particular country context.

The first project, Major Cereal Crops in Africa (946-11-990-419), provided a USDA maize geneticist who worked at Kitale beginning in 1964 to develop and evaluate various methods of maize breeding. From the USDA perspective, the project was an experiment in breeding methodology; at the same time (and this is the reason for Kenyan interest in the activity) each cycle of breeding generated new varieties of maize, some of which could be expected to be of interest to commercial growers. In fact it was foreseen that the project would lead to steady improvements in the yield quality of the original Kitale hybrid, produced several years earlier by Michael Harrison for the Kenya government. The breeding program was to produce new hybrids for use by large-scale (generally European) farmers, while less expensive composite maize varieties (generated as intermediate products in the hybridization program) were to be disseminated to small-scale African farmers. Composites are less expensive than hybrids because they do not require the purchase of new seed for each planting. What actually happened was that an aggressive privately-owned seed multiplication and marketing

enterprise (Kenya Seed Company) succeeded in making hybrid seed available to smallholders as well as large-scale farmers. It is often claimed that Kenyan small farmers were attracted to the expensive hybrid rather than the cheaper composite varieties because of yield superiority and because the hybrid had high status as a "European" seed, and this may be partly true; equally important, however, must be the circumstance that, for marketing reasons, relatively little long maturing composite seed was ever made available to smallholders in commercial quantities. Thus most Kenyan smallholders were never offered a choice between a high-yielding hybrid and a high-yielding composite--the choice was rather between the hybrid and unimproved local varieties. Whatever their motivation, Kenyan smallholders began to purchase hybrid seed in large amounts soon after it was introduced; there is some evidence that by 1970 the smallholder market for hybrid seed was larger than the market among large-scale farmers.

The second project, Major Cereals and Legume Improvement (618-11-130-652), began in 1969. It continued the maize breeding activity at Kitale and also provided two field trial officers to evaluate the performance of improved maize varieties in Uganda and Tanzania.

The earlier project had also provided some support for field trials in locations dispersed widely throughout East Africa, but the work was generally done by local researchers who were slow to respond to the information needs of the Kitale breeders. The new A.I.D.-financed field trials officers were meant to alleviate that problem. In all cases the field trials were carried out in pure stands on experimental plots; the investigations were to assess the suitability of improved maize varieties to varying soil, rainfall, temperature, insect and disease regimes, not to see how the maize varieties could complement or replace other cultigens within existing smallholder farming systems. Of course, it is important to recognize that these two experimental goals need not conflict with each other. In the case of hybrid maize, for example, many smallholders experienced little difficulty incorporating the new seed into existing cropping patterns, provided that basic agro-climatic conditions were met. Thus detailed research into the role of maize in existing farming systems would have contributed little to making the new maize varieties more accessible to smallholders. On the other hand, there is a significant number of Kenyan smallholders (mostly the "poor majority" as defined above) who even today have not been able to benefit from the adoption of hybrid maize. None of the earlier projects were designed in a way that would have allowed the breeding research to respond to the needs of this disadvantaged category of smallholders, although the latest project in the series (Dryland Cropping Systems Research) may do so. This is rather an important issue, and deserves to be examined in more detail.

The A.I.D. funded breeding program was linked closely to the needs of large-scale farmers, mostly because of the physical proximity of the Kenya government agricultural research station and the Kenya Seed Company; both of these institutions have maintained close ties with European (and later African) large-scale farmers from the late 1950s to the present day. The breeding program was also linked, if more tenuously, with the needs of "progressive" smallholders--partly through the Kenya Seed Company (which depends on the smallholder market for a large proportion of its total seed sales), and partly through the extension services of the Kenya Ministry of Agriculture. The "maize tours" undertaken jointly by Kitale researchers,

extension officials and personnel of the Kenya Seed Company, for instance, allowed opportunities for communication with the better-off category of Kenya smallholders. By contrast there were no lines of communication whatever between the plant breeders and poor smallholders—a cynic might note that neither the Kenya Seed Company nor the extension service was motivated to identify and transmit the requirements of poor smallholders to the Kitale maize breeders, the former because the financial rewards would have been limited and the latter because individual extension agents were presented with little incentive to work with poor farmers. In today's circumstances, of course, it is thought to be the task of a development assistance agency to create and maintain such lines of communication, but this was not generally conceded in the 1960s.

