CORRELATED RESPONSES TO RECIPROCAL RECURRENT SELECTION AND MODIFIED EAR-TO-ROW SELECTION IN YIELD COMPONENTS AND OTHER CHARACTERS OF MAIZE (Zea Mays L.)

BY

DAVID KIEMA MUTHOKA

Thesis submitted in partial fullfilment for the degree of
MASTER OF SCIENCE
IN
PLANT BREEDING

of the
UNIVERSITY OF NAIROBI

FACULTY OF AGRICULTURE

1980

CERTIFICATES

This thesis is my original work and has not been presented for a degree in any other University.

28/03/80
Date

Muthoka
D.K. Muthoka

This thesis has been submitted for examination with our approval as University supervisors.

28 March, 1980
Date

R S Pathak
Dr. R.S. Pathak
(First supervisor)

28/03/80
Date

Dr. A.C. van Eijnsbergen
(Second supervisor)

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

My sincere thanks are due to my supervisors Dr. R.S. Pathak and Dr. A.C. van Eijnsbergen, both of the Department of Crop Science, University of Nairobi for guidance and constructive criticism. Special thanks go to Dr. L.L. Darrah for the encouragements during this study.

I am grateful to the Ministry of Agriculture, Kenya and especially to the Scientific Research Division for sponsoring this study. Special thanks to Mr. P.K. Kusewa, Director of National Agricultural Research Station, Kitale.

I would like to thank Mr. A. Wafula, Mr. F. Makokha, Mr. F. Bunyasi and Mr. W. Mgonjwa and all my colleagues in the Maize Breeding Section, who helped me in one way or the other during the time of carrying out of this study at the National Agricultural Research Station, Kitale. I also wish to thank Mrs Jane N. Mbugua for excellent work in typing the thesis.

Last, but not least, I wish to thank my loving wife, Monica Munanie and my children Beautrice, Nancy, Stephen and Esther who showed limitless patience especially when I had to be away from home during this study.

28/3/80

ABSTRACT

Maize breeding work started at Kitale in 1955. A large collection of maize germplasm was introduced in 1959 from Central and South America. One of the varieties, Ec 573 performed well in a top cross yield trial with KSII. The cross of KSII and Ec 573 was released in 1964 as H611. The composite KCA is an open pollinated advanced generation of H611.

The aims of this study were to:

(1) Examine the response of KSII and Ec 573 to five cycles of reciprocal recurrent selection and KCA to ten cycles of modified ear-to-row selection.

(2) Compare the correlated changes in yield components of the four populations, and

(3) Identify important yield components for improving grain yield in a selection programme.

During reciprocal recurrent selection in KSII and Ec 573 grain yield of their crosses, H611 was the only criterion for selection. Similarly yield was the only selection criterion during modified ear-to-row selection in KCA. However, selection for low ear placement, root lodging

resistance, leaf blight and rust resistance was carried out in the nursery. Diseased ears were discarded.

The entries were from five cycles of reciprocal recurrent selection in KSII and Ec 573 and their six F_1 hybrids crosses, H611 and five cycles of KCA. Ec 573 did not have cycle zero. H614C and H622 were used as checks. These 25 entries were grown at locations N.A.R.S. - (Kitale), Sabwani and Elgon Rock in a randomized complete block design with six replications. Analysis using orthogonal polynomials was done.

Combined mean values of grain yield in KSII varied from 43.8 q/ha to 53.0 q/ha and in Ec 573 it varied between 43.1 q/ha to 49.9 q/ha. H611 showed an increase of 5.41% (2.07 q/ha) per cycle of selection. The combined mean grain yield of H611, increased highly significantly from 67.7 q/ha in (C0) to 86.0 q/ha in (C5). Open pollinated KCA showed an increase of 5.38% (2.03 q/ha) per cycle of selection. There was highly significant increase in grain yield in KCA, which varied from 41.8 q/ha in (C0) to 66.3 q/ha in (C10). H611 and KCA showed highly significant positive linear response.

Most of the yield components in KSII and Ec 573 showed decline except the number of ears per 100 plants which showed an increase after five cycles of reciprocal recurrent selection. The decrease observed in yield components and some of the other characters affecting grain yield in KSII and Ec 573 was due to inbreeding depression, while increasing the frequency of favourable alleles. The H611 showed heterosis in most of the yield components, except number of rows per ear which was stable. Some hybrid vigour was also observed in some of the other characters affecting grain yield. The hybrid vigour observed in all characters in H611 was due to exploitation of non-additive gene effects. Most of the yield components in KCA showed increase except 1000-kernel weight which decreased after ten cycles of modified ear-to-row selection. Most of the yield components and some of the other characters affecting grain yield in KCA showed increase because of utilizing additive gene effects. Thus, H611 was more efficient in partitioning of assimilates whereby achieved higher grain yields than KCA.

Harvest index showed small increases in KSII and Ec 573 after five cycles of reciprocal recurrent selection. However, there were substantial increases in harvest index in H611 and KCA.

For practical purposes the number of ears per 100 plants (i.e. number of ears per plant or prolificacy) and weight of kernels per ear were identified to be the most reliable components of grain yield, which could be used as effective criteria of selection. Also, harvest index though not a direct component of yield, could be considered as an important selection criterion in maize improvement programmes.

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Maize is the most important crop in Kenya, being the staple food for over 95% of Kenya's 15.3 million people. It is grown on about 1.2 million hectares annually, giving approximately 2.5 million tonnes of grain. The crop is grown by nearly every small scale farmer in the country. These small scale farmers grow the crop primarily for subsistance and only what is surplus to their own needs reach the market. Only 5% of the area under maize is grown by the large scale commercial farmers.

Maize breeding is, perhaps, the most important part of the research component which goes into the development of this crop. In Kenya, the maize breeding effort, had its humble beginning about two decades ago, in 1955, at Kitale. Initially the genetic improvement was based on the locally available material, Kenya Flat White which after many generations of selection by the farmers, had acquired a high level of adaptation and disease resistance.

Eberhart et al. (1967) reported that half-sib family selection was used to develop a number of lines which went to form Kitale Synthetic II. The second cycle lines using the same method went to form Kitale Synthetic III. Kitale Synthetic II was released in 1961 and was successfully taken up by the farmers. A small number of selected lines out of this programme were further selfed to go into a hybrid programme. The first three-way and double cross hybrids were released in 1964.

Harrison (1970) recognized the possibility of using exotic germ plasm in the Kitale programme. He introduced a large collection of material from Central and South America in 1959. The material from the centre of diversity was readily adapted to the Kenya highlands, near the equator, with similar ecological conditions to that of Central and South America. While the inbreeding and hybridization continued in the local material, the exotic material was screened for adaptation and tested in crosses with Kitale Synthetic II. One of the accessions, Ecuador 573 (Ec 573), performed well in the top cross yield trial with Kitale Synthetic II (KS II). Ecuador 573 is an unimproved farmers stock and a type of collection of the Ecuador race Montana. Ecuador 573 has long and narrow ears. The cross of Kitale Synthetic II and Ecuador 573 was released in

1964 as a "Variety Hybrid 611". Hybrid 611 outyielded Kitale Synthetic II by 40%. Utilising KS II and EC 573 populations subsequent superior three way hybrids 612C, 613C and 614C were produced. These are our highest yielding hybrids at present.

One thing was clear, that inbreeding was not the only way and certainly not the fastest method to develop a high yield potential variety. While there was a search for the best method to exploit the situation, a comprehensive breeding system (Eberhart, Harrison and Ogada, 1967) was developed. The flexibility of the system provides for alternative products of selection for release to farmers. These alternatives are either the cross between two populations as a variety cross hybrid; a synthetic variety derived from the advanced generation of the variety cross between two diverse populations; single, three-way or double cross hybrids formed from lines extracted from the elite material after each cycle of selection.

Darrah and Mukuru (1977) pointed out that the successful development of hybrid maize in Kenya in the early 1960's was not only a significant achievement by agricultural scientists, but it also posed a challenge to them to improve upon this initial success. The challenge stimulated an effort jointly sponsored by the then E.A.A.F.R.O. and the USDA-USAID to make in depth comparative studies of maize breeding methods. Thus, a breeding methods study was initiated at Kitale, Kenya in 1964, to compare relative efficiencies of different methods of selection for population improvement *per se* and for variety cross hybrid production. Mass, ear-to-row half-sib, full-sib, S_1 testing and reciprocal recurrent selection were compared. Some of the additional variables involved were selection intensity, plant population, testers and base populations. The study has now produced interesting and useful results which can assist to select the methodology best suited to our seasonal pattern, available resources and commercial use of the improved populations.

Darrah *et al*. (1978) reported that six years of reciprocal recurrent selection in the parental varieties, (1) Kitale Synthetic II and (2) Ecuador 573, the variety cross (3) KS II x Ec 573 and six years of ear-to-row selection in the (4) Kitale Composite A, had produced rapid improvement.

Yield improvement in a population usually requires the manipulation of multiple characters, many of which are correlated on the basis of improvement in yield within each of them. It was therefore probable that there were correlated changes to selection in yield components after five cycles of selection.

Leng (1954) reported that the total grain yield per plant in corn is the product of the major components which could be divided into primary and secondary components of grain yield. The primary components are number of ears per plant, kernel weight, row number, and number of kernels per row. These are relatively distinct morphological entities which cannot readily be further subdivided. The secondary or more complex components of grain yield are weight of grain per ear and number of kernels per ear.

A clear understanding of the correlated changes in the major yield components could be used to enhance the grain yield and its stability through suitable selection methods.

The objectives of this research project, therefore, are to:

(a) Examine the response of Ecuador 573, Kitale Synthetic II and Hybrid 611 to five cycles of reciprocal recurrent selection and Kitale Composite A to ten cycles of modified ear-to-row selection with respect to grain yield and its components and the other associated desirable agronomic characters.

(b) Compare the correlated changes in yield components of the four populations.

(c) Identify important yield components for improving grain yield in a selection programme.

CHAPTER II

REVIEW OF LITERATURE

The importance of the relationship of yield to yield components was realised quite early and various correlations have been reported by several authors.

Kyle and Stoneberg (1925) found that inbred lines having small number of kernel rows had a greater length of ear per plant, were more resistant to corn smut, had fewer plants with certain heritable deleterious characters, and were generally more vigorous and productive than the lines having larger number of kernel rows.

Jorgenson and Brewbaker (1927) reported that positive and significant correlations were obtained between the following characters of parents and the same characters of the F_1 hybrids. All of these characters with the possible exception of kernel rows per ear, are expressions of vigour. The more important correlation coefficients are as follows:

Character expressing vigour	Coefficient of correlation
Yield (grams per hill)	0.50 ± 0.08
Length of ear	0.58 ± 0.08
Diameter of ear	0.63 ± 0.06
Number of kernel rows per ear	0.79 ± 0.04
Height of Stalk	0.47 ± 0.08
Weight of Seed	0.39 ± 0.09

A multiple correlation coefficient was culculated with yield of the F_1 as the dependent variable and the characters of length of ear, diameter of ear, number of kernel rows per ear, height of plants, and yield in grams per hill of the parents as the independent factors. The correlation coefficient was 0.61. These characters of the parental lines were found to account for about 20% of the variability of yield of the F_1 hybrids.

Jenkins (1929) reported that within the inbred lines yield was correlated significantly and positively with plant height, number of ears per plant, ear length, ear diameter and shelling percentage, and it was correlated significantly and negatively with date of silking, shrinkage of the harvested ears, chlorophyll grade, and ear-shape index.

Within the F_1 crosses yield was correlated significantly and positively with date of tasseling, date of silking, plant height, number of nodes per plant, number of nodes below ear, number of ears per plant, ear length, ear diameter and shelling percentage, and it was correlated significantly and negatively with percentage of plants smutted, percentage of ears moldy and ear-shape index.

Positive correlations between characters in the inbred parents and the same characters in the crossbred progeny were obtained for all of the 19 different characters studied. The correlations between characters of the inbred parent and the mean values of the same characters in the crossbred progeny were sufficiently high in many cases to be of value for predictive purposes.

Yield of the F_1 cross was correlated significantly and positively with the following characters in the parents: Date of tasseling, date of silking, plant height, number of nodes per plant, number of nodes below ear, number of ears per plant, ear length, ear diameter and yield. It was correlated significantly and negatively with ear shape index in the parents.

The mean yield of the crossbred progeny was correlated significantly and positively with plant height, number of nodes per plant, number of nodes below ear and yield of the inbred parent line.

Hayes and Johnson (1939) found that correlation coefficients with yield based on 110 strains, ranged from 0.36 for plant height to 0.57 for maturity all exceeding the 1% point for level of significance.

Twelve characters of the inbreds, by means of total correlations, were found to be significantly related to yielding ability in inbred-variety crosses. The correlation coefficients ranged from + 0.19 for tassel index of inbreds and yield of inbred-variety crosses to + 0.54 for root volume of inbreds and yield of inbred-variety crosses. In these studies the significant values of r for significance levels 0.05 and 0.01, respectively, were + 0.18 and + 0.24, all coefficients exceeding the 1% point except the correlation between tassel index and yield.

A multiple correlation coefficient of 0.66 was obtained for association between yield of inbred-variety crosses and the following characters of inbred lines, date silked, plant height, ear height, leaf area, pulling resistance, root volume, stalk diameter, total brace roots, tassel index, pollen yield, yield index, and ear length. When date of silking was held constant a partial multiple correlation coefficient of 0.53 was obtained for the correlation between inbred-variety yield and 11 other characters of the inbreds.

Robinson *et al.* (1951) computed 28 possible genotypic and phenotypic correlations from the combine analyses of three populations of prolific corn for the following characters: plant height, ear height, husk extension, husk score, ear per plant, ear length, ear diameter and yield. Ear length and ear diameter had relatively low positive or negative correlations with each of the other characters. Ears per plant had the highest positive genetic correlation with yield of all characters. The only other characters found to have an appreciable genetic association with yield were plant and ear height.

Lonnquist (1953) reported that a proportionately greater number of high-yielding crosses were obtained among the combinations of high x high lines than among high x low crosses which is interpreted to be indicative of action of favorable dominant or partially dominant gene action. Limited evidence of greater genotype x season interaction of high x low crosses as well as the proportionately greater number of high yielding crosses among high x high lines indicates the action of favorable growth factors as being more important than overdominance in determining yielding ability in his study.

Leng (1954) reported that the hybrids were found to exceed their 'top parents' by highly significant and consistent margins in total grain yield, weight of grain per ear, number of kernels per ear and number of kernels per row. Number of kernels per row was the only primary component in which consistent superiority of hybrids over their 'top parents' was found in all comparisons. The hybrids were found to exceed their 'top parents' in mean kernel weight by a small but highly significant margin.

In mean row number, the F_1 hybrids were almost identical with the 'top parent' mean value, while in mean number of ears per plant, the hybrids were significantly lower than their 'top parents'. A more detailed analysis of the row number data showed that, as a rule, hybrids involving one or both parents having a mean row number above 18 did not show heterosis in this character, while the majority of hybrids involving parents with 16 rows or less showed a significant degree of heterosis in row number. It was postulated that this difference might indicate that more than one genetic system was operative in the control of kernel-row number.

Penny *et al*. (1963) reported approximately 5% improvement per cycle from reciprocal recurrent selection in Stiff Stalk Synthetic (SSS) and Corn Borer Synthetic (CBS).

Bagshaw (1964) found that prolificacy was a highly heritable trait and that ear number was controlled by one to three genes. He found there could be complete dominance or lack of it for two ears and complete dominance for one ear and that this mechanism was independent of early silking.

Moll and Robinson (1966) reported that there was good agreement between observed and expected selection response of the primary trait, yield, in three of the four experiments. Number of ears per plant showed a reasonably consistent increase associated with selection for high yield. Correlated responses of two other traits, ear height, and days to tassel, were less consistent and generally in poor agreement with expectation.

Reciprocal recurrent selection for crossbred performance and full-sib family selection for purebred performance were compared in their effectiveness for improving both purebred and crossbred performance.

After 3 cycles of selection, it appeared that full-sib family selection was at least as effective as reciprocal recurrent selection in improving crossbred performance.

Lonnquist and Webel (1967) reported that mean yield increased an average of 9.44% per cycle relative to the parental variety after four cycles of modified ear-to-row in Hays Golden variety.

Eberhart *et al*. (1967) reported that the improvement program for late maturing maize varieties began at Kitale in 1955 with the collection and evaluation of local farmer's strains. Since the Kitale Agricultural Station strain was one of the best local varieties, recurrent selection for general combining ability was initiated using the method of half-sib family selection and recombination of remnant S_1 seed. Each cycle required five years but steady progress was obtained.

In the Kenya maize programme, Harrison (1970) realized the value of prolificacy in the inbreds. Inbred A, which went into all of the original conventional hybrids H.621, H.622, H.631 and H.632, had a high level of prolificacy and this seemed to carry through to the hybrids. Harrison, stated that the varietal hybrid 611 out yielded the best parent, Kitale Synthetic II by 40%. The increase in yield was mainly due to the extra average weight of ears, which was due to the extra length inherited from one of the parents, Ecuador 573. Heterosis in both cases was due to dominance and additive effects.

Vera and Crane (1970) quoting Green (1955) reported that yield and plant height were correlated with r = 0.81 in Indonesia and r = 0.64 in Florida.

Hallauer (1970) found that there was no difference in the estimates of additive genetic variance for the Co and C4 of Corn Borer Synthetic No. 1. The stimates for Stiff Stalk Synthetic showed a decrease from the Co to the C4 which approached the 10% probability level. There was a significant reduction in the estimates of additive genetic variance from the Co x Co to C4 x C4 populations. All the estimates of additive genetic variance exceeded twice their standard errors. None of the changes in the estimates of dominant genetic variance was significant between the populations.

Four cycles of reciprocal recurrent selection showed an increase in yield of the Stiff Stalk Synthetic and hybrid populations and a decrease in Corn Borer Synthetic No. 1 populations. It appeared that only modest gains have been made for yield with a reduction in genetic variation

Tomozei (1970) reported that a study of four inbred lines and F_1 and F_2 hybrids showed that heritability was greatest for number of rows of grain per ear (0.79) followed by number of grains per row (0.72), number of grains per plant (0.65 - 0.73), 1000 grain weight (0.42 - 0.56) and number of ears per plant (0.15 - 0.36).

Penny and Eberhart (1971) reported that five cycles of reciprocal recurrent selection in two synthetic varieties of maize (Zea mays L.) were summarized. Yields of the varietal cross and one parental variety were increased significantly, but the yield of the other variety decreased slightly. Expected gain in the varietal cross yield, calculated from pooled heritabilities and selection differential, was 7.2% per cycle, but observed gain was only 1.7% per cycle.

In the sixth cycle, selection among S_1 plants was substituted for selection among S_0 plants. Selection within the randomly mated varietal cross was initiated for comparison with selection within the two parental varieties individually. Estimates of genetic variance within the parental population in the sixth cycle were higher than for the three previous cycles, and genetic variance was higher within the randomly mated varietal cross than within the parental varieties.

Martin and Salvioli (1971) found that in 41 lines of the variety Venezuela 1, the associations between mean diameter of the ears and 100 grain weight and between moisture content of the grain and the shelling index were significant. Associations between seven combinations of the components diameter of the ears, shelling index and total ear length per plant with yield were also significant and the association between (1) mean diameter combined with total ear length and (2) yield was the most significant. An index of selection based on this last combination was devised.

Moll and Stuber (1971) found that significant increases in yield were observed after six selection cycles in six of the seven populations tested. The exception was the response of the Indian chief variety to reciprocal recurrent selection, which was not statistically significant. Responses of both varieties to full-sib family selection were 2:1 times greater than their responses to reciprocal recurrent selection. Response of the variety hybrid to reciprocal recurrent selection was 1:3 times greater than the responses to full-sib family selection. Response of the variety composite to full-sib family selection was no greater than for Jarvis, which was the most responsive of the two varieties. Heterosis in the variety hybrid increased markedly after reciprocal recurrent selection, but showed little change after full-sib family selection. An evaluation of five additional traits showed that increases in yield were generally accompanied by a change toward shorter plants with lower ear height, more tillers and more ears. No change in time of flowering was observed.

Brown and Allard (1971) found that reciprocal recurrent selection had little effect on gene or genotypic frequencies, the few changes that occurred could be ascribed to random genetic drift associated with restriction of population size (to about N = 30) at a time of selection of lines for advance to the next cycle of reciprocal recurrent selection.

Darrah _et al_. (1972) reported that four years of reciprocal recurrent selection has produced rapid improvement in one of the parental varieties, Ecuador 573, in a variety cross and in a commercial topcross maize (_Zea mays_ L.) hybrid. The improved strain of Ecuador 573 is now used as the male parent of the commercial hybrids, H.611C, H.613C and H.614C; and they yield approximately 25% more than the original versions.

An increased number of ears per plant, lodging resistance and blight resistance was associated with yield improvement by reciprocal recurrent selection.

Torregroza *et al*. (1972) reported that two cycles of reciprocal recurrent selection in two commercial open-pollinated varieties from Mexico, resulted in increased yields in both populations when compared with the original populations.

Johnson and Tanner (1972) reported that grain yield in corn (*Zea mays* L.) is a function of the rate and duration of dry matter accumulation in the grain. At least 90% of the grain accumulated linearly beginning 2½ weeks after silking.

Eberhart *et al*. (1973) reported that evaluation of progress from five cycles of reciprocal recurrent selection (R) in the BSSS(R) and BSCB1(R) maize (*Zea mays* L.) populations indicated that the improvement in grain yield of the population cross had been linear at the rate of 2.73 q/ha (4.6%) per cycle. No significant changes, however, were detected in the parents.

Heterosis increased from 15% in the C0 x C0 to 37% for BSSS(R) C5 x BSCB1 (R) C5. Because only 10 lines were recombined each cycle, the estimated inbreeding of the C5 population (22%) probably accounted for part of the increased heterosis and lack of progress in the parental populations.

The improvement in yield of the population crosses was obtained with no changes in ear height or maturity, and stalk lodging was reduced.

Johnson (1973) reported that a model including additive effects of row number and weight per 300 kernels and additive plus dominance effects for kernels per row adequately accounted for the variation in yield due to variability in the components. Maximum yield with regard to additive effects was characterized by high row number and weight per 300 kernels, whereas yield response to dominance effects was due to kernels per row only.

The results indicated that yield response to non-additive effects was maximized by crosses among lines that on the basis of additive effects exhibited high row number and weight per kernel.

Dornescu (1973 a) reported that the yield components of three double hybrids and their parents were studied during 1970-71. In the simple hybrids, the yield components showed heterosis in varying degrees, apart from grain percentage and number of rows. Grain weight per ear showed the strongest heterosis and was directly correlated with ear and grain length. Heterosis of yield components was not apparent in the double hybrids.

Dornescu (1973b) found that ear weight was mainly dependent on grain weight per ear in six single hybrids studied. The most important components of grain weight per ear were number of rows per ear, which was indirectly influenced by 1,000 grain weight and the grain length; and number of grains per row, which was indirectly influenced by grain number per ear.

Cross and Zuber (1973) reported that the results for ten strains indicated that although plant height at maturity was highly correlated with the number of days from planting to anthesis, in a limited range of environments, this relationship was very low when considered over a wider range of environments. A significant correlation existed between plant height and number of leaves for most strains.

Using data from thirteen strains of sweet corn, Sharma (1974) reported that yield was positively associated with leaf length. Partial correlation coefficients revealed that ear length, row number per ear and grain number per row make positive and significant contributions towards yield, while multiple correlation coefficients indicated that row number per ear was the most important yield component.

Krivosheya and Zozulya (1974) while studying 78 hybrids, found that grain yield was in high positive correlation with grain weight per ear (r = 0.88), moderate correlation (r = 0.4 to 0.6) with growth period, 1,000 grain weight, and ear length, and weak correlation (r = 0.2 to 0.3) with diameter of ear and length of grain.

Growth period was in high positive correlation with length of grain (r = 0.98), moderate correlation with 1,000 grain weight and grain weight per ear, and weak correlation with ear length.

Ear length was in high positive correlation with number of grains per row (r = 0.82) and diameter of cob (r = 0.76).

Diameter of ear was in high positive correlation with grain length (r = 0.81), but high negative correlation with number of ears per plant (r = 0.86).

Zinsly and Moro (1974) found that yield was correlated with plant height (r = 0.54) and ear height (r = 0.42).

Lanza and Dionigi (1974) found that a close negative correlation existed between earliness and yield.

Kumar (1974) reported a high correlation of yield with ear weight, kernels per ear, 100 kernel weight and cob weight in ten inbred lines. Additive and nonadditive effects were important for all characters except 100 kernel weight.

Specific combining ability was high for yield, ear weight, kernels per ear, and cob weight while general combining ability was high only for 100 kernel weight and days to silking. Specific combining ability for correlated characters may be a useful index in selecting for yield.

Johnson (1974) reported that yield was related to additive genetic variance for leaf area in the upper leaves through weight per kernel and to non-additive variation in the upper and lower leaves, via kernels per row. The relationships between yield and non-additive leaf area effects in the upper leaves appeared to be dependent upon, and subordinate to, the relationship between yield and non-additive leaf area effects in the lower leaves. Though two distinct genetic pathways linking leaf area to yield via the yield components were evident, the two pathways were not genetically independent but were negatively correlated.

Sharkov (1975) reported that ear weight was most closely correlated with ear diameter and number of grains per row.

Replicated selection studies were undertaken by Moll et al. (1975) to evaluate the predictability and repeatability of correlated responses and responses to selection indexes. In each of six samples of the variety "Jarvis" (Zea mays L.), first generation families were selected for five criteria yield, ear height, and three indexes, based on both yield and ear height. In three additional samples, families were selected for yield alone. Each sample was composed of 300 full-sib families evaluated in a different location - year environment.

Evaluation of response to divergent selection showed that response of both traits were generally symmetrical. Large average deviations from predictions were observed for correlated responses and response to index selection. Variation among replicates for correlated responses was no greater on the average, than variation for direct responses. Responses of component traits to index selection were more variable in general, than responses to single trait selection. Therefore, index selection responses tended to be less repeatable than response to single trait selection.

Although correlated responses to single trait selection deviated considerably from expectation, they appeared to be as repeatable as the direct responses, which agreed satisfactorily with expectation. Further investigation of the relationship between the two traits suggested a non linear association. Failure to account for this non-linearity in predictions and indexes may have contributed to the discrepancies between observed and expected results.

Law and Fisher (unpublished 1975) compared the growth of three Kenya maize varieties, namely hybrids 613C, 512 and Katumani Composite B for 2 years at Kitale. Katumani Composite B had a low leaf area index, but a high harvest index of 46 to 48 per cent. This seems largely attributed to the smaller stem which accounted for only 22 to 24 per cent of shoot dry weight in comparison with 27 to 35 per cent in the other varieties. Grain yields were low but at a higher plant density the variety might be expected to give a gain in yield per day of growing season, comparable to the other varieties. Hybrid 512 had a low net assimilation rate in the vegetative phase which is attributed to limitation of photosynthesis, probably caused by the cold environment. In the reproductive phase net assimilation rates were high. Hybrid 613C produced more dry matter than any other variety but in one year an excessive proportion of this was used for stem growth, giving a rather low harvest index.

Law (1975) compared the growth pattern of cycle 0 and cycle 4 of Hybrid 611(R). He found that growth analysis of the Co and C4 materials did not give significant differences in leaf area or crop growth pattern, but the stem morphology was clearly different, the C4 stems being considerably thicker than those of the Co material. The C4 was slightly shorter than the Co material. However, 1975 was a relatively bad year for lodging and 69 per cent lodging was recorded in the Co plots compared to only 32 per cent in the C4 plots. Consequently in the post tasselling grain filling period the production of dry matter in the grain advanced at a faster rate to give on a per plant basis 212 gm per plant grain in the Co plots compared to 260 gm per plant in the C4 plots. When the plots were harvested the actual yields obtained were Co 95 q/ha and C4 102 q/ha.

Kotova et al. (1976) found that yield was correlated most closely with number of ears and ear weight and fairly closely with ear length and diameter. The best heritability was shown by the following characters: height of ear insertion, number of grain rows per ear, 1,000 grain weight and earliness.

Mason and Zuber (1976) reported that leaf angle from vertical orientation was negatively correlated with yield and with the yield components, grain weight per ear and number of ears per 100 plants. Leaf area index was positively correlated with yield, the two yield components, and population density. Plant density was negatively correlated with the two yield components.

Jain *et al*. (1976) found that it has not been possible to combine high biological yields with a high harvest index. There is a negative correlation between bilogical yield and harvest index. The weakening of the negative correlation could result in increased grain yields.

Cornelius and Dudley (1976) estimated the genetic and environmental variance components in maize (*Zea mays* L.) synthetic open pollinated from covariances among 12 generations (1 noninbred, 7 sib-mated, 4 selfed) in 1970 and 1971 experiments. The results showed:

(a) Significant variance due to multiple alleles for plant height and ear height in 1971 and for grain yield in 2 years analysis.

(b) Significant variance due to dominance for plant height and ear height in 1971 and for grain yield in both years.

(c) Satisfactory fit of an additive genetic model for percent moisture at harvest and percent oil, and

(d) Significant lack of fit of an additive and dominance model for kernel weight.

Darrah and Mukuru (1976) stated that selection for height, lodging and disease resistance in the breeding nurseries resulted in slight improvements in Kitale Synthetic II, and Ecuador 573 and their crosses. However, greater attention to ear height and lodging resistance is required to reduce harvesting losses in the commercial maize crop in Kenya.

Heterosis (F_1-midparent) for hybrid 611 was 25.0 q/ha (62%) and it increased slightly in hybrid 611(R) C_2 to 30.8 q/ha (65%). The relatively small increase in heterosis in hybrid 611(R) suggests that many loci may be showing complete dominance, although overdominance also may be involved. Heterosis in hybrid 611 in this and previous study is much larger than is normally obtained between variety crosses of open-pollinated maize varieties. The rate of gain in hybrid 611 (R) was 7 per cent per cycle, which is slightly less than the 10 per cent reported previously.

Compton and Bahadur (1977) stated that after a modified ear-to-row selection programme in Corn (Zea mays L.), the linear regression of grain yield on cycles of selection showed that grain yield increased at a rate of 5.26% per cycle. The rate of plant lodging was reduced. An average increase of 1.45% per cycle in grain moisture was observed. Ear height, though quite variable, showed an increase of 2.87% per cycle. Ears per plant reported by a number of previous authors (see Moll and Stuber, 1974) to be positively correlated with yield, increased at a rate of 3.16% per cycle.

Darrah *et al.* (1978) evaluated results of six years of selection in the Kitale maize breeding methods study and found that reciprocal recurrent selection was an effective inter-population improvement method. Yield gains were associated with increases in ears per 100 plants. In hybrid 611 the yield gain was estimated at 3.5% per year (7% per cycle).

CHAPTER III

MATERIALS AND METHONDS

Materials

The following 25 populations obtained from the National Agricultural Research Station, Kitale formed the materials of this study.

1. Kitale Synthetic II

   Reciprocal recurrent selection (R):
   6 cycles, C0, C1, C2, C3, C4 and C5.

2. Ecuador 573

   Reciprocal recurrent selection (R):
   5 cycles, C1, C2, C3, C4 and C5.

3. Hybrid 611

   Crosses of KS II and Ec 573 and each
   cycle: 6 cycles, Co, C1, C2, C3, C4
   and C5.

4. Kitale Composite A

   Modified ear-to-row selection (E):
   6 cycles, C0, C2, C4, C6,C8 and C10.

5. Check varieties.

   Hybrid 614C and 622.

The R and E refer to reciprocal recurrent selection and modified ear-to-row selection in the parental populations, respectively.

Kitale Composite A will give intrapopulation improvement in the random mated variety cross values. Interpopulation improvement will be expressed in hybrids between KS II x Ec 573 after each selection cycle.

A brief description of materials is given below:

1. Kitale Synthetic II (KS II) was formed by Harrison (1960) by recombining the top lines from the one cycle of half-sib selection in the Kitale Station maize.

2. Ecuador 573 (Ec 573) was introduced from South America (Harrison, 1970) and came from a farmer's stock of the race Montana. Ec 573 was improved against KS II.

3. Hybrid 611 (H6 11) is a derivative of KS II and Ec 573 crosses formed at each cycle of reciprocal recurrent selection (R).

4. Kitale Composite A (KCA) is merely the advanced generation of Hybrid 611 - KS II x Ec 573 and was formed by Eberhart (1964). Six generations of random mating were practised before ear-to-row selection (E) began in KCA.

Brief description of breeding methods is given below:

1. Reciprocal recurrent selection procedure (Comstock *et al*. 1949) used three seasons per cycle was completed in two years with irrigation at Kitale. Yield evaluation were done at four sites in Western Kenya with two replications of 100 entries for each population. A 10 per cent selection intensity was used, with yield alone as the selection criterion. Selection for disease resistance, lodging resistance and lower ear placement was done only in the nursery crops, (Darrah and Penny, 1975).

2. A cycle of modified ear-to-row selection (Lonnquist 1964) was completed in one year. 100 ear-rows per population were evaluated in yield trials at four locations in Western Kenya with 2 replications and 20 families were selected. The best 5 plants within each of these 20 families were then selected from a crossing block in which the ear-rows were detasseled and were cross-pollinated by male rows made up by bulking equal quantities of seed from each ear-row.

Summary of seasonwise activities required for the reciprocal recurrent selection and modified ear-to-row selection:

Selection Method	Season 1	Season 2	Season 3
Reciprocal recurrent:	Make reciprocal testcrosses	Yield trials; increase remnant seed by selfing.	Recombination of selected entries.
Ear-to-row:	Yield trial(s).		

Design of experiment

These 25 populations were grown in a yield trial in a randomized complete block design with 6 replications at three sites, namely, N.A.R.S. (Kitale), Sabwani and Elgon Rock. Plots of 4 rows each of 11 plants were grown. Spacing was 75 cm between the rows and 30 cm between the plants, making a plot size of 3.0m x 3.3m = $9.9m^2$, with 44 plants. Only 22 plants from the two middle rows were harvested. The harvested net plot size was 1.5m x 3.3m = $4.95m^2$.

Fertilizer was applied at rates of 60 kg/ha of P_2O_5 at planting time and 100 kg/ha of nitrogen top-dressed at knee height. 5% DDT powder was applied to control stalk borer. Weed control was done with atrazine applied at 3 kg/ha active ingredient before emergence and by hand.

Observations and data collection. The following data were collected at all the three sites.

Grain yield and its components

3.1. Grain yield. After shelling all usable ears, the grain was weighed in kilograms. The grain weight per plot was adjusted to 12.5% grain moisture content and converted to grain yield in q/ha (1q = 100kg).

Because the number of plants per plot harvested was often not equal to 22 plants, the yields were adjusted for stand level. The procedure adjusted the yield for each plot for the deviation of plot stand from the mean stand according to the following formular.

$$Y^*_{ij} = Y_{ij} - b\ (X_{ij} - \bar{X})$$

where Y_{ij} = the observed yield

Y^*_{ij} = adjusted yield

b = estimated regression coefficient.