In 1972 A.I.D. support for agricultural research at Kitale was continued under a third project, East African Community Food Crop Research (618-110-11-657). Support was now given to the development of high-yielding varieties suited to low-altitude (i.e., medium potential) areas. All the previous breeding work, by contrast (as well as most of that which followed) was aimed at increasing the yields of long maturing varieties adapted to conditions in the high potential areas of western Kenya. But during the preceding seven years the Kenya government maize research program (cooperating with but distinct from the EAC program supported by A.I.D.) had produced several maize varieties, both hybrid and composite, suited to medium potential areas. This was a consequence of political pressure—Kenyan farmers and their elected representatives in the medium potential areas were anxious to benefit from new maize varieties as farmers in high potential areas had been doing for some time. This Kenyan political development may have been reinforced by the desire of other EAC states to see the regional project become more relevant to their needs; in any event the outcome was that the new maize breeder at Kitale spent much time travelling to research stations elsewhere in Kenya, attempting to spread the use of the efficient maize breeding methodologies that had been developed at Kitale. It may be stretching a point to regard this development as a response to the needs of poor farmers, but it does seem reasonable to conclude that explicit efforts were being made to spread the benefit of the breeding methodology program more widely among Kenyan smallholders—or indeed among East African smallholders generally. Unfortunately, the effort to produce maize varieties suited to the medium potential areas has not accomplished much, partly because the breeding program has become bogged down in attempts to improve the protein content of maize, and partly due to difficulty in maintaining certain of the parent lines.

In 1975 the ongoing regional project was redesigned. Two earlier sub-projects—marginal areas cropping systems and breeding for disease resistance in maize—received increased emphasis, and a new subproject was added—breeding for protein quality in maize. The basic breeding work at Kitale was continued, as were several other project activities.

The marginal areas research, undertaken by an agronomist, an agrometeorologist and an agricultural economist, was aimed at assessing the response of major food grains (including maize) to various water and soil conditions encountered in the drier parts of East Africa. It was also foreseen that recommended practices would reflect the views of the economist, whose job it was to develop farm management models appropriate to marginal areas cropping patterns. Clearly, this was an attempt to make plant research

respond to the needs of a relatively disadvantaged group of smallholders. Unfortunately, by mid-1978 relatively little had been accomplished by the technicians charged with conducting this program of research, which may explain why it is now FAO, and not A.I.D., that has the responsibility for conducting adaptive research in the cropping systems project.

The new subproject to breed for disease resistance in maize initially identified two problem areas: low-to-medium altitude (medium potential) zones, where maize streak virus (MSV) is a significant factor affecting maize yields; and high altitude (high potential) zones, especially Kitale, where sugar-cane mosaic virus (SCMV) is widespread. A decision was soon made to concentrate work on SCMV rather than MSV, and extensive attempts to identify sources of resistance to SCMV in commercially valuable germplasm were undertaken. Only minimal progress was achieved in incorporating resistant germplasm into ongoing breeding efforts, perhaps largely because the EAC fell apart, and the Kitale effort with it, soon after the initial screening was done.

Although there were sound reasons for the decision to focus A.I.D.-assisted disease work on SCMV in commercial hybrids, it is appropriate to note that this research was considerably less relevant to the needs of poor smallholders than research into diseases (e.g., MSV) characteristic of the medium potential zones. Available documents make it clear that the Kenya Seed Company and the Kitale breeders, as well as the government of Kenya, influenced the plant pathologist's decision to work on diseases characteristic of the more developed high potential zones. Once again we see the power of established lines of communication and the disadvantage of being without these.