X_{ij} = stand count

$\bar{X}$ = mean stand

(The i index refers to the populations and the j index to the replication).

The calculations were facilitated by the use of computer programme (RBMN programme of Ministry of Agriculture).

3.2. Grain moisture content (%). Grain moisture content of shelled grain was read from an electronic grain moisture tester (Dickey-john) and was recorded as a percentage.

3.3. Number of usable ears (%). All ears from the two middle rows were harvested but only usable ears were packed in sand bags for shelling in the laboratory. The number of usable ears per cent was recorded per 100 plants.

3.4. 1000-kernel weight (g). A sample of 1000-kernels per plot was weighed in grams. The grain weight was adjusted to 12.5% grain moisture content.

3.5. Number of rows per ear. Mean number of rows per ear was obtained from a sample of ten randomly chosen ears.

3.6. Number of kernels per row. These were obtained by dividing the number of total kernels per ear by the number of rows per ear on a sample of ten ears.

3.7. Number of kernels per ear. Each of the randomly chosen ten ears was shelled separately in a paper bag and counted to find out the number of kernels per ear. The mean for the plot was obtained by dividing each total by ten.

3.8. Weight of kernels per ear (g). Each of the randomly chosen ten ears was shelled separately in a paper bag and kernels weighed to find out the grain yield per ear in grams. The mean for the plot was obtained by dividing the total by ten. The mean grain weight per ear was adjusted to 12.5% grain moisture content.

3.9. Ear diameter (cm). Each of the randomly chosen ten ears was measured in centimetres using the caliper and averaged.

3.10. Ear length (cm). Each of the randomly chosen ten ears was measured in centimeters using a ruler and averaged.

Other characters affecting grain yield

3.11. Ear height (cm). The ear height was measured from ground level to the node of the top ear. This measurement was taken on randomly chosen ten plants from the two middle rows per plot after their physiological maturity. The physiological maturity of the maize plant is achieved when the maize grains form the black layer (Daynard *et al*. 1969).

3.12 Plant height (cm). The plant height was measured from the ground level to the collar of the top most leaf on ten plants after physiological maturity of the plants.

3.13 Root and Stem lodging (%). Root and stem lodging was counted only for the two middle rows consisting of 22 plants. Root lodged plants were taken as those plants that were inclined at an angle of more than 45 degrees. Stem lodged plants were taken as those plants that were bend for more than 45 degrees below the ear. The lodged plants were counted and the number was recorded as a percentage.

3.14 Bare tipped ears (%). The bare tip on any usable ear was counted and percent bare tipped ears was recorded per plot.

3,15 Days to pollination. This was calculated from the date of planting to the days taken to 50 per cent tasselling.

3.16 Number of leaves. The number of leaves per plant was counted on randomly chosen ten plants of the two middle rows and averaged.

3.17 Diseased ears (%). The diseased ears were counted per plot and discarded. The number of diseased ears per cent was recorded.

3.18 Leaf blight and rust score. Visual score (0-5) of the leaf blight (Helminthosporium sp.) and leaf rust (Polysora sp.) was done on the whole plot of 44 plants before tasselling.

3.19 Shelling percentage. Shelling percentage was calculated using following formula:

$$\text{Shelling \%} \ \frac{\text{Weight of usable grain}}{\text{Weight of unshelled ears}} \times 100$$

All the unshelled usable ears were weighed per plot before shelling and the weight was recorded in kilograms.

3.20 Total biological yield. This is the weight (kg/plot) of stover dry matter + dry weight of cobs + grain yield (moisture free).

(i) Stover dry matter. The maize stover of the harvested two middle rows was cut with a panga and tied with sisal twine and weighed in kilograms in the field. One kilogram sample of the maize stover was taken in a paper bag and dried in an oven for 3 days at 100^{0} centigrade. The sample of maize stover was weighed again after drying on an electrical weighing balance and the weight was recorded.

The amount of water in the sample of maize stover was obtained by subtracting the weight of sample maize stover after drying from the weight of sample maize stover before drying. The weight in kilograms of maize stover dry matter per harvested plants per plot was calculated using the following formula:

$$\text{Stover dry matter} = \frac{\text{Weight of sample stover after drying}}{\text{Weight of sample stover before drying}} \times \text{Stover weight per plot}$$

(ii) <u>Dry weight of cobs.</u> This was obtained by putting all the maize cobs per plot in one paper bag after shelling and drying them at 100^{0} centigrade for 3 days in an oven. They were then weighed and recorded in grams.

(iii) <u>Grain yield (moisture free).</u> This was obtained by using the following formula:

$$\text{Grain yield (moisture free)} = \text{Grain yield (moisture content at 12.5\%)} \times \frac{87.5}{100}$$

Total biological yield means only the recoverable biological yield because some parts of the plant in the soil (roots) were not harvested and weighed.

3.21. Harvest index. This is also known as crop index. This was calculated using the following formula:

$$\text{Harvest index \%} = \frac{\text{Grain yield (Moisture free)}}{\text{Total biological yield}} \times 100$$

Statistical Analysis.

The experiment was laid out as a complete randomized block design. The analysis of variance for each character recorded was calculated for each location. The combined analysis of variance for each character was computed.

1. Analysis for single location

Statistical model:

$$Y_{ij} = \mu + G_i + R_j + E_{ij}$$

where Y_{ij} = (adjusted) yield of the i^{th} genotype in the j^{th} replication.

μ = overall mean effect

G_i = Effect of the i^{th} genotype $(i=1,2....g)$

R_j = Effect of the j^{th} replication$(j=1,2....r)$

E_{ij} = Effect of random error

Analysis of variance table for one location

Source	d.f.	Ems
Replications	(r - 1)	
Genotypes	(g - 1)	$\sigma_e^2 + r\sigma_g^2$
Error	(g - 1) (r - 1)	σ_e^2
Total	(gr - 1)	

Where σ_g^2 = genetic variance

σ_e^2 = error variance

2. <u>Combined analysis over locations</u>

Statistical model:

$$Y_{ijk} = \mu+G_i+R_j+L_k+(GL)_{ik}+E_{ijk}$$

where Y_{ijk} = (adjusted) yield of i^{th} genotype in the j^{th} replication at the k^{th} location.

L_k = Effect of the k^{th} location (k = 1,2 ....l)

$(GL)_{ik}$ = Effect of the interaction between i^{th} genotype and k^{th} location.

E_{ijk} = Effect of random error.

Combined analysis of variance table for locations

Source	d.f.	Ems
Locations	(l-1)	
Replications within locations	l(r-1)	
Genotypes	(g-1)	$\sigma_e^2+r\sigma_{gl}^2+rl\sigma_g^2$
Genotypes x locations interaction	(l-1) (g-1)	$\sigma_e^2+r\sigma_{gl}^2$
Pooled error	l(r-1) (g-1)	σ_e^2
Total	(lgr-1)	

where σ_{gl}^2 = genotype x location interaction

3. <u>The coefficient of variation (C.V.)</u> is the ratio of the standard deviation of a sample to the mean, expressed as a percentage.

$$C.V. = \frac{s}{\bar{y}}$$

where s = Standard deviation.

$\bar{y}$ = mean of sample

The standard deviation was obtained from the error mean square for each location. The mean is the overall mean in each location.

4. The least significant difference (LSD) for a single location at 0.05 significant level was calculated from the following formula:

$$LSD = t\sqrt{\frac{2(\text{Error mean sum of squares}}{\text{No. of replications.}}}$$

t = critical value of the t statistic

(α = 5%)

The LSD for combined data was based on the entry by location mean square.

$$LSD = t\sqrt{\frac{2\ (\text{Location x Genotype mean square})}{\text{replications x locations}}}$$

The LSD was used as a guide to judging the true differences among genotypes and the reliability of the data was shown by the C.V.

5. Combined analysis of variance table to partition the genotypes sums of squares.

Further combined analysis of variance using orthogonal polynomials was done to partition the genotypes sums of squares. Only data from Kitale and Sabwani was used.

A graph of the combined means of each character (Y) for each population on cycles of selection (X) were done. The cycles of selection

Co, C1, C2, C3, C4 and C5 were given the time values o, 2, 4, 6, 8, and 10 years respectively. Lines and parabolas were drawn in the graphs for significant linear responses and significant quadratic response curves respectively.

If the remainder was significant no graph was drawn because the relationship between the character and cycles of selection was too difficult to understand.

Combined analysis of variance table to partition the genotypes sums of squares.

SOURCE	d.f.		
Replicates	10		
Locations	1		
Genotypes	24		
Between populations		4	
Cycles within KS II (R)		5	
Linear			1
Quadratic			1
Remainder			3
Cycles within EC 573 (R)		4	
Linear			1
Quadratic			1
Remainder			2
Cycles within H6 11		5	
Linear			1
Quadratic			1
Remainder			3
Cycles within KCA (E)		5	
Linear			1
Quadratic			1
Remainder			3
Within checks		1	
Genotypes x Locations	24		
Error	240		
Total	299		

CHAPTER IV

RESULTS

The combined analysis of variance of data from two locations, Kitale and Sabwani sites was done. The data from Elgon Rock site was omitted due to a number of reasons.

1. Coefficient of variation were high. This gave difficulties in the assumptions of combined model. It was assumed that the error variance was constant.
2. The biological reason was that there were hailstorms during flowering period. This caused most of the plants to root lodge.

So, it was justified to leave out data from Elgon Rock in the further combined analysis of variance using orthogonal polynomials.

Grain yield and its components

4.1. Grain yield (q/ha.).

The mean values of grain yield in different selection cycles are presented in Table 1. The increase or decrease over original means are entered in Table 2. Under reciprocal recurrent selection mean yields over locations in different selection cycles of both parental populations KS II and Ec 573 did not differ significantly. The combined mean values of grain yield in KS II varied from 43.8 to 53.0 q/ha and that for Ec 573 varied between 43.1 to 49.9 q/ha. However, there was a slight increase or decrease in the mean values from CO to C5. This indicates that the reciprocal recurrent selection did not improve the grain yield in the two parental populations even after five cycles of selection.

It may be interesting to note that the hybrid populations of H611 which were developed from the crosses between the two population KS II and Ec 573 gave significantly higher yields than the parental yields at all selection cycles. This indicates high specific combining ability between the two parents. The combined mean yield of H611 increased from 67.7 q/ha in CO to 86.0 q/ha in C5. H611 showed an average increase of 5.41% (2.07 q/ha) per cycle of selection (Table 2).

Table 1. Mean grain yields (q/ha) of different maize populations at three locations.

		Location				
Population		Kitale	Sabwani	Mean	Elgon Rock	Combined mean
K.S. II(R)	C0	68.3	62.7	65.5	21.8	50.9
	C1	54.2	56.6	55.4	31.6	47.5
	C2	51.8	53.1	52.4	26.6	43.8
	C3	49.2	54.1	51.7	29.4	44.2
	C4	64.4	61.2	62.8	33.5	53.0
	C5	53.3	53.3	53.3	33.1	46.6
Ec.573(R)	C1	49.6	56.6	53.1	36.6	47.6
	C2	52.0	48.8	50.4	28.5	43.1
	C3	46.2	60.3	53.3	43.3	49.9
	C4	49.5	51.5	50.5	28.8	43.2
	C5	58.6	49.9	54.2	36.0	48.2
H611	C0	79.3	78.8	79.0	44.8	67.7
	C1	75.2	84.4	79.8	49.5	69.7
	C2	79.6	91.1	85.3	41.4	70.7
	C3	85.8	86.7	86.3	63.6	78.7
	C4	86.6	96.3	91.5	71.7	84.9
	C5	87.9	91.6	89.8	78.6	86.0
KCA (E)	C0	49.6	54.0	51.8	21.9	41.8
	C2	67.9	66.1	67.0	31.0	55.0
	C4	63.0	73.7	68.4	55.2	64.0
	C6	66.3	74.0	70.1	35.8	58.7
	C8	67.7	72.4	70.1	50.2	63.4
	C10	69.4	83.2	76.3	46.3	66.3
H.614C		81.2	89.1	85.2	59.3	76.6
H.622		58.8	68.1	63.5	29.1	52.0
Mean		64.6	68.7	66.7	41.1	58.1
L.S.D. 5%		9.8	11.8		15.1	9.9
L.S.D. 1%						13.2
C.V.		13.2	14.9		31.9	

Table 2. Increase and decrease over original (C0) in grain yields in different selection cycles in maize.

Population		Yield q/ha	% of original	% gain	Difference in q/ha
K.S.II(R)	C1	47.5	93.3	- 6.7	- 3.5
	C2	43.8	86.0	-14.0	- 7.1
	C3	44.2	86.8	-13.2	- 6.7
	C4	53.0	104.1	+ 4.1	+ 2.1
	C5	46.6	91.5	- 8.5	- 4.3
Ec 573(R)	C2	43.1	90.5	- 9.5	- 4.5
	C3	49.9	104.8	+ 4.8	+ 2.3
	C4	43.2	90.7	- 9.3	- 4.4
	C5	48.2	101.3	+ 1.3	+ 0.6
H611	C1	69.7	102.9	+ 2.9	+ 2.0
	C2	70.7	104.4	+ 4.4	+ 3.0
	C3	78.6	116.1	+16.1	+10.9
	C4	84.9	125.4	+25.4	+17.2
	C5	86.0	127.0	+27.0	+18.3
KCA (E)	C2	55.0	131.6	+31.6	+13.2
	C4	64.0	153.1	+53.1	+22.2
	C6	58.7	140.4	+40.4	+16.9
	C8	63.4	151.7	+51.7	+21.6
	C10	66.3	153.8	+53.8	+24.5

This suggests that the reciprocal recurrent selection though not effective in improving the mean yield of the parental populations was found effective in improving the mean yield of the hybrids developed from populations improved with respect to each other and that the increase was consistent from C0 to C5. There was a substantial improvement in H611 from Co to C3 at 5% significant level as well as from C0 to C4 and C5 at 1% significant level.

In the intra-population improvement of KCA, the modified ear-to-row selection was found to be effective in improving the mean grain yield from 41.8 q/ha in C0 to 66.3 q/ha in C10. KCA showed an increase of 5.38% (2.03 q/ha) per cycle of selection each completed in one year (Table 2). There was a significant yield increase in KCA from C0 to C2 and from C2 to C10 at 5% level and from C0 to C10 at 1% level (Table 1).

Further analysis using orthogonal polynomials (Table 3) confirmed the above statements. The decrease in yield in KS II fitted a quadratic curve which was significant at 5% level. The increase in yield in Ec 573 did not fit any response curve. The increase in yield observed in H6 11 and KCA had a linear trend which was significant at 1% level (Figure 1).

Table 3. Combined analysis of variance of grain yield (q/ha) in maize.

Source	d.f.	ms	F
Replicates	10	279.49	2.56*
Locations	1	1256.24	11.52**
Genotypes	24	2347.10	21.52**
Between populations	4	11421.40	104.70**
Cycles within KSII(R)	5	412.33	3.78*
Linear	1	272.35	2.5
Quadratic	1	506.88	4.65**
Remainder	3	427.48	3.92*
Cycles within Ec 573 (R)	4	36.64	0.34
Cycles within H611	5	307.70	2.82*
Linear	1	1374.98	12.60**
Quadratic	1	26.23	0.24
Remainder	3	45.76	0.42
Cycles within KCA (E)	5	815.83	7.48**
Linear	1	3064.79	28.09**
Quadratic	1	367.45	3.37
Remainder	3	215.64	1.98
Within checks	1	2818.83	25.84**
Genotypes x locations	24	109.09	1.20
Error	240	90.73	
Total	299	283.53	

*Significant at 5% level

**Significant at 1% level

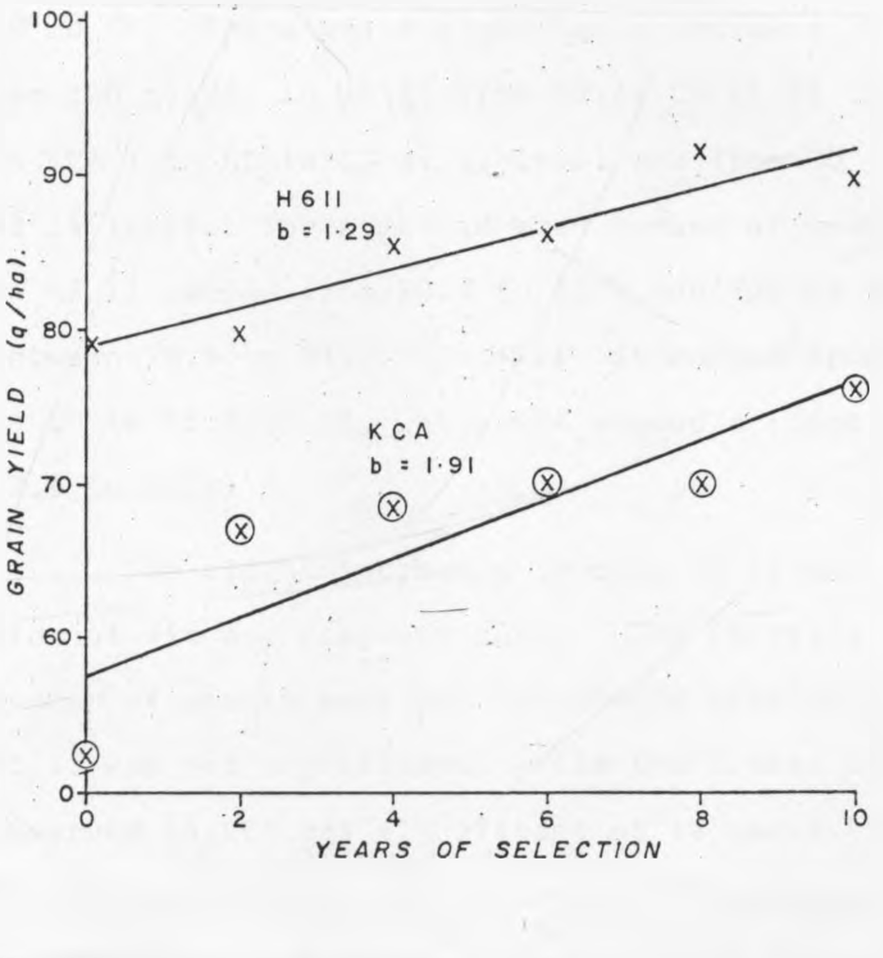

Figure 1. Response of grain yield in H611 and KCA maize populations to recurrent selection.