The protein quality laboratory at Kitale was desired greatly by all of the EAC member states, as well as by USDA plant breeders, AID/W and the Nairobi mission. In 1975 there was still a good deal of optimism about the potential for raising the protein quality of maize by incorporating the opaque-2 gene into high-yielding germplasm. Today high lysine maize finds some place in the highly capitalized U.S. livestock feeding industry, but associated problems of poor storage quality and reduced yields appear to be insuperable obstacles preventing wider usage. In 1975 the protein quality laboratory at Kitale could be viewed as an attempt to address the needs of maize consumers in developing countries; in 1980 this is no longer so. There is wide agreement among maize scientists that a good deal more basic research will have to be done into the combining qualities of high-lysine germplasm before further practical advances can be made in maize protein quality. Moreover, there is a question whether consumers in the developing world need high-lysine maize at all. Nutrition work done in Kenya revealed no protein-deficiency disease associated with maize consumption, not even in the case of hybrid maize which has much less protein per gram than unimproved varieties. This is because maize is ordinarily eaten in combination with legumes that compensate for protein deficiencies found in maize. In sum, there are good reasons for thinking the protein quality research is marginal to the needs of small farmers and developing nations as these needs are currently perceived.

As a footnote, we should not overlook the possibility that the unsuccessful search for ways to increase the protein quality of maize may have hampered breeding work aimed at releasing new improved varieties to smallholders. Maize breeding by whatever method is a time-consuming

process, and limited facilities at Kitale and elsewhere placed bounds on the number of maize qualities breeders could select for in their breeding populations. To the extent that attention was directed at protein quality, other important lines of investigation were ignored. The Kenyan officer in charge of the Katumani research station, for example, was explicit in his observation that concern for protein quality had hindered the production of new composite maize varieties suited to medium potential areas.

The most recent project in support of Kenyan agricultural research was funded in 1979. Dryland Cropping Systems Research (615-0180) expands A.I.D.'s interest in analyzing problems of food grain production in Kenya's marginal areas, while maintaining A.I.D. support for other activities funded in earlier projects. While it is far too early in the life of the new project to make comprehensive statements about the extent to which it responds to the small farmer mandate, several observations are in order. First, this project is the first in the series of projects reviewed here to regard the satisfaction of small farmer needs as the primary objective of the research. Second, the project provides personnel and work plans that are appropriate to a research effort aimed at identifying soil, water and economic constraints to smallholder production in marginal areas. Third, the project provides support for a facility, the protein quality laboratory, that seems marginally relevant to the needs of poor Kenyan farmers. The special danger here, revealed in a close reading of the maize breeder job descriptions, is that the maize breeders hired for the new project, who (based at Kitale and Muguga) are supposed to breed for many plant characteristics besides protein quality, will devote more time to this effort than is warranted. As noted above, breeding to improve agronomic characteristics, yield quality and disease resistance may address needs of small farmers; breeding to improve protein quality is unlikely to do so.

The sixteen-year sequence of project activity outlined here presents an interesting pattern. The first project was to support maize breeding, and the dissemination of breeding materials and knowledge; the second project added to this provision for field trials; the third project included a rather complex effort to assess the needs of marginal rainfall areas; the fourth project was even broader, seeking to answer new questions regarding disease resistance and protein quality; the fifth (and latest) project continues all of these earlier activities but expands the marginal areas component significantly. The common thread uniting these projects into a coherent program has been support for the basic breeding work done at Kitale. Until recently, no element in any project succeeded in creating any but the most tenuous links between this research activity and small farmer needs; at the same time the relevance of the research effort to Kenyan smallholders has increased with each expansion in program activity. (Ignoring for the moment the protein quality laboratory.) This may seem a contradiction--how can research become more relevant while small farmer needs go unassessed? The answer is that certain kinds of research are of universal value: breeding for yield quality and disease resistance, for example, or breeding for lodge resistance, or breeding for ability to withstand moisture stress. Such efforts attack problems of plant growth that are relevant to all maize growers, large or small, and these are the kinds of efforts supported by A.I.D. in Kenya.