4.2. Usable ears per 100 plants. The mean number of usable ears in different populations are summarized in Table 4. There was a continuous increase in number of usable ears in the four populations. The slight increase in the number of usable ears per 100 plants in KS II and Ec 573 was not significant from C0 to C5. There was a significant increase in ears per 100 plants in H611 from C0 to C5 at 5% level while in KCA from C0 to C2 at 5% level and from C0 to C10 at 1% level. The combined mean number of usable ears in KS II varied from 70.4 to 80.5 and for Ec 573 varied between 78.9 to 91.2. In H611 it ranged from 78.5 in C0 to 95.0 in C5, while KCA showed a range from 57.5 to 85.4.

The slight increases in both KS II and Ec 573 did not fit any response curve. The increase in the number of usable ears per 100 plants observed in H6 11 was not significant, while the linear trend observed in KCA was significant at 1% level (Table 5). The linear response for H611 and KCA are shown in figure 2.

4.3. 1000-kernel weight (g).

The mean values and coefficient of variation of 1000-kernel weight are presented in Table 6. In KS II, there was a significant decline from C0 to

Table 4. Mean number of usable ears per 100 plants in different populations of maize.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined mean
K.S.II(R)	C0	90.9	79.0	85.0	41.3	70.4
	C1	75.4	75.7	75.5	54.6	68.6
	C2	77.7	79.3	78.5	56.4	71.1
	C3	83.4	86.3	84.8	67.2	78.9
	C4	88.6	85.7	87.2	62.7	79.0
	C5	87.5	83.4	85.4	70.7	80.5
Ec.573(R)	C1	81.0	82.6	81.8	73.2	78.9
	C2	90.5	82.5	86.5	48.9	74.0
	C3	79.0	94.1	86.5	76.0	83.0
	C4	93.6	88.2	90.9	64.1	82.0
	C5	99.3	91.7	95.5	82.7	91.2
H611	C0	89.3	84.4	86.8	61.8	78.5
	C1	90.7	91.8	91.2	70.2	84.2
	C2	93.7	98.6	96.2	61.9	84.7
	C3	92.4	94.7	93.5	86.1	91.0
	C4	100.8	97.7	99.2	95.3	97.9
	C5	94.0	98.4	96.2	92.7	95.0
KCA (E)	C0	68.7	76.6	72.7	27.2	57.5
	C2	89.3	80.7	85.0	54.4	74.8
	C4	82.1	86.2	84.2	83.7	84.0
	C6	81.4	91.2	86.3	56.6	76.4
	C8	95.4	90.8	93.1	81.1	89.1
	C10	85.8	102.2	94.0	68.2	85.4
H.614C		86.8	97.0	91.9	81.4	88.4
H.622		90.8	92.6	91.7	54.7	79.4
Mean		87.5	88.4	88.0	66.9	81.0
L.S.D. 5%		14.2	13.5		22.8	13.3
L.S.D. 1%						17.9
C.V.		14.1	13.3		29.6	29.6

Table 5. Combined analysis of variance table for usable ears per 100 plants in maize

Source	d.f.	ms	F
Replicates	10	370.81	2.34*
Locations	1	64.87	0.41
Genotypes	24	517.51	3.26**
Between populations	4	1287.24	8.11**
Cycles within KS II (R)	5	255.84	1.61
Cycles within Ec 573 (R)	4	320.41	2.02
Cycles within H611	5	231.11	1.46
Cycles within KCA (E)	5	710.94	4.48**
Linear	1	3032.02	19.11**
Quadratic	1	102.60	0.65
Remainder	3	140.03	0.88
Within checks	1	0.24	0.00
Genotypes x locations	24	158.62	1.10
Errors	240	144.40	
Total	299	182.79	

*Significant at 5% level.

**Significant at 1% level.

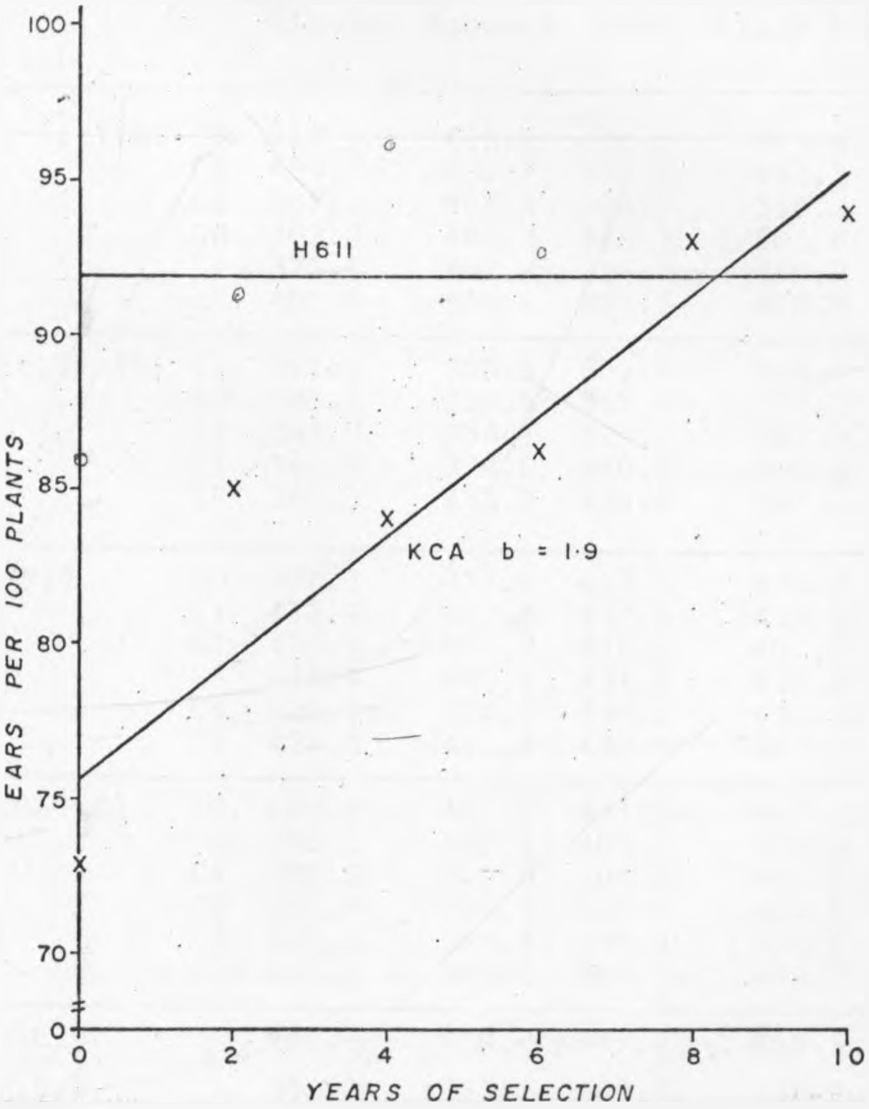

Figure 2. Response of number of ears per 100 plants in H611 and KCA maize populations to recurrent selection.

Table 6. 1000-kernel weight (g) in different populations of maize.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined mean
K.S.II(R)	C0	412.9	440.9	426.9	423.5	425.8
	C1	430.7	439.7	435.2	423.2	431.2
	C2	367.2	425.4	396.3	358.7	383.8
	C3	362.0	405.3	386.7	363.6	377.0
	C4	375.1	397.4	386.3	380.8	384.4
	C5	406.0	393.4	399.7	398.8	399.4
Ec.573(R)	C1	341.2	368.9	355.0	355.1	355.1
	C2	348.5	353.5	351.0	377.3	359.8
	C3	341.0	338.1	339.5	392.3	357.1
	C4	345.8	374.6	360.2	350.8	357.1
	C5	340.1	333.0	336.6	347.2	340.1
H611	C0	398.7	427.4	413.1	440.7	422.3
	C1	417.4	417.8	417.6	415.8	417.0
	C2	403.5	422.7	413.1	404.2	410.1
	C3	415.4	448.1	431.8	419.5	427.7
	C4	422.1	454.3	438.2	433.8	436.7
	C5	424.8	441.9	433.4	467.7	444.8
KCA (E)	C0	420.9	401.6	411.2	457.1	426.5
	C2	399.2	407.1	403.2	370.0	392.1
	C4	392.2	416.0	404.1	401.7	403.3
	C6	381.4	420.5	400.9	421.0	407.6
	C8	376.6	394.1	385.4	405.9	392.2
	C10	385.1	405.1	395.1	409.7	400.0
H.614C		435.5	459.8	447.7	450.5	448.6
H.622		351.3	453.3	402.3	422.7	409.1
Mean		387.8	409.6	498.7	403.7	400.4
L.S.D. 5%		38.9	35.8		46.1	29.1
L.S.D. 1%						38.9
C.V.		8.8	7.6		10.0	

C3 while from C4 to C5 there was a slight increase. In Ec 573, there was a slight decrease in 1000-kernel grain weight. In H611 there was a decline from C0 to C2 while there was a significant steady increase at 5% level from C3 to C5. KCA showed a significant decrease from C0 to C2 and C8 at 5% level.

The decline observed in KS II had a linear trend which was significant at 1% level. In Ec 573 and KCA there was no significant response curve which could fit the steady increase or decrease in 1000-kernel grain weight. Slight increase observed in H611 was also not significant (Table 7). The linear response for KS II and Ec 573 are shown in figure 3.

4.4. Number of rows per ear.

The mean number of rows per ear obtained in different populations are presented in Table 8. The results indicated that the number of rows per ear remained unchanged in KS II, Ec 573 and H611, after five cycles of selection. Modified ear-to-row selection in KCA increased mean number of rows in all the selected populations from C0 to C10 at 5%.

In KS II, there was no significant response curve which could fit the decline in number of rows

Table 7. Combined analysis of variance table for 1000-kernel grain weight in maize.

Source	d.f.	ms	F
Replicates	10	2118.60	1.18
Locations	1	35666.99	19.81**
Genotypes	24	11490.91	6.38**
Between populations	4	54675.72	30.37**
Cycles within KS II (R)	5	5518.82	3.06*
Linear	1	14953.15	8.31**
quadratic	1	5239.35	2.91
Remainder	3	2467.20	1.37
Cycles within Ec 573 (R)	4	1224.20	0.68
Cycles within H611	5	1509.49	0.84
Cycles within KCA (E)	5	940.16	0.52
Within checks	1	12339.74	6.85*
Genotypes x locations	24	1800.06	1.68*
Error	240	1068.12	
Total	299	2114.33	

* Significant at 5% level.

** Significant at 1% level.

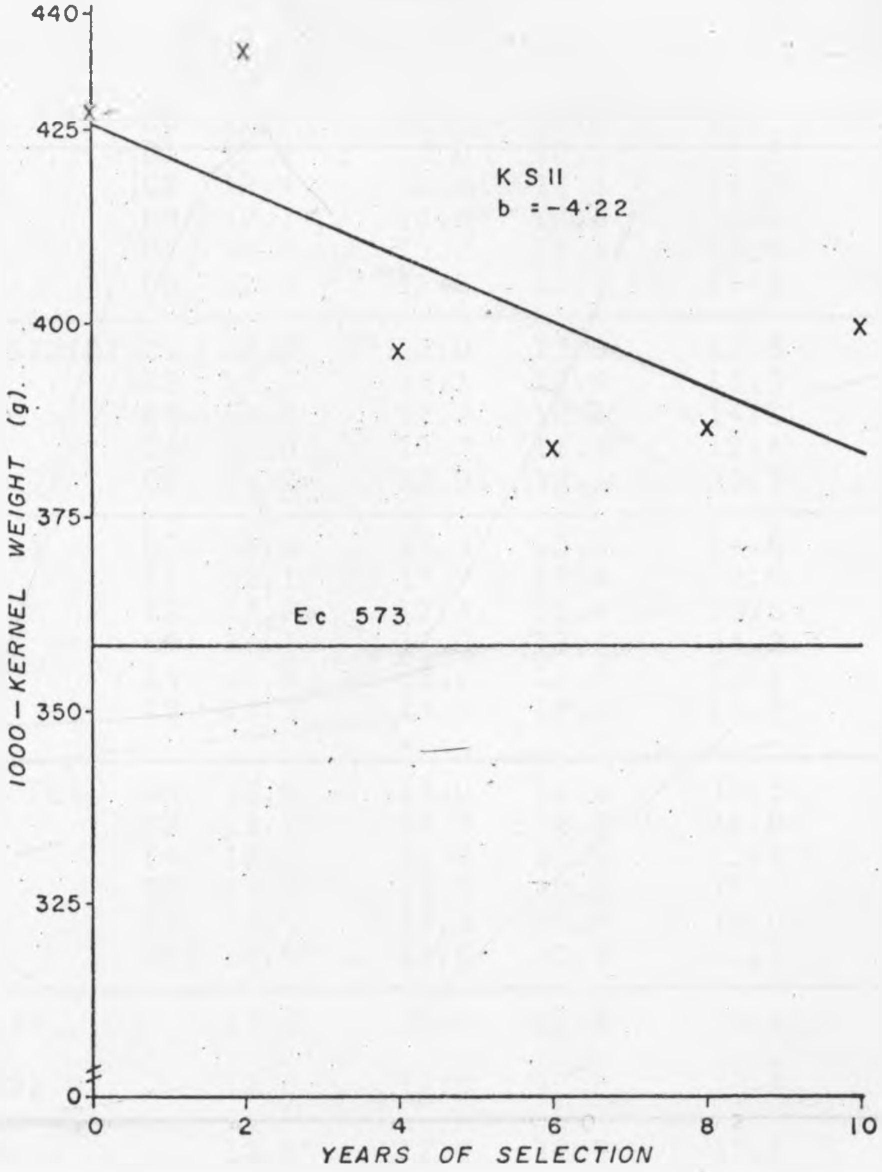

Figure 3. Response of 1000-kernel weight in KSII and Ec573 maize populations to reciprocal recurrent selection.

Table 8. Mean number of rows per ear in different populations of maize.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined mean
K.S.II(R)	C0	12.7	12.9	12.8	13.7	13.1
	C1	12.9	12.0	12.5	13.2	12.7
	C2	12.4	12.6	12.5	14.2	13.1
	C3	12.7	12.8	12.8	13.5	13.0
	C4	13.0	13.2	13.1	13.5	13.2
	C5	12.4	12.5	12.5	13.1	12.7
Ec.573(R)	C1	12.9	13.0	13.0	13.8	13.2
	C2	12.7	12.1	12.4	13.3	12.7
	C3	12.6	12.7	12.6	14.1	13.1
	C4	12.0	11.7	11.8	12.4	12.0
	C5	13.2	12.9	13.1	13.3	13.1
H611	C0	13.3	13.3	13.3	14.5	13.7
	C1	13.1	13.7	13.4	13.5	13.4
	C2	12.8	12.4	12.9	13.5	13.1
	C3	13.1	12.3	12.7	14.2	13.2
	C4	12.9	12.9	12.9	13.5	13.1
	C5	13.5	13.1	13.3	13.7	13.4
KCA (E)	C0	12.6	13.0	12.8	13.3	13.0
	C2	13.1	12.8	12.9	14.0	13.3
	C4	13.6	13.4	13.5	13.9	13.6
	C6	13.8	13.5	13.6	14.3	13.9
	C8	13.5	13.9	13.7	14.0	13.8
	C10	13.5	13.6	13.6	13.8	13.6
H.614C		13.1	12.8	12.9	13.4	13.1
H.622		12.6	12.0	12.3	13.4	12.7
Mean		13.0	12.9	12.9	13.6	13.2
L.S.D. 5%		0.7	0.6		1.3	0.5
L.S.D. 1%						0.7
C.V.		4.8	3.8		8.0	

per ear. The decrease observed in Ec 573 fitted a quadratic curve at 1% significant level while in H611 it was not significant. The increase observed in KCA had a linear trend which was significant at 1% level (Table 9). The linear response for H611 and KCA are shown in figure 4.

4.5. Number of kernels per row.

The mean number of kernels per row obtained in different populations are summarized in Table 10. In KS II and Ec 573 there was a decline in number of kernels per row, while in H611 and KCA there was a steady increase in number of kernels per row. In KS II C3 and C5 the number of kernels per row declined significantly from C4 at 5% level. But the reduction in number of kernels per row in Ec 573 was not significant. The increase was not significant in H611. There was a significant increase in number of kernels per row in all selected populations of KCA as compared to C0 at 5% level.

The decrease in number of kernels per row in KS II and Ec 573 and increase in H611 did not fit any response curve. The increase in number of kernels per row in KCA had a linear trend which was significant at 1% level (Table 11).

Table 9. Combined analysis of variance table for number of rows per ear in maize.

Source	d.f.	ms	F
Replicates	10	0.32	0.78
Locations	1	0.54	1.29
Genotypes	24	2.58	6.18**
Between populations	4	7.20	17.24**
Cycles within KS II (R)	5	0.74	1.77
Cycles within Ec 573 (R)	4	3.07	7.35**
Linear	1	0.17	0.40
Quadratic	1	5.83	13.96**
Remainder	2	3.14	7.51**
Cycles within H611	5	1.08	2.58
Cycles within KCA (E)	5	1.84	4.40**
Linear	1	7.15	17.12**
Quadratic	1	1.52	3.65
Remainder	3	0.17	0.41
Within checks	1	2.53	6.07*
Genotypes x locations	24	0.42	1.34
Error	240	0.31	
Total	299	0.50	

* Significant at 5% level.

** Significant at 1% level.

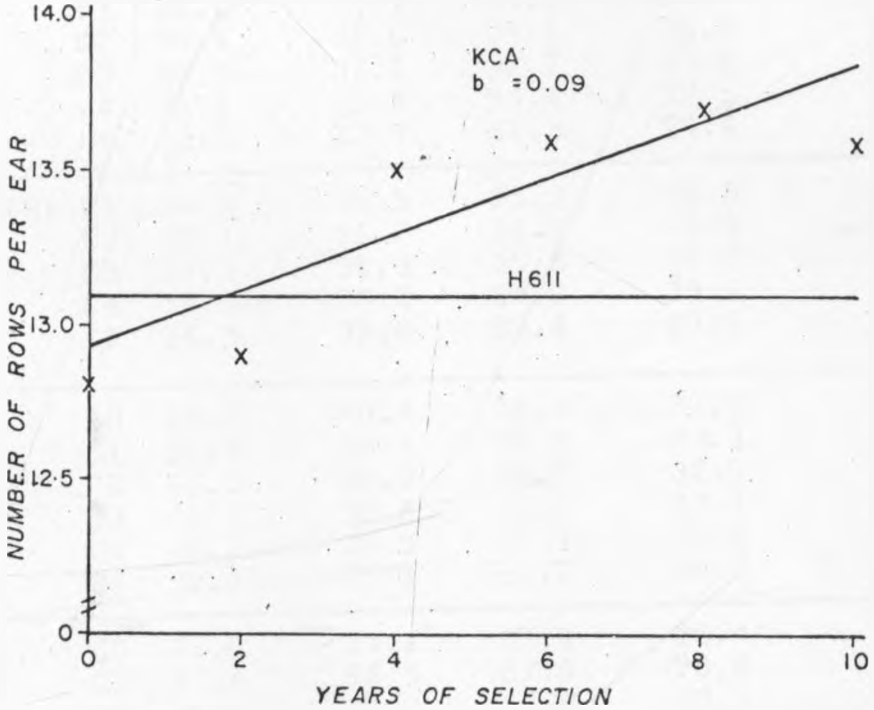

Figure 4. Response of number of rows per ear in H611 and KCA maize populations to recurrent selection.

Table 10. Mean number of kernels per row obtained in different populations of maize.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined mean
K S II(R)	C0	34.9	34.4	34.7	24.4	31.2
	C1	34.0	33.5	33.8	24.9	30.8
	C2	35.5	32.8	34.1	25.2	31.1
	C3	32.3	32.1	32.2	23.0	29.1
	C4	35.5	33.2	34.4	27.5	32.1
	C5	31.5	32.0	31.8	24.4	29.3
Ec 573(R)	C1	34.4	36.3	35.3	30.8	33.8
	C2	35.1	35.7	35.4	27.5	32.8
	C3	35.3	36.3	35.8	30.0	33.9
	C4	35.6	34.3	34.9	29.1	33.0
	C5	34.3	32.6	33.4	29.5	32.1
H611	C0	38.5	40.4	39.4	31.9	36.9
	C1	39.1	38.9	39.0	33.1	37.0
	C2	40.1	39.3	39.7	32.9	37.4
	C3	41.1	39.6	40.3	33.1	37.9
	C4	40.2	39.9	40.1	37.6	39.3
	C5	39.4	39.1	39.2	35.6	38.0
KCA (E)	C0	31.6	34.2	32.9	26.4	30.7
	C2	37.4	38.5	37.9	26.0	34.0
	C4	34.1	37.2	35.7	33.1	34.8
	C6	35.6	36.9	36.3	26.8	33.1
	C8	37.1	36.0	36.6	32.0	35.0
	C10	37.7	37.8	37.8	33.4	36.3
H 614C		39.0	40.3	39.7	32.8	37.4
H 622		32.8	36.5	34.6	27.6	32.3
Mean		36.1	36.3	36.2	29.5	34.0
L.S.D. 5%		3.0	2.6		4.2	2.6
L.S.D. 1%						3.5
C.V.		7.3	6.3		12.5	

Table 11. Combined analysis of variance table for number of kernels per row in maize.

Source	d.f.	ms	F
Replicates	10	7.24	0.91
Locations	1	3.85	0.48
Genotypes	24	83.02	10.44**
Between populations	4	374.05	47.06**
Cycles within KS II (R)	5	17.41	2.19
Cycles within Ec 573 (R)	4	10.51	1.32
Cycles within H611	5	3.12	0.39
Cycles within KCA (E)	5	40.20	5.06**
Linear	1	74.23	9.34**
Quadratic	1	11.02	1.39
Remainder	3	38.59	4.85**
Within checks	1	150.50	18.94**
Genotypes x locations	24	7.95	1.30
Error	240	6.09	
Total	299	12.44	

* Significant at 5% level.

** Significant at 1% level.

4.6. Weight of kernels per ear (g).

The mean kernel weights and coefficients of variation for different maize populations are summarised in Table 12. In KS II and Ec 573, there was a decline in weight of kernels per ear, while in H611 and KCA there was an increase in weight of kernels per ear. KS II C5 had significantly less weight of kernels per ear than C0 at 1% level. The decrease of weight of kernels per ear in Ec 573 from C0 to C5 was not significant. The increase of weight of kernels per ear in H611 from C2 to C4 and C5 was significnat at 5% level. There was a substantial increase in weight of kernels per ear in KCA from C0 to C4 which was significant at 5% level and to C10 which was significant at 1% level.

The decrease in weight of kernels per ear in KS II had a linear trend which was significant at 1% level. The decline in Ec 573 and increase in H611 in weight of kernels per ear were not significant. The increase in weight of kernels per ear in KCA had a linear trend which was significant at 1% level (Table 13 and Figure 5).

4.7. Number of kernels per ear.

The mean number of kernels per ear and coefficients of variation are shown in Table 14. In KS II and Ecuador 573 there was a decline in

Table 12. Mean weight of kernels per ear (g) obtained in different populations of maize.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined mean
K S II(R)	C0	190.6	200.4	195.5	133.8	174.9
	C1	180.4	186.6	183.5	141.4	169.5
	C2	174.0	172.4	173.2	124.7	157.0
	C3	149.1	162.9	156.0	118.1	143.4
	C4	177.0	168.7	172.8	136.8	160.8
	C5	155.9	159.2	157.5	124.1	146.4
Ec 573(R)	C1	146.1	171.7	158.9	146.1	154.6
	C2	155.7	153.0	154.4	143.2	150.6
	C3	149.0	157.4	153.2	166.3	157.6
	C4	144.2	145.6	144.9	122.3	137.4
	C5	148.3	138.3	143.3	132.0	139.5
H611	C0	212.2	236.6	224.4	212.8	220.5
	C1	218.0	240.7	229.3	188.6	215.8
	C2	210.3	224.3	217.3	177.8	204.1
	C3	231.6	222.4	217.0	204.2	219.4
	C4	223.6	230.1	226.9	219.8	224.5
	C5	225.6	232.6	229.1	222.9	227.0
KCA(E)	C0	164.9	180.7	172.8	159.4	168.3
	C2	195.5	198.7	197.1	143.4	179.2
	C4	182.5	208.6	195.5	179.2	190.1
	C6	196.0	218.6	207.3	157.4	190.7
	C8	187.1	206.0	196.5	182.8	192.0
	C10	204.7	224.5	214.6	187.3	205.5
H 614C		219.8	246.5	233.1	193.3	219.9
H 622		152.1	189.4	170.7	150.8	164.1
Mean		183.8	195.0	189.4	162.7	180.5
L.S.D. 5%		21.0	20.0		28.1	20.0
L.S.D. 1%						26.7
C.V.		10.0	9.0		15.1	

Table 13. Combined analysis of variance table for weight of kernels per ear in maize.

Source	d.f.	ms	F
Replicates	10	737.00	1.53
Locations	1	9542.88	19.80**
Genotypes	24	10972.76	22.77**
Between populations	4	52722.75	109.42**
Cycles within KS II (R)	5	2747.95	5.70**
Linear	1	9803.10	20.34**
Quadratic	1	1205.64	2.50
Remainder	3	910.34	1.89
Cycles within Ec 573 (R)	4	527.48	1.09
Cycles within H611	5	238.45	0.49
Cycles within KCA (E)	5	2408.92	5.00**
Linear	1	8234.40	17.09**
Quadratic	1	660.08	1.37
Remainder	3	1050.04	2.18
Within checks	1	23368.80	48.50**
Genotypes x Locations	24	481.84	1.49
Error	240	322.76	
Total	299	123.51	

* Significant at 5% level.

** Significant at 1% level.

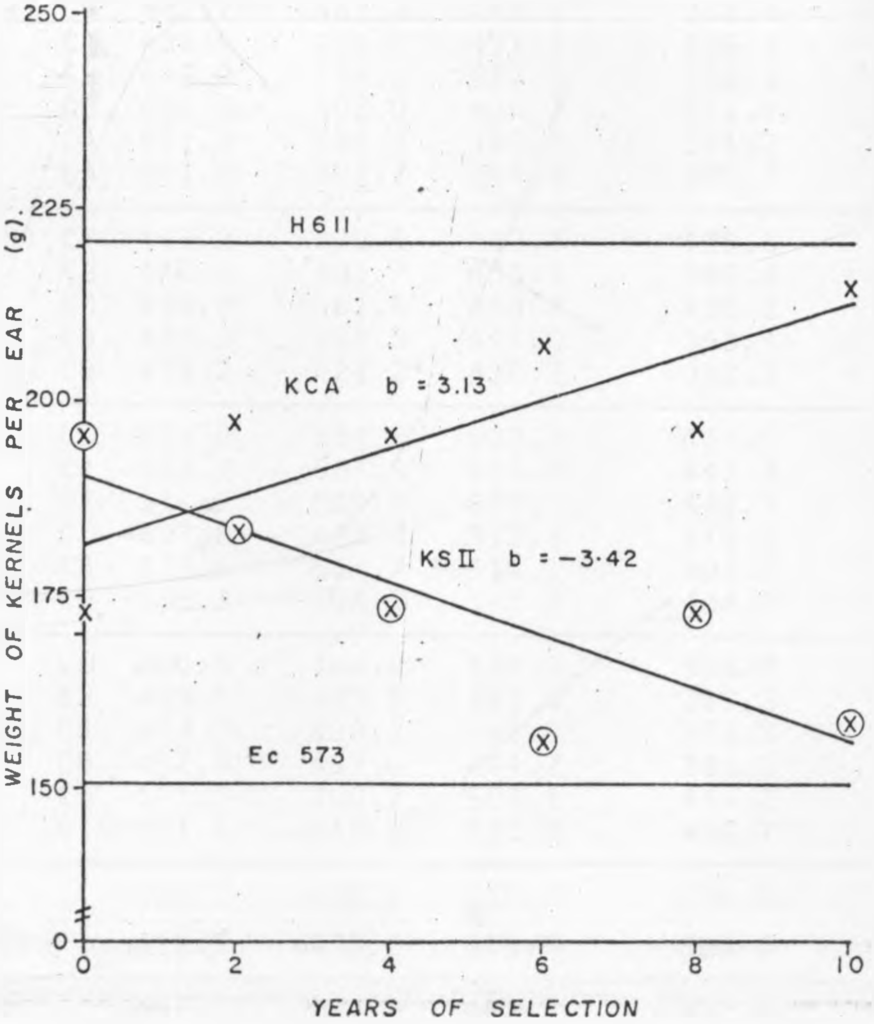

Figure 5. Response of weight of kernels per ear in KSII, Ec573, H611 and KCA maize populations to recurrent selection.

Table 14. Mean number of kernels per ear obtained in different maize populations.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined mean
K S II(R)	C0	442.7	443.7	443.2	332.8	406.7
	C1	439.5	403.5	421.5	326.8	389.9
	C2	440.0	414.2	427.1	358.0	404.1
	C3	409.5	408.0	408.7	311.0	376.2
	C4	461.3	439.3	450.3	371.2	423.9
	C5	391.5	401.7	396.6	320.7	371.3
Ec 573(R)	C1	445.2	470.8	458.0	425.3	447.1
	C2	446.0	431.7	438.8	362.8	413.5
	C3	444.8	461.5	453.2	420.8	442.4
	C4	422.2	403.0	412.6	358.5	394.6
	C5	451.2	421.2	436.2	392.3	421.6
H611	C0	513.2	534.2	523.7	463.5	503.6
	C1	512.7	534.5	523.6	441.3	496.2
	C2	514.2	506.0	510.1	442.3	487.5
	C3	537.8	487.8	512.8	470.8	498.8
	C4	517.5	514.7	516.1	504.8	512.3
	C5	533.3	514.2	523.7	484.8	510.8
KCA (E)	C0	400.5	444.2	422.3	355.2	400.0
	C2	489.5	493.5	491.5	365.3	449.4
	C4	464.2	498.2	481.2	458.3	473.6
	C6	492.3	497.0	494.7	381.3	456.9
	C8	501.5	500.7	501.1	444.2	482.1
	C10	511.5	516.2	513.8	460.7	496.1
H 614C		508.2	516.2	512.2	436.5	487.0
H 622		412.2	439.0	425.6	366.8	406.0
Mean		468.1	467.8	467.9	402.2	446.0
L.S.D. 5%		43.5	36.8		49.4	33.1
L.S.D. 1%						44.1
C.V.		8.1	6.9		10.7	

the number of kernels per ear, while in H611 and KCA there was an increase in number of kernels per ear. The decrease in number of kernels per ear in KS II from C0 to C5 was significant at 5% level. In Ec 573 there was a significant decrease from C0 to C4 at 1% level. The increase in H611 was not significant,while it was significant in KCA from C0 to C10 at 1% level.

The decrease observed in KS II and Ec 573 and increases in H611 did not fit any response curve. The increase in number of kernels per ear in KCA had a linear trend which was significant at 1% level and a quadratic curve which was significant at 5% level (Table 15). The linear response for H611 and response curve for KCA are shown in figure 6.

4.8. Ear diameter (cm).

The mean ear diameter obtained in different populations are presented in Table 16. There was a slight reduction in ear diameter in KS II and Ec 573, while it increased in H611 and KCA. The decrease in ear diameter in KS II and Ec 573 from original cycles to C5 was significant at 5% level. The increase in ear diameter in H611 from C0 to C5

Table 15. Combined analysis of variance table for number of kernels per ear in maize.

Source	d.f.	ms	F
Replicates	10	1536.32	0.96
Locations	1	7.06	0.00
Genotypes	24	22243.88	13.98**
Between populations	4	96193.27	60.46**
Cycles within KS II (R)	5	4941.25	3.10*
Linear	1	4653.01	2.92
Quadratic	1	38.50	0.02
Remainder	3	6671.57	4.19*
Cycles within Ec 573 (R)	4	3794.33	2.38
Cycles within H611	5	452.93	0.28
Cycles within KCA (E)	5	12390.35	7.79**
Linear	1	42814.29	26.91**
Quadratic	1	11685.14	7.34*
Remainder	3	2484.10	1.56
Within checks	1	44980.04	28.27**
Genotypes x locations	24	1590.98	1.28
Error	240	1241.23	
Total	299	2960.88	

* Significant at 5%.

** Significant at 1% level.

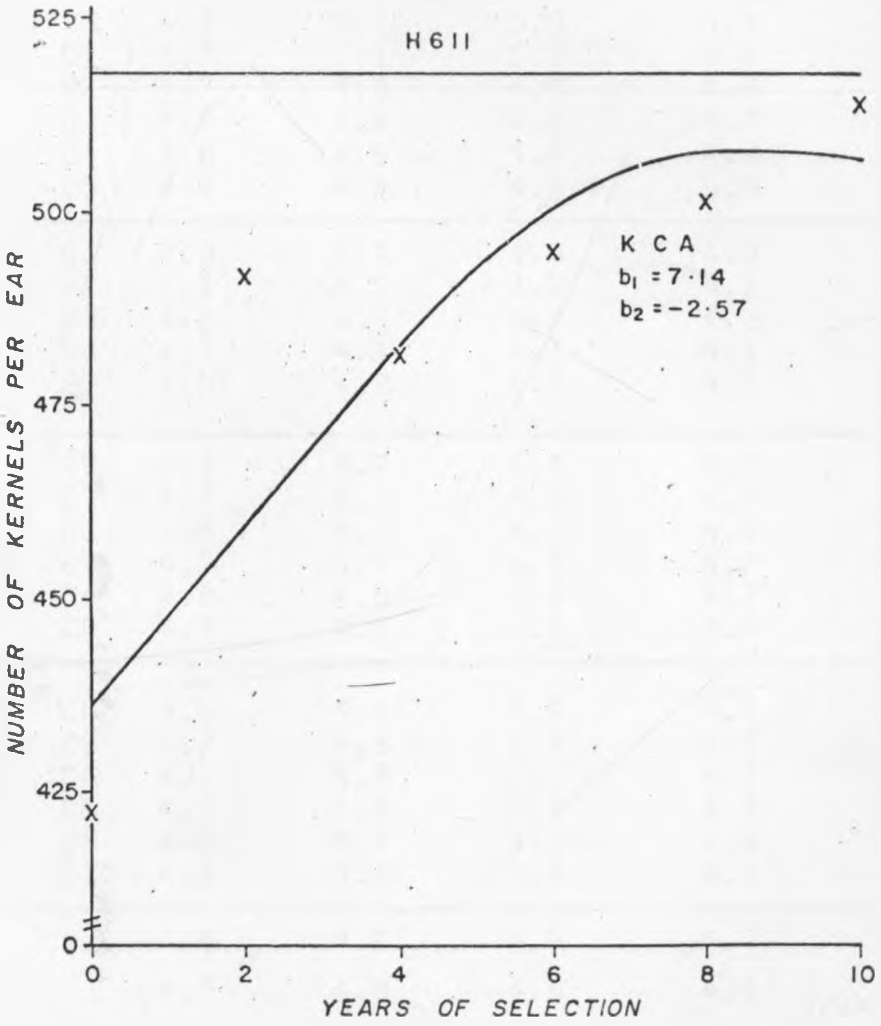

Figure 6. Response of number of kernels per ear in H611 and KCA maize populations to recurrent selection.