There is of course a whole range of other problems--not plant growth problems but farm production problems--that are of particular concern to small, poorly-capitalized maize growers, and the agricultural research supported by A.I.D. has never succeeded in identifying or responding to these problems. Only meager efforts have been made to assess the performance of maize varieties when interplanted with legumes, for instance, and yet the majority of Kenyan smallholders plant maize no other way. Efforts to reduce the size of the hybrid plant, and, concomitantly, the drain on scarce soil nutrients, have not been central to the breeding program, and yet many poor farmers are unable to grow hybrid precisely because it demands so much from the soil. No work whatever has been done to breed for improved performance during storage, yet post-harvest grain losses on smallholder farms in Kenya have been estimated at 25-40% of total yields.

This list of things not done in the program of agricultural research could be expanded considerably, but the essential point is that they were not done because no mechanism for introducing small farmer concerns into the research agenda was ever established. The recent dryland cropping systems project goes further in this direction than any earlier project, but may not succeed in making small farmer needs known to the basic plant and soil scientists--this is because responsibility for basic research rests with A.I.D., but responsibility for adaptive research is vested in FAO, while responsibility for assessing socio-economic constraints is given to yet a third party, the University of Nairobi.

In sum, we find that AID support for agricultural research in Kenya has indeed benefited small farmers. This is because the research was devoted to a basic food crop grown by smallholders everywhere in Kenya, and was designed to answer questions regarding plant growth that are of concern to all maize producers, regardless of size. Little in the A.I.D. program, however, has been directed at the special and specific needs of small farmers. This is because no links--planned or otherwise--were ever established to identify small farmer needs and communicate these to the A.I.D.-supported researchers. The 1972 attempt to do so proved abortive; the 1979 attempt has yet to be carried through to completion. Small farmer interests were addressed directly only when outside forces--Kenyan political developments--made this obligatory.

APPENDIX C

A TECHNICAL NOTE ON MAIZE BREEDING

A TECHNICAL NOTE ON MAIZE BREEDINGI. Introduction

In this note we will use the following terms in the description of maize breeding and maize agronomy.

Hybrid -- A single, double or triple cross of selected inbred lines, normally with wide variability in genetic background, that attempts to enhance certain predetermined characteristics such as yield, insect or disease resistance, stalk strength, etc., and attain hybrid vigor or heterosis.

Synthetic -- This is an open pollinated variety derived from the combination of a number of selected self pollinated  
 Previous Page Blank | combining ability of which has been pre-  
 :esting all possible first generation (F<sub>1</sub>)

Composite -- Composites are open pollinated varieties selected from the random combination of a large number of recognized breeding lines that in theory have good combining quality and the genetic characteristics desired for a specific location.

Synthetics and composites are generally developed for adverse or marginal maize growing conditions or where demand for maize seed is not sufficient to make hybrid seed production viable.

II. Maize Breeding

The large scale commercial farmers in the Western highlands of Kenya became interested in hybrid maize in the early 1950s. Their request to the Kenyan Government (GOK) resulted in the employment of Michael Harrison as maize breeder in 1954. Inbreeding and crossing of local varieties did not result in hybrids of any particular superiority. However, when the inbred lines were formed into synthetic varieties in 1961, the resulting Kitale Synthetic II proved highly successful and was the most popular variety until a hybrid, H611 was released in 1964. While a number of introduced lines, crossed with local lines, had been tried in Kenya, it was an Ecuadorian line, EC573, that crossed with the Kitale Synthetic II to produce the hybrid vigor, high yield, and desirable agronomic characteristic required

by the Kenya farmer. This high altitude Ecuadorian variety was acquired with a number of other Central and South American lines during Harrison's AID/Rockefeller-sponsored trip to the U.S. and Mexico to collect germ plasm and to observe maize breeding methods. The hybrid was superior under small farmer management practices in the Western Highlands and in times of favorable cost/price ratios he readily purchased the hybrid seed (see Table 1).

TABLE 1  
AREA OF IMPROVED MAIZE GROWN IN KENYA  
1963 to 1979  
(in hectares)

<u>Year</u>	<u>Large Scale Farms</u>	<u>Small Scale Farms</u>	<u>Total</u>
1963	158	4	162
1964	11,615	708	12,323
1965	22,137	8,110	30,247
1966	25,860	15,269	41,129
1967	55,501	46,642	102,143
1968	36,501	51,331	87,832
1969	39,500	64,291	103,791
1970	47,110	97,372	144,482
1971	63,785	149,864	213,649
1972	73,944	206,904	280,848
1973	53,370	264,699	318,069
1974	39,214	292,358	331,572
1975	50,697	352,053	402,750
1976	50,903	377,092	427,995
1977	59,357	429,602	488,959
1978	29,016	407,860	436,876
1979	20,146	347,550	367,696

Source: F.M. Ndambuki

In this Table one can see the rapid expansion of small farmer improved maize production far exceeded large farmer production after 1968.

It was not until the unfavorable price and marketing situation of late 1977 and 1978 that hybrid sales for 1978 and 1979 declined from the 1977 peak. Even then small farmer sales were only down 5 and 15 percent respectively as compared to a 50 and 33 percent decrease for large farmers.

Breeding programs were developed at the Katumani station in Machakos for short season, low rainfall varieties in 1957; at the Embu station in 1965 for mid-season, medium rainfall varieties; and in 1975 at the Coast station, Kikambala, for mid-season varieties suited to the hot, humid, disease prevalent coastal area. Open pollinated composite varieties were selected for the lower potential, dry and coastal areas to meet the needs of small farmers for low-risk crops.

TABLE 2  
MAIZE RECOMMENDED FOR GROWING  
IN KENYA

Hybrid or variety	Year of first release	Maturity classification and remarks
Coast Composite	1974	-- 120-150 days. -- 0-1000m. above sea level -- 35 bags/ha.
Katumani Composite B	1967	-- Early (100-200 days) -- 1000-1900m. -- Marginal Rainfall two seasons below coffee belt, dry woodland and bush areas. -- 25 bags/ha.
H511	1967	-- Medium (150-180 days) -- 1000-1700m. -- 40 bags/ha. -- 20% higher yielding than local maize (Muratha) -- Lower Kikuyu areas.

TABLE 2...Continued

Hybrid or variety	Year of first release	Maturity classification and remarks
H512	1970	-- Medium (150-180 days) -- 1200-1800m. -- 45 bags/ha. -- 25% higher yielding than local maize (Muratha) -- Coffee areas.
H622	1964	-- Late (180-240 days) -- 1000-1700m. -- Double cross -- 56 bags/ha.
H632	1965	-- Late (180-240 days) -- 1000-1700m. -- Three-way cross -- 58 bags/ha.
H612	1966	-- Late (180-270 days) -- 1500-2100m. -- Single cross x Variety -- 65 bags/ha.
H611C	1971	-- Late (180-270 days) -- 1800-2400m. -- Synthetic x Variety -- Tea and pyrethrum areas -- 62 bags/ha.

TABLE 2...Continued

Hybrid or variety	Year of first release	Maturity classification and remarks
H613C	1972	-- Late (180-270 days) -- 1500-2100m. -- Single cross x Variety -- 75 bags/ha.
H614C	1976	-- Late (180-270 days) -- 1500-2100m. -- Single cross x Variety -- 75 bags/ha.

Source: F.M. Ndambuki

In 1963 AID was requested by the Kenyan Government to evaluate and make recommendations for their maize breeding program. Dr. Steve Eberhart from Iowa State University performed the evaluation and subsequently was the first of three USDA contracted maize breeders to work at Kitale under an AID financed regional project. He served from 1964 to 1968; Dr. Penney from 1968 to 1970; and Dr. Larry Darrah from 1970 to 1977.