Table 16. Mean ear diameter (cm) obtained in different populations of maize.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined Mean
K S II(R)	C0	4.9	5.1	5.0	4.9	5.0
	C1	5.0	5.1	5.0	4.9	5.0
	C2	4.7	4.8	4.8	4.6	4.7
	C3	4.7	4.9	4.8	4.7	4.8
	C4	5.0	4.9	5.0	4.7	4.9
	C5	4.9	4.9	4.9	5.0	4.9
Ec 573(R)	C1	4.3	4.4	4.3	4.3	4.3
	C2	4.1	4.2	4.2	4.1	4.1
	C3	4.2	4.2	4.2	4.3	4.2
	C4	4.1	4.1	4.1	4.1	4.1
	C5	4.3	4.2	4.3	4.2	4.2
H611	C0	4.7	4.9	4.8	4.8	4.8
	C1	4.7	5.0	4.9	4.7	4.8
	C2	4.6	4.7	4.7	4.6	4.6
	C3	4.7	4.7	4.7	4.7	4.7
	C4	4.8	4.8	4.8	4.7	4.8
	C5	4.9	5.0	4.9	4.9	5.0
KCA (E)	C0	4.6	4.8	4.7	4.7	4.7
	C2	4.7	4.6	4.7	4.5	4.6
	C4	4.5	4.8	4.6	4.7	4.7
	C6	4.7	4.8	4.7	4.5	4.7
	C8	4.6	4.7	4.7	4.6	4.6
	C10	4.8	5.0	4.9	4.7	4.8
H 614C		4.8	4.9	4.9	4.7	4.8
H 622		4.7	4.8	4.8	4.6	4.7
Mean		4.6	4.7	4.7	4.6	4.7
L.S.D. 5%		0.2	0.2		0.2	0.1
L.S.D. 1%						0.2
C.V.		3.7	3.4		3.5	

was significant at 1% level. Also the increase in ear diameter in KCA from C0 to C10 was significant at 5% level.

The decrease in ear diameter in KS II and Ec. 573 fitted a quadratic response curve which was significant at 1% level and 5%, respectively. The increase in ear diameter in H611 fitted a quadratic response curve at 1% significant level. The increase in ear diameter in KCA had a linear trend which was significant at 1% level (Table 17 and Figure 7).

4.9. Ear length (cm).

The mean ear length of different maize populations and coefficients of variation are summarised in Table 18. There was a decrease in ear length in the parental populations KS II and Ec.573, while in H611 and KCA there was an increase in ear length. The decreases in ear length in KS II and Ec 573 from original cycle to C5 were significant at 1% level. The increase in ear length in H611 was not significant; while it was significant in KCA from C0 to C10 at 5% level.

The decrease in ear length, observed in KS II had a linear trend which was significant at 1% level; while in Ec 573 it was not significant (Figure 8).

Table 17. Combined analysis of variance table for ear diameter in maize.

Source	d.f.	ms	F
Replicates	10	0.03	0.96
Locations	1	0.74	27.01**
Genotypes	24	0.85	30.89**
Between populations	4	4.65	166.43**
Cycles within KS II (R)	5	0.12	4.59**
Linear	1	0.09	3.29
Quadratic	1	0.23	8.47**
Remainder	3	0.10	3.74*
Cycles within Ec 573 (R)	4	0.09	3.32*
Linear	1	0.03	0.98
Quadratic	1	0.20	7.31*
Remainder	2	0.07	2.50
Cycles within H611	5	0.11	4.23**
Linear	1	0.04	1.67
Quadratic	1	0.35	12.79**
Remainder	3	0.06	2.23
Cycles within KCA (E)	5	0.09	3.21*
Linear	1	0.26	9.51**
Quadratic	1	0.09	3.27
Remainder	3	0.03	1.08
Within checks	1	0.06	2.19
Genotypes x Locations	24	0.97	
Error	240	0.03	
Total	299	0.10	

* Significant at 5% level

** Significant at 1% level.

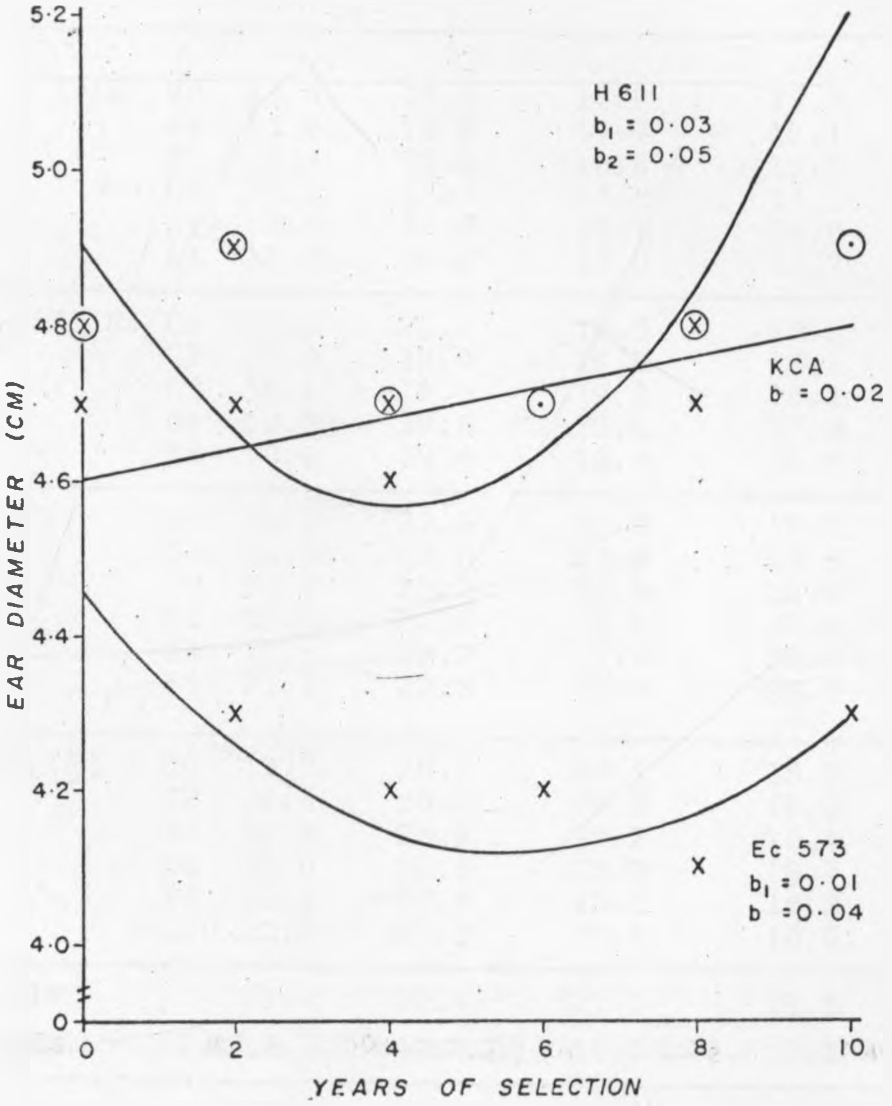

Figure 7. Response in ear diameter in Ec573, H611 and KCA maize populations to recurrent selection.

Table 18. Mean ear length (cm) obtained in different maize populations.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined Mean
K S II(R)	C0	18.8	18.9	18.9	15.0	17.6
	C1	18.9	18.6	18.7	16.1	17.9
	C2	18.7	19.0	18.9	15.3	17.7
	C3	18.0	17.7	17.8	14.1	16.6
	C4	18.5	17.7	18.1	14.8	17.0
	C5	17.2	16.9	17.0	13.7	15.9
Ec 573(R)	C1	19.6	20.1	19.8	18.5	19.4
	C2	19.8	19.9	19.9	18.1	19.3
	C3	19.1	19.3	19.2	18.1	18.8
	C4	19.5	19.5	19.5	17.3	18.8
	C5	18.6	18.4	18.5	16.7	17.9
H611	C0	21.5	22.9	22.2	19.0	21.1
	C1	20.9	22.0	21.4	18.9	20.6
	C2	21.7	22.2	21.9	19.2	21.0
	C3	22.5	22.6	22.6	20.5	21.9
	C4	21.5	22.2	21.8	20.4	21.4
	C5	21.7	22.3	22.0	20.3	21.4
KCA (E)	C0	19.5	20.6	20.1	18.0	19.4
	C2	20.4	20.0	20.3	16.6	19.0
	C4	19.6	20.7	20.2	18.4	19.6
	C6	20.0	21.8	20.9	16.7	19.5
	C8	20.2	20.8	20.5	18.3	19.8
	C10	20.2	22.2	21.2	18.6	20.3
H 614C		21.4	22.4	21.9	19.5	21.1
H 622		18.1	19.3	18.7	17.2	18.2
Mean		19.8	20.3	20.0	17.6	19.2
L.S.D. 5%		1.3	1.1		1.4	1.0
L.S.D. 1%						1.4
C.V.		5.6	4.8		6.8	

Table 19. Combined analysis of variance of ear length in maize.

Source	d.f.	ms	F
Replicates	10	0.93	0.56
Locations	1	17.67	10.68**
Genotypes	24	28.38	17.15**
Between populations	4	138.66	83.78**
Cycles within KS II (R)	5	6.44	3.89*
Linear	1	25.38	15.34**
Quadratic	1	2.32	1.40
Remainder	3	1.51	0.91
Cycles within Ec 573 (R)	4	3.75	2.27
Cycles within H611	5	1.78	1.08
Cycles within KCA (E)	5	2.29	1.38
Within checks	1	58.91	35.60**
Genotypes x locations	24	1.65	0.39
Error	240	4.22	
Total	299	3.39	

* Significant at 5% level.

** Significant at 1% level.

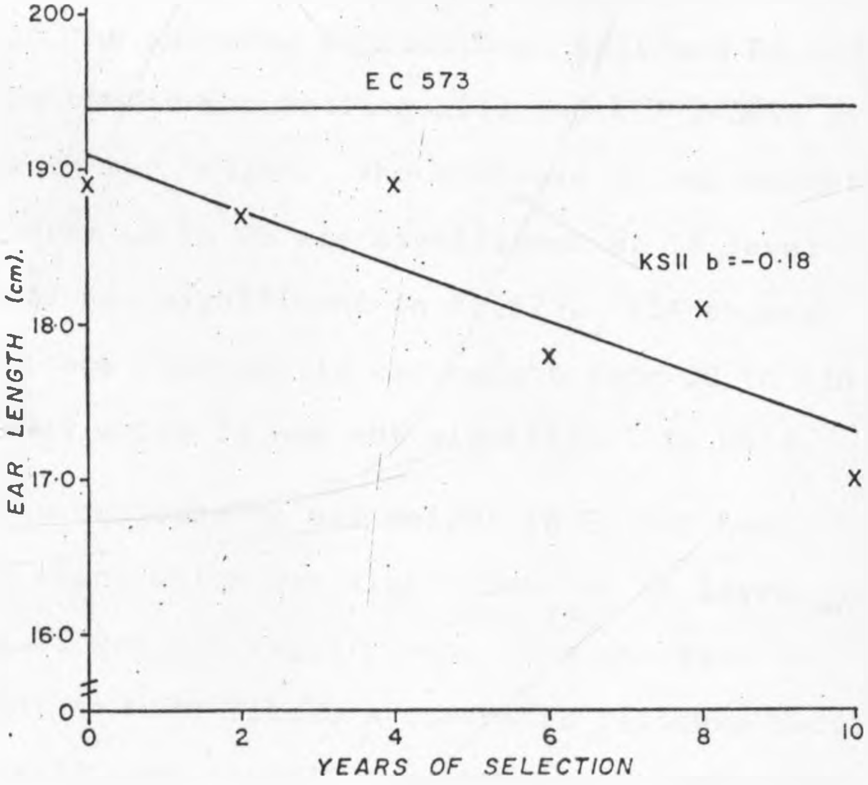

Figure 8. Response in ear length in KSII and Ec573 maize populations to reciprocal recurrent selection.

The increase in ear length in H611 and KCA did not fit any response curve (Table 19).

Other characters affecting grain yield

4.10. Ear height (cm).

The mean ear height obtained in different populations and coefficients of variation are presented in Table 20. There was decrease in ear height in the parental populations, KSII and Ec 573, while the hybrid populations H611 and KCA showed an increase in ear height. The decrease in ear height in KSII from C0 to C5 was significant at 1% level but it was not significant in Ec 573. KCA showed a significant increase in ear height from C0 to C10 at 5% level,while it was not significant in H611.

The decrease in ear height in Ec 573 had a linear trend which was significant at 5% level, while in KS II it was not significant. The increase in ear height in H611 fitted a quadratic response curve at 1% significant level. The increase in ear height in KCA did not fit any response curve (Table 21). The response curve of H611 and KCA are shown in figure 9.

Table 20. Mean ear heights (cm) in different populations of maize.

Population	Location				
	Kitale	Sabwani	Mean	Elgon Rock	Combined Mean
K S II(R)C0	230.2	214.2	222.2	235.5	226.6
C1	226.2	217.5	221.8	236.5	226.7
C2	218.0	226.3	222.2	230.5	224.9
C3	219.0	209.8	214.4	215.0	214.6
C4	220.7	210.5	215.6	223.0	218.1
C5	208.7	209.2	208.9	210.3	209.4
Ec 573(R)C1	234.7	218.5	226.6	244.2	232.4
C2	214.7	236.8	239.2	261.7	246.7
C3	224.8	221.2	223.0	245.2	230.4
C4	224.8	215.0	219.9	237.3	225.7
C5	225.8	217.2	221.5	233.7	225.6
H611 C0	249.3	244.3	246.8	261.8	251.8
C1	227.2	237.3	232.2	260.0	241.5
C2	242.5	235.7	239.1	245.5	241.2
C3	231.2	217.5	224.3	244.2	230.9
C4	232.8	234.3	233.6	245.8	237.7
C5	247.2	232.2	239.7	255.8	245.1
KCA (E) C0	237.2	235.8	236.5	253.0	242.0
C2	239.8	229.5	234.7	253.2	240.8
C4	245.2	225.8	235.5	248.3	239.8
C6	250.2	235.5	242.8	258.5	248.1
C8	249.5	230.2	239.8	261.3	247.0
C10	246.7	240.7	243.7	266.7	251.3
H 614C	235.2	218.3	226.7	241.3	231.6
H 622	217.3	198.5	207.9	211.2	209.0
Mean	233.0	224.5	228.7	243.2	233.6
L.S.D.	13.2	11.0		10.6	9.3
L.S.D. 1%					12.4
C.V.	4.9	4.2		3.8	

Table 21. Combined analysis of variance table for ear height in maize.

Source	d.f.	ms	F
Replicates	10	449.78	2.30*
Locations	1	5486.96	28.07**
Genotypes	24	1457.85	7.46**
Between populations	4	5929.30	30.34**
Cycles within KS II (R)	5	358.05	1.83
Cycles within Ec 573 (R)	4	726.44	3.72*
Linear	1	1048.49	5.36*
Quadratic	1	67.70	0.35
Remainder	2	894.79	4.58*
Cycles within H611	5	711.16	3.64*
Linear	1	364.53	1.86
Quadratic	1	1827.37	9.35**
Remainder	3	454.63	2.33
Cycles within KCA (E)	5	178.27	0.91
Within checks	1	2128.16	10.89**
Genotypes x Locations	24	195.44	1.76
Error	240	110.97	
Total	299	255.17	

* Significant at 5% level.