The USDA breeders introduced several different breeding methodologies but eventually settled on the reciprocal recurrent selection (RRS) method from which was developed the Kitale comprehensive breeding system. This involved the maintenance of two separate parent populations, i.e., the Kitale synthetic and the Ecuadorian 573, inbreeding the population, making selections for improvement then, either crossing with the other parent lines for hybrid, or inbreeding for another cycle to gain further improvement. At any point in the continuing cycles of improvement, hybrids synthetics or composites can be developed depending on needs for commercial production or selection criteria. The advantage of the RRS system is that there can be continued improvement of parent lines and the time frame for developing new hybrids is shortened.

An area of maize breeding research which continues today and which is of questionable value is the work on opaque and other mutant genes to enhance the protein quality of maize. Though a great deal of research has been accomplished in this area, the trade off between increasing protein quality and decreasing yields has proven to be an intractable problem.

### III. Maize Agronomy

To maximize the yields of hybrids or local varieties, it was necessary to develop a package of cultural practices suitable to the growing environment. While a number of single factor studies had been accomplished prior to the interest in hybrids, it was the potential for major yield gains of six and eight fold that convinced researchers to place emphasis and consequently resources on maize agronomy.

In 1963 the Government of Kenya, with the assistance of Rockefeller Foundation and the British Government, hired A.Y. Allen to develop a systematic program of agronomic research. Working closely with the maize breeding program he conducted multifactorial trials to investigate a number of agronomic problems. The trials provided information on the benefit of individual practices, and on the cumulative effects resulting from the complementarity of practices used in combination (see Table 3). Even with local varieties, improved management provided a 3 to 4 fold potential increase. 1000 to 1200 Kg/Ha. was the average Kenya maize yield in 1963. Local maize with the best management yielded 4000 Kg/Ha. in Kitale on a three-year average, 1964-1966. However, hybrids were capable of yielding 8000 Kg/Ha. under similar conditions.

TABLE 3  
FACTORS AFFECTING 1966 YIELDS AT  
6 LOCATIONS IN WESTERN KENYA

Factor	Level	Yield (q/ha)	Diff.	Increased Return	Cash Outlay	Profit per ha
Time of planting	Early	52.8	18.6	\$80.91	\$ nil	\$80.91
	Late	32.4				
Variety	H613B	52.9	18.8	81.78	4.17	77.61
	Local	34.1				
Plant popula- tion	36,000	49.1	11.2	48.72	2.78	45.94
	18,000	37.9				
Weed control	Clean	48.4	9.8	42.63	6.96	35.67
	Once- late	38.6				
Phosphate (P <sub>2</sub> O <sub>5</sub> )	56 kg.	44.6	2.2	9.57	11.65	-2.08
	0	42.4				
Nitrogen (N)	79 kg.	45.0	3.0	13.05	24.60	-11.55
	0	42.0				

Source: G.F. Sprague

The factors that most influenced maize production were: 1) early planting; 2) seed rate; 3) seed variety; 4) weeding; 5) fertilizer; and 6) insect control. Of these, early planting, weeding and seed rate required low capital inputs and could be accomplished even by subsistence farmers. The relative influence of various cultural practices are depicted in Figure 1.

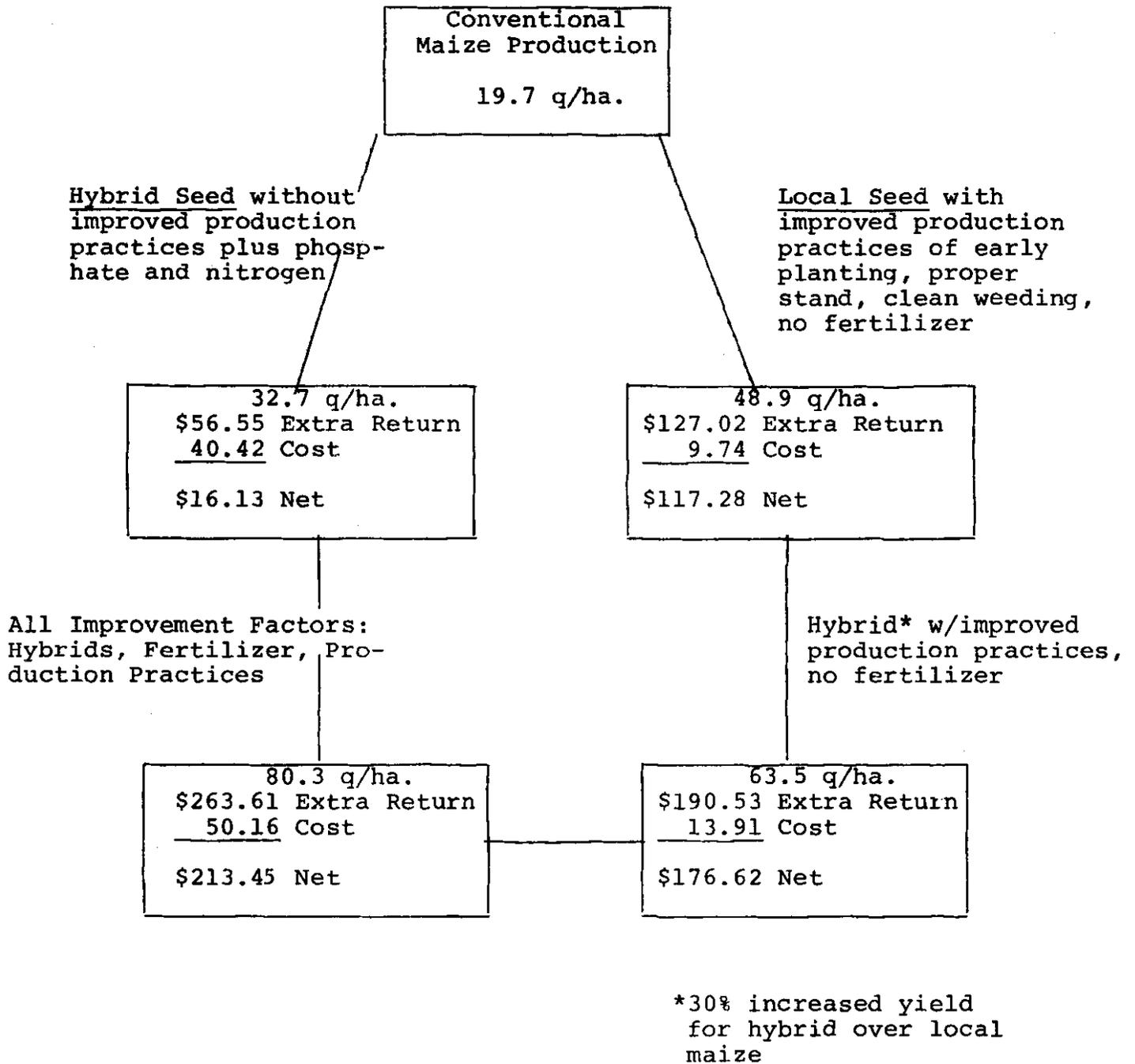


FIGURE 1. Comparisons involving hybrid seed, fertilizers, and improved production practices in Kenya.

Source: A.Y. Allan as presented by G.F. Sprague and modified by K. Byergo.

Taking the research findings from the station to the farmer was the next task. Research teams established classes and training programs for extension staff. This started in the Kitale area and eventually spread to most of the maize growing areas of the country. The Kenya Seed Company was also involved in extension activities. The literature and promotional activities with small shopkeepers helped to inform farmers. Demonstration plots, established by both extension staff and progressive farmers, also helped to spread the hybrid seed. In the early years hybrids were also promoted by the news media and government information services. These elements in the diffusion process are summarized in the following Table.

TABLE 4  
 "FROM WHOM DID YOU FIRST HEAR ABOUT  
 HYBRID MAIZE?"  
 (All answers in percentages)

Source	Zones in order of decreasing agricultural potential				Weighted Average
	Zone 1	Zone 2	Zone 3	Zone 4	
Extension agent	30.5	33.3	43.2	40.2	35.4
Dealer/stockist	15.8	6.7	4.5	4.1	9.9
Friend/neighbor	42.1	50.0	44.3	18.0	44.7
Employer	3.2	0	1.1	2.7	1.7
Agricultural show/field day	0	0	1.1	4.1	0.4
Newspaper	2.1	1.1	0	5.5	1.2
Can't recall, other	6.3	8.9	5.7	11.1	6.7
	100.0	100.0	100.0	100.0	100.0

(sic)\*

Source: J. Gerhart (\*Note that Zone 4 totals 85.7%. The error appears to be in the line "Friend/neighbor".)