** Significant at 1% level.

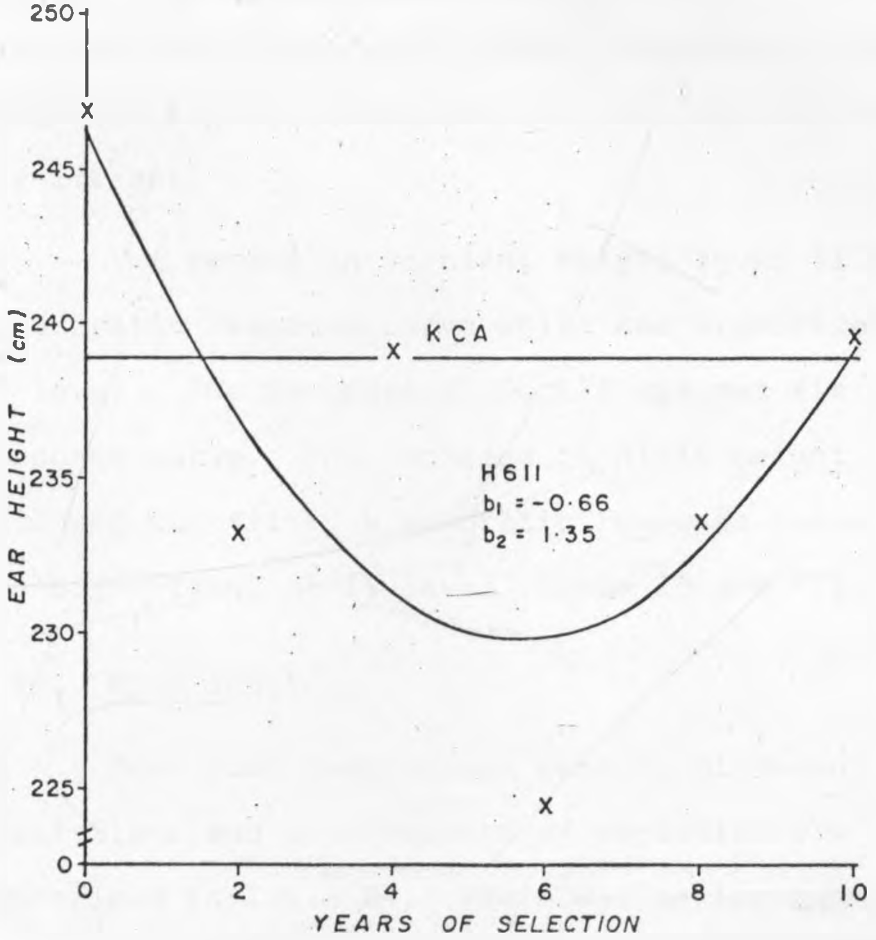

Figure 9. Response of ear height in H611 and KCA maize populations to recurrent selection.

4.11. Plant height (cm).

The mean values of plant height and coefficients of variation are presented in Table 22. There was reduction in plant height in KSII while it increased in Ec 573, H611 and KCA populations after selections. However, the reduction in plant height in KS II from CO to C5 was not significant. Similarly, increase in plant height in Ec 573, H611 and KCA from CO were not significant.

The reduction in plant height in KS II fitted a quadratic response curve which was significant at 1% level. The increase in Ec 573 did not fit any response curve. The increase in plant height in H611 and KCA fitted a quadratic response curve which was significant at 1% level (Table 23 and Figure 10)

4.12. Root lodging.

Mean root lodging per cent in different populations and coefficients of variation are summarised in Table 24. There was an improvement in KS II, Ec 573 and H611 by reducing the number of root lodged plants after reciprocal recurrent selection. Modified ear-to-row selection in KCA also effected improvement in reducing the number of root

Table 22. Mean plant heights (cm) obtained in different populations in maize.

Population		Location				Combined mean
		Kitale	Sabwani	Mean	Elgon Rock	
K S II(R)	C0	377.0	368.2	372.6	365.5	370.2
	C1	382.3	374.2	378.2	369.5	375.3
	C2	392.7	382.2	387.4	372.0	382.3
	C3	382.3	372.2	377.2	361.0	371.8
	C4	397.0	379.5	388.2	360.0	378.8
	C5	372.8	378.2	367.2	355.7	368.9
Ec 573(R)	C1	370.2	359.8	365.0	357.8	362.6
	C2	388.8	383.0	385.9	370.3	380.7
	C3	359.7	357.3	358.5	368.0	361.7
	C4	376.3	358.0	367.2	363.8	366.1
	C5	387.5	346.5	367.0	361.2	365.1
H611	C0	406.2	401.3	403.7	381.2	396.2
	C1	386.3	382.3	384.3	361.2	376.6
	C2	397.3	387.7	392.5	362.7	382.6
	C3	392.0	376.2	384.1	369.3	379.2
	C4	406.3	396.3	401.3	385.5	396.1
	C5	413.7	399.3	406.4	367.8	393.6
KCA (E)	C0	410.8	385.2	398.0	364.5	386.8
	C2	395.8	378.0	386.9	369.0	380.9
	C4	385.3	373.7	379.5	374.0	377.7
	C6	402.2	382.3	392.2	367.8	384.1
	C8	393.8	389.8	391.8	364.3	382.7
	C10	407.2	394.0	400.6	377.3	392.8
H 614C		386.3	367.3	376.8	359.2	370.9
H 622		361.8	347.8	354.8	353.0	354.2
Mean		389.3	376.1	382.7	366.5	377.5
L.S.D. 5%		19.4	15.4		16.3	12.8
L.S.D. 1%						17.1
C.V.		4.3	3.5		3.9	

Table 23. Combined analysis of variance table for plant height in maize.

Source	d.f.	ms	F
Replicates	10	759.18	3.82**
Locations	1	12936.33	65.06**
Genotypes	24	2432.08	12.23**
Between populations	4	9262.34	46.58**
Cycles within KS II (R)	5	815.15	4.10**
Linear	1	9.01	0.05
Quadratic	1	2283.02	11.48**
Reminder	3	594.57	2.99
Cycles within Ec 573 (R)	4	1258.15	6.33**
Linear	1	261.08	1.31
Quadratic	1	31.72	0.16
Remainder	2	2369.90	11.92**
Cycles within H611	5	1164.58	5.86**
Linear	1	536.00	2.70
Quadratic	1	3604.00	18.13**
Remainder	3	560.97	2.82
Cycles within KCA (E)	5	697.05	3.51*
Linear	1	280.03	1.41
Quadratic	1	2310.19	11.62**
Remainder	3	298.34	1.50
Within checks	1	2904.00	14.61**
Genotypes x Locations	24	198.83	1.01
Error	240	197.38	
Total	299	438.27	

* Significant at 5% level.

** Significant at 1% level.

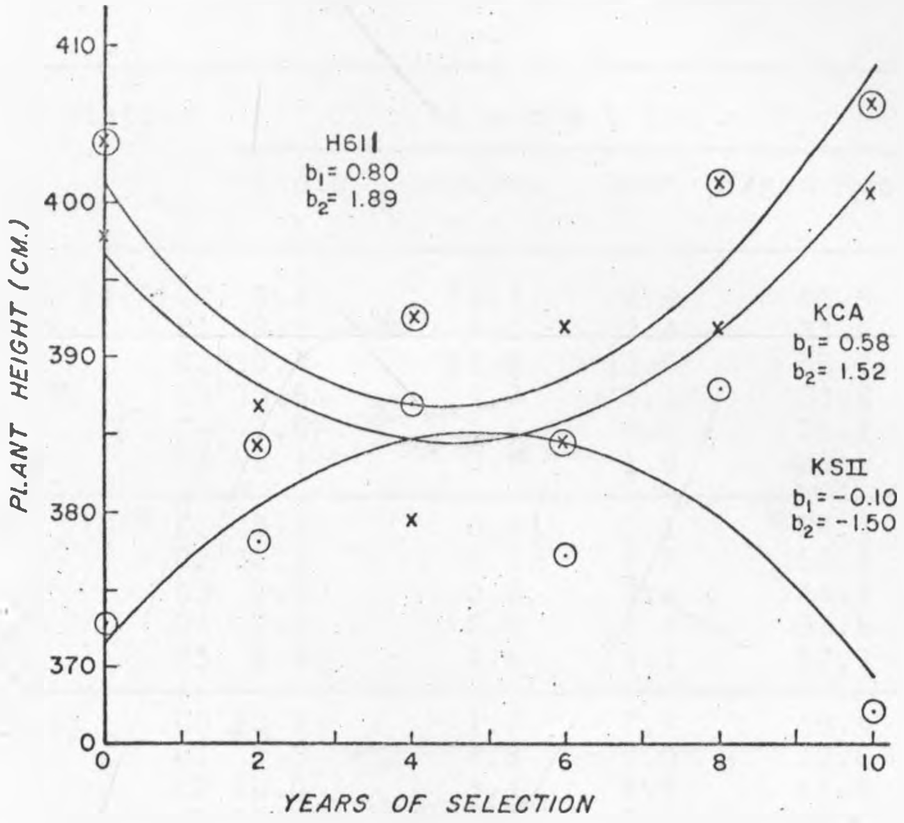

Figure 10. Response of plant height in KSII, H611 and KCA maize populations to recurrent selection.

Table 24. Mean root lodging per cent obtained in different maize populations.

Population	Location				
	Kitale	Sabwani	Mean	Elgon Rock	Combined Mean
K S II(R) C0	6.1	13.1	9.6	46.6	22.0
C1	7.8	7.0	7.4	31.9	15.6
C2	10.8	16.6	13.6	56.1	27.8
C3	13.6	4.7	9.1	31.6	16.6
C4	1.5	4.6	3.0	26.2	10.8
C5	3.1	0.8	1.9	23.2	9.0
Ec 573(R) C1	5.5	0.8	3.1	24.1	10.1
C2	12.3	4.1	8.2	53.0	23.1
C3	7.0	0.8	3.9	44.7	17.5
C4	2.3	0.0	1.1	33.5	11.9
C5	6.4	1.9	4.1	27.7	12.0
H611 C0	13.7	1.7	7.7	39.4	18.3
C1	9.3	4.6	7.0	19.6	11.2
C2	10.0	3.1	6.6	41.9	19.9
C3	13.2	1.6	7.3	22.0	12.2
C4	6.8	0.0	3.4	28.1	11.6
C5	0.7	0.8	0.8	31.0	10.8
KCA (E) C0	25.2	10.9	18.0	50.5	28.9
C2	13.6	3.0	8.3	40.3	19.0
C4	7.8	1.5	4.6	25.9	11.7
C6	12.2	0.8	6.5	32.0	15.0
C8	6.9	2.4	4.6	29.5	13.0
C10	9.6	0.0	4.8	24.2	11.3
H 614C	10.0	2.3	6.2	48.5	20.3
H 622	3.8	0.9	2.3	47.0	17.3
Mean	8.8	3.5	6.1	35.1	15.9
L.S.D. 5%	11.7	7.2		21.6	9.8
L.S.D. 1%					13.1
C.V.	11.34	17.73		53.3	

lodged plants. KS II C5 had significantly fewer root lodged plants than C0 at 5% level. There was no significant reduction in number of root lodging from C0 to C5 in Ec 573 and H611. KCA C10 had significantly fewer root lodged plants than C0 at 1% level.

In KS II, Ec 573 and H611, there was no significant response curve which could fit the decline in the number of root lodged plants. The decrease observed in in KCA had a linear trend which was significant at 1% level and a quadratic curve which was significant at 5% level (Table 25 and Figure 11).

4.13. Stalk lodging.

Mean stalk lodged plants percent of different populations and coefficients of variation are presented in Table 26. There was an improvement in KS II and Ec 573 by reducing the number of stalk lodged plants after reciprocal recurrent selection. This improvement was also observed in H611. On the contrary KCA showed a slight increase in the number of stalk lodged plants after modified ear-to-row selection. However, the reduction in the number of stalk lodged plants percent was not significant in KS II, Ec 573 and H611.

Table 25. Combined analysis of variance table for number of root lodged plants per cent in maize.

Source	d.f.			ms	F
Replicates	10			354.63	3.95**
Locations	1			2064.04	22.98**
Genotypes	24			180.91	2.01*
Between populations		4		175.52	1.95
Cycles within KSII (R)		5		229.96	2.56
Cycles within Ec573(R)		4		79.08	0.88
Cycles within H611		5		91.99	1.02
Cycles within KCA (E)		5		325.11	3.62*
Linear			1	972.44	10.83**
Quadratic			1	455.90	5.08*
Remainder			3	65.73	0.73
Within checks		1		88.17	0.98
Genotypes x locations	24			89.81	1.28
Error	240			70.15	
Total	299			96.80	

* Significant at 5% level.

** Significant at 1% level.

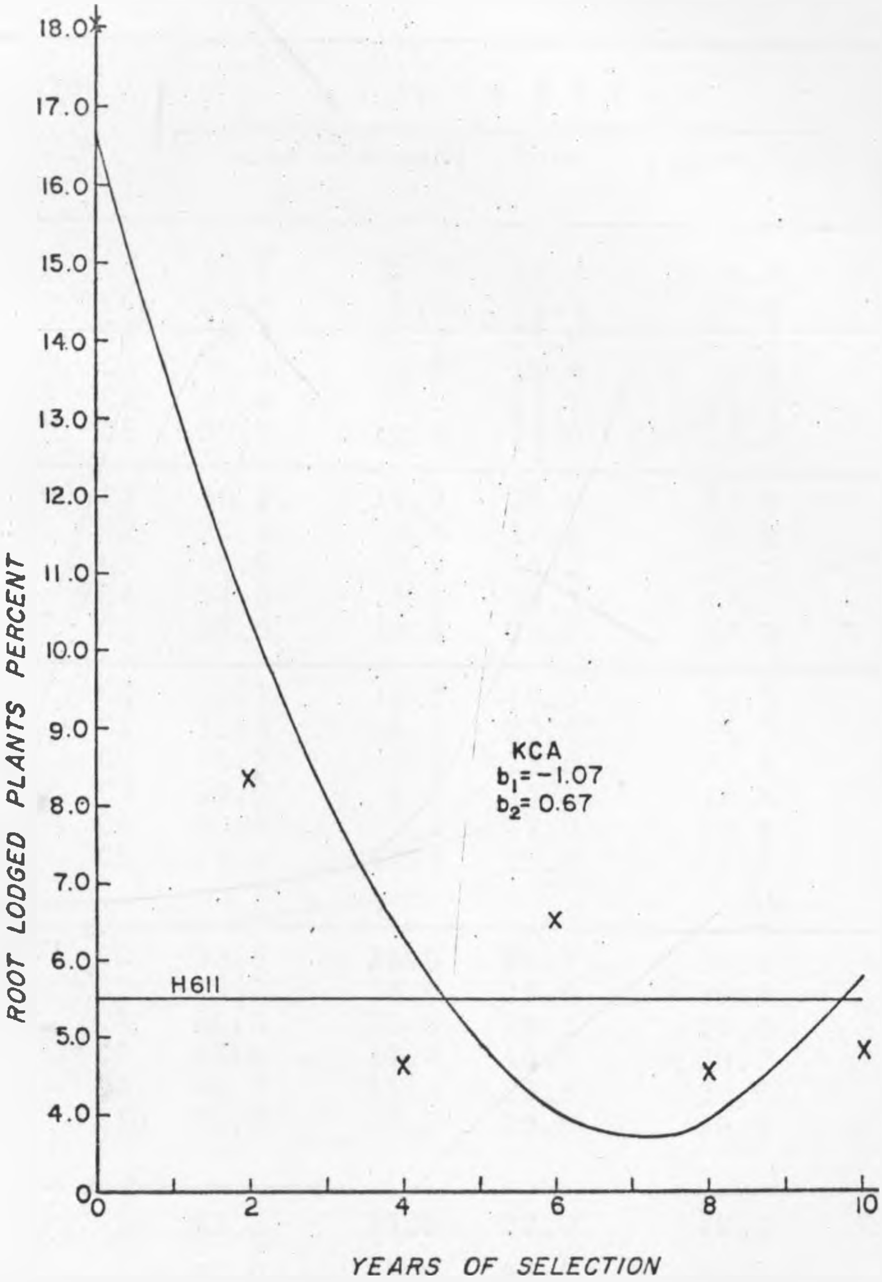

Figure 11. Response of root lodged plants per cent in H611 and KCA maize populations to recurrent selectio.

Table 26. Mean Stalk lodging percent in different maize populations.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined Mean
K S II(R)	C0	32.1	20.8	26.4	18.9	23.9
	C1	20.8	5.5	13.1	17.0	14.4
	C2	35.4	14.7	25.0	22.4	24.2
	C3	25.4	13.9	19.6	32.5	23.9
	C4	33.0	10.5	21.7	24.1	22.5
	C5	33.2	13.9	23.6	18.2	21.8
Ec 573(R)	C1	38.2	19.7	29.0	31.0	29.7
	C2	25.5	10.3	17.9	23.6	19.8
	C3	44.9	25.6	35.2	29.2	33.2
	C4	31.6	8.6	20.1	17.1	19.1
	C5	39.5	13.9	26.7	27.0	26.8
H611	C0	20.1	18.2	19.1	34.3	24.2
	C1	32.5	14.5	23.5	26.3	24.4
	C2	18.7	7.9	13.3	27.5	18.1
	C3	16.0	9.2	12.6	18.0	14.4
	C4	23.8	10.4	17.0	22.6	18.9
	C5	28.1	17.5	22.8	17.5	21.0
KCA (E)	C0	33.5	16.0	24.7	16.6	22.0
	C2	25.2	14.0	19.6	27.4	22.2
	C4	36.0	20.6	28.3	27.0	27.9
	C6	25.9	11.4	18.6	30.7	22.6
	C8	35.7	11.4	23.5	30.7	25.9
	C10	31.6	15.6	23.6	26.6	24.6
H 614C		32.3	11.8	22.0	19.3	21.1
H 622		87.0	45.0	66.0	27.0	53.0
Mean		32.2	15.2	23.7	24.5	24.0
L.S.D. 5%		13.4	12.0		13.4	11.8
L.S.D. 1%						15.8
C.V.		35.9	68.2		47.3	

Neither the decrease in number of stalk lodged plants percent observed in KSII, Ec 573 and H611 nor the increase observed in KCA fitted any response curve significantly (Table 27).

4.14. Number of bare tipped ears (%).

The mean number of bare tipped ears obtained in different selection cycles and coefficients of variation are presented in Table 28. There was reduction in number of bare tipped ears in KS II, Ec573 and H611 populations. The reduction of number of bare tipped ears in KS II from C0 to C5 was significant at 5% level, while it was not significant in Ec 573 and H611. On the contrary there was an increase in the number of bare tipped ears in KCA which was significant at 1% level.