As shown in Table 1 the area planted to hybrid seed declined in both 1978 and 1979; however, the adoption of recommended practices appears to have been maintained or perhaps increased in some areas. These trends are shown in Table 5.

TABLE 5

DISTRIBUTION OF INPUTS AND HUSBANDRY  
IN DIFFERENT MAIZE ZONES, PERCENT

FACTOR		A	A	B	B	A	C	A	A	C	All Zones
		1	2	3	4	5	6	7	8	9	
Used Hybrid	1975	85	82	35	28	57	21	99	72	7	60
	1977	93	86	48	43	79	40	98	81	15	78
	1978	100	92	74	62	89	24	95	64	18	80
Tractor or Oxen	1975	71	71	58	28	10	47	92	44	12	53
	1977	91	64	76	43	2	77	96	45	15	71
	1978	96	79	85	34	30	82	93	62	--	75
Mech Planter	1975	1	--	--	--	--	--	57	3	--	9
	1977	2	1	--	7	--	--	48	3	--	17
	1978	10	6	--	--	--	4	47	--	--	22
Planted Early	1975	15	7	11	42	44	58	26	44	17	27
	1977	14	13	19	36	28	29	22	32	5	21
	1978	8	25	--	10	19	20	20	26	27	19
Planted Rows	1975	77	72	45	69	94	76	100	97	7	72
	1977	100	81	72	79	100	74	100	100	25	88
	1978	100	90	78	100	100	84	100	100	--	87
Used Fertilizer	1975	64	20	4	27	60	13	90	44	2	41
	1977	75	22	7	36	66	23	90	35	5	52
	1978	76	35	19	43	44	12	87	48	--	48
Used Insecticide	1975	25	4	5	23	36	8	57	41	--	24
	1977	16	2	1	29	32	11	60	26	--	28
	1978	30	10	4	24	33	12	55	29	--	25
Thinned	1975	62	47	54	72	51	47	47	78	23	56
	1977	75	68	80	64	62	66	73	65	10	69
	1978	80	83	78	76	93	72	71	79	82	81
Clean Weeded	1975	55	71	73	79	78	87	65	75	60	70
	1977	84	92	93	100	98	100	98	100	90	95
	1978	90	100	93	90	100	92	94	100	91	93
Interplanted	1975	35	48	54	79	55	68	19	38	82	53
	1977	38	44	64	71	64	80	19	58	60	44
	1978	40	27	52	43	52	40	32	38	55	45

Source: M P B Yield Surveys 1975 - 1978.

Definition of zones:

Area	Altitude (m)	Rainfall (mm)
1 Bungoma, Kakamega, Kisii, Kericho, Nandi	1500 - 2800	Above 1500
2 Bungoma, Kisii, Kakamega (lower areas)	1200 - 1500	1200 - 1500
3 Nyanza (excluding Kisii)	1100 - 1400	1000 - 1200
4 Lower Meru, Embu, Muranga, Kirinyaga, Kiambu	1100 - 1500	800 - 1000
5 Upper Nyeri and districts in zone 4	1500 - 2400	1000 - 1500
6 Machakos, Kitui	1000 - 1400	500 - 800
7 Trans-Zoia, Uasin Gishu, Nakuru (large scale)	1500 - 2000	Above 1000
8 Highlands in Nyandarua	1800 - 2400	800 - 1200
9 Coastal Belt	0 - 50	900 - 1200

A = high potential area  
B = medium potential area  
C = low potential area

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Source: Njogu Njeru

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**APPENDIX D**

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**APPENDIX E**

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