The reduction in number of bare tipped ears in KS 11 did not fit any response curve. The reduction in Ec 573 had a linear trend which was significant at 5% level. The reduction in H611 fitted quadratic response curve which was significant at 5% level (Figure 12). The increase in number of bare tipped ears percent in KCA had a linear trend which was significant at 1% level (Table 29).

Table 27. Combined analysis of variance table for number of stalk lodged plants percent in maize.

Source	d.f.		ms	F
Replicates	10		305.57	1.76
Locations	1		21714.12	124.88**
Genotypes	24		1255.05	7.22**
Between populations	4		3195.09	18.38**
Cycles within KS II (R)	5		274.69	1.58
Cycles within Ec 573(R)	4		581.86	3.35*
Linear		1	7.06	0.04
Quadratic		1	6.76	0.04
Remainder		2	1156.82	6.65**
Cycles within H611	5		254.62	1.46
Cycles within KCA (E)	5		151.05	0.87
Within checks	1		11611.60	66.78**
Genotypes x locations	24		173.88	1.44
Error	240		120.81	
Total	299		294.52	

*Significant at 5% level.

**Significant at 1% level.

Table 28. Mean number of bare tipped ears % obtained in different population of maize.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined Mean
K S II(R)	C0	11.6	11.0	11.3	30.5	17.7
	C1	19.0	10.0	14.5	17.3	15.5
	C2	12.9	8.3	10.6	10.7	10.6
	C3	12.3	15.9	14.1	12.3	13.5
	C4	8.6	6.8	7.7	12.4	9.3
	C5	11.9	6.5	9.2	10.5	9.6
Ec 573(R)	C1	11.4	14.6	13.0	8.3	11.4
	C2	11.1	5.9	8.5	18.9	12.0
	C3	18.3	12.2	15.2	15.3	15.3
	C4	11.0	5.0	8.0	11.8	9.3
	C5	4.9	3.9	4.4	6.5	5.1
H611	C0	24.1	32.1	28.1	19.4	25.2
	C1	20.5	19.3	19.9	16.6	18.8
	C2	20.3	12.9	16.6	15.7	16.3
	C3	24.2	20.6	22.4	15.7	16.3
	C4	24.4	13.3	18.8	11.8	16.5
	C5	21.7	18.9	20.3	20.3	20.3
KCA (E)	C0	12.5	13.2	12.8	19.4	15.0
	C2	22.6	24.5	23.6	16.0	21.0
	C4	32.2	26.5	29.3	21.5	26.7
	C6	25.4	24.7	25.0	22.8	24.3
	C8	26.5	22.2	24.3	14.0	20.9
	C10	31.8	35.9	33.8	21.0	29.5
H 614C		17.5	8.4	12.9	18.3	14.7
H 622		23.8	20.3	22.0	24.0	22.7
Mean		18.4	15.7	17.0	16.6	16.9
L.S.D. 5%		10.5	9.7		12.7	7.6
L.S.D. 1%						10.1
C.V.		49.2	53.4		66.3	

Table 29. Combined analysis of variance table for bare tipped ears percentage in maize.

Source	d.f.			ms	F
Replicates	10			187.90	2.94*
Locations	1			548.37	8.57**
Genotypes	24			698.84	10.92**
Between populations		4		2762.40	43.17**
Cycles within KS II (R)		5		86.03	1.34
Cycles within Ec 573 (R)		4		222.54	3.48*
Linear			1	377.01	5.89*
Quadratic			1	10.05	0.16
Remainder			2	251.54	3.93*
Cycles within H611		5		186.76	2.92*
Linear			1	226.20	3.53
Quadratic			1	316.91	4.95*
Remainder			3	130.22	2.04
Cycles within KCA (E)		5		593.41	9.27**
Linear			1	1823.99	28.50**
Quadratic			1	147.81	2.31
Remainder			3	331.75	5.18**
Within checks		1		501.42	7.84**
Genotypes x locations	24			64.00	0.84
Error	240			76.23	
Total	299			130.54	

* Significant at 5% level.

**Significant at 1% level.

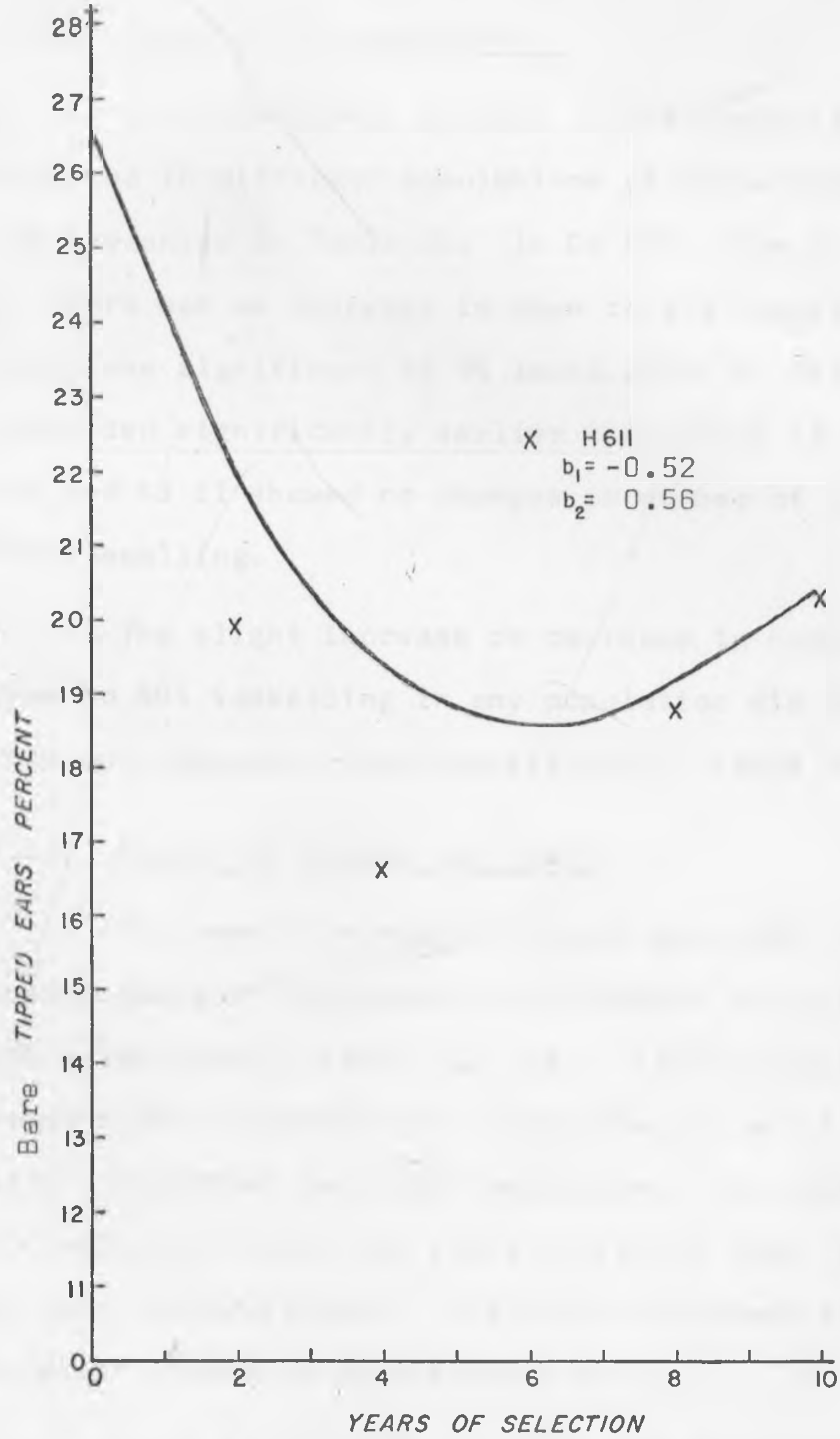

Figure 12. Response of bare tipped ears per cent in H611 maize population to recurrent selection.

4.15. Days to 50% tasselling.

The mean number of days to 50% tasselling obtained in different populations at three locations are presented in Table 30. In Ec 573, from C1 to C5 there was an increase in days to 50% tasselling which was significant at 5% level, while in H611 C5 tasselled significantly earlier than C0 at 1% level. KCA and KS II showed no changes in number of days to 50% tasselling.

The slight increase or decrease in number of days to 50% tasselling in any population did not fit into any response curve significantly (Table 31).

4.16. Number of leaves per plant.

The mean of number of leaves per plant and coefficients of variation for different populations are summarised in Table 32. KS II C5 had significantl fewer number of leaves per plant than C0 at 5% level after reciprocal recurrent selection. The decrease of number of leaves per plant in Ec 573 from C1 to C5 was not significant. H611 and KCA showed almost constant number of leaves per plant.

In KS II, Ec 573, H611 and KCA there was no significant response curve which could fit the decrease or increase in number of leaves per plant (Table 33).

Table 30. Average number of days from planting to 50% tasselling for different population in maize.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined Mean
K S II(R)	C0	106.0	115.0	110.5	118.3	113.1
	C1	105.2	115.5	110.3	119.0	113.2
	C2	105.8	116.0	110.9	119.0	113.6
	C3	108.7	114.5	111.6	120.3	114.5
	C4	105.3	115.5	110.4	117.5	112.8
	C5	106.3	115.5	110.9	118.3	113.4
Ec 573(R)	C1	108.5	113.3	110.9	119.0	113.6
	C2	112.0	116.5	114.2	122.8	117.1
	C3	110.2	114.2	112.2	121.2	115.2
	C4	108.2	115.3	112.1	122.8	115.7
	C5	110.0	116.8	113.4	120.3	115.7
H611	C0	107.5	112.3	109.9	121.0	113.6
	C1	105.7	113.0	109.3	119.8	112.8
	C2	105.3	112.0	108.7	118.0	111.8
	C3	103.5	111.2	107.3	114.5	109.7
	C4	105.5	112.2	108.8	116.7	111.4
	C5	103.8	113.0	108.4	115.8	110.9
KCA (E)	C0	106.5	114.7	110.6	119.7	113.6
	C2	105.2	112.5	108.8	118.2	111.9
	C4	105.2	110.2	107.7	118.0	111.1
	C6	105.2	112.5	108.8	118.3	112.0
	C8	105.0	113.5	109.2	117.5	112.0
	C10	106.0	113.3	109.7	118.5	112.6
H 614C		100.8	109.8	105.3	113.5	108.1
H 622		101.7	109.3	105.5	112.7	107.9
Mean		106.1	113.5	109.8	118.4	112.7
L.S.D. 5%		2.2	2.3		2.5	1.9
L.S.D. 1%						2.5
C.V.		1.8	1.8		1.8	

Table 31. Combined analysis of variance table for days to 50% tasselling in maize.

Source	d.f.	ms	F
Replicates	10	24.55	2.43*
Locations	1	4062.72	402.65**
Genotypes	24	54.00	5.35**
Between populations	4	274.97	27.25**
Cycles within KS II(R)	5	2.62	0.26
Cycles within Ec 573 (R)	4	20.02	1.96
Cycles within H611	5	9.20	0.91
Cycles within KCA (E)	5	11.36	1.12
Within checks	1	0.17	0.02
Genotypes x locations	24	10.09	2.63*
Error	240	3.84	
Total	299	22.63	

* Significant at 5% level.

** Significant at 1% level.

Table 32. Average number of leaves per plant in different population of maize.

Population		L o c a t i o n				
		Kitale	Sabwani	Mean	Elgon Rock	Combined Mean
K S II(R)	C0	17.5	16.3	16.9	17.0	16.9
	C1	17.0	16.5	16.7	17.3	16.9
	C2	17.2	16.3	16.7	16.7	16.7
	C3	16.7	16.3	16.5	16.3	16.4
	C4	16.5	16.3	16.4	17.0	16.6
	C5	16.3	15.5	15.9	16.8	16.2
Ec 573(R)	C1	17.0	16.0	16.5	17.0	16.7
	C2	17.5	17.0	17.2	17.0	17.2
	C3	17.2	15.3	16.2	17.0	16.5
	C4	17.5	16.2	16.8	16.8	16.8
	C5	17.0	16.0	16.5	16.5	16.5
H611	C0	17.3	16.8	17.1	17.3	17.2
	C1	16.5	16.0	16.2	17.0	16.5
	C2	17.3	17.0	17.2	17.0	17.1
	C3	16.5	16.7	16.6	17.3	16.8
	C4	17.2	16.5	16.8	17.3	17.0
	C5	17.5	16.8	17.2	17.7	17.3
KCA (E)	C0	17.3	16.5	16.9	17.3	17.1
	C2	17.3	16.5	16.9	17.2	17.0
	C4	16.7	15.8	16.2	16.8	16.4
	C6	17.0	16.0	16.5	17.2	16.7
	C8	17.0	16.3	16.7	17.2	16.8
	C10	17.2	16.7	16.9	17.3	17.1
H 614C		16.3	16.8	16.6	17.2	16.8
H 622		15.3	15.3	15.3	16.2	15.6
Mean		16.9	16.3	16.6	17.0	16.8
L.S.D. 5%		0.8	0.9		0.6	0.5
L.S.D. 1%						0.7
C.V.		4.3	4.9		2.8	

able 33. Combined analysis of variance table for number of leaves per plant in maize.

ource	d.f.	ms	F
eplicates	10	2.05	2.91*
ocations	1	31.36	44.56**
enotypes	24	2.17	3.09*
Between populations	4	3.79	5.39**
Cycles within KS II (R)	5	1.52	2.17
Cycles within Ec573 (R)	4	1.79	2.54
Cycles within H611	5	1.65	2.34
Cycles within KCA (E)	5	0.92	1.31
Within checks	1	9.37	13.32*
enotypes x locations	24	0.70	1.20
rror	240	0.59	
otal	299	0.88	

* Significant at 5% level.

** Significant at 1% level.

4.17. Diseased ears percent.

The mean values of diseased ears percent and coefficients of variation are presented in Table 34. There was slight improvement through selection in the decreased number of ears in KS II, Ec 573 and KCA, while in H611 there was a slight increase.

There was no significant response curve which could fit the decline or increase in number of diseased ears percent in any population (Table 35).

4.18. Blight score.

The average blight scores obtained from three locations and coefficients of variation are shown in Table 36. All populations except Ec 573 were uniform in resistance to this disease. Ec 573 was more infected by the blight than the other populations. Further analysis was done using orthogonal polynomials but the results did not give additional information.

4.19. Rust score.

The average rust scores obtained from three locations and combined means are presented in Table 37. KS II, Ec 573, H611 and KCA showed almost uniform resistance to average rust score.

Table 34. Mean number of diseased ears percent obtained in different populations of maize.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined Mean
K S II(R)	C0	3.9	9.9	6.9	0.8	4.9
	C1	11.5	6.2	8.9	8.0	8.6
	C2	11.5	5.6	8.7	1.6	6.3
	C3	8.6	3.3	5.9	10.8	7.6
	C4	6.9	2.4	4.6	6.5	5.3
	C5	10.4	3.3	6.8	4.3	6.0
Ec 573(R)	C1	3.3	2.4	2.8	1.9	2.5
	C2	3.9	4.0	4.0	1.8	3.2
	C3	4.6	2.3	3.5	1.7	2.9
	C4	2.3	0.8	1.5	0.9	1.3
	C5	1.6	0.8	1.2	0.8	1.1
H611	C0	0.8	2.4	1.6	0.8	1.3
	C1	1.6	0.8	1.1	0.8	1.0
	C2	4.7	1.6	3.1	0.9	2.4
	C3	2.3	0.0	1.1	0.8	1.0
	C4	2.3	0.8	1.5	0.9	2.4
	C5	3.8	3.1	3.4	1.8	2.9
KCA (E)	C0	7.0	4.7	5.8	2.8	4.8
	C2	3.0	3.1	3.1	1.6	2.6
	C4	2.3	3.8	3.0	0.8	2.3
	C6	3.9	2.5	3.2	0.8	2.4
	C8	3.9	1.5	2.7	3.3	2.9
	C10	3.4	1.7	2.6	3.1	2.7
H 614C		4.7	0.8	2.7	1.6	2.3
H 622		10.7	1.7	6.2	6.6	6.3
Mean		4.9	2.8	3.8	2.6	3.4
L.S.D. 5%		5.4	4.8		5.7	3.3
L.S.D. 1%						4.4
C.V.		96.1	150.5		187.8	

Table 35. Combined analysis of variance table for number of diseased ears percent in maize.

Source	d.f.	ms	F
Replicates	10	39.24	1.39
Locations	1	338.14	11.94**
Genotypes	24	63.22	2.23*
Between populations	4	266.89	9.42**
Cycles within KSII (R)	5	31.15	1.10
Cycles within Ec 573 (R)	4	17.62	0.62
Cycles within H611	5	12.31	0.43
Cycles within KCA (E)	5	17.93	0.63
Within checks	1	72.45	2.56
Genotypes x locations	24	28.32	1.42
Error	240	19.93	
Total	299	25.79	

* Significant at 5% level.

** Significant at 1% level.

Table 36. Average blight scores obtained at three locations in maize populations.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined Mean
K S II(R)	C0	1.0	1.0	1.0	1.0	1.0
	C1	1.0	1.0	1.0	1.0	1.0
	C2	1.0	1.3	1.2	1.0	1.1
	C3	1.0	1.2	1.1	1.0	1.0
	C4	1.0	1.1	1.0	1.0	1.0
	C5	1.0	1.2	1.1	1.0	1.0
Ec 573(R)	C1	1.1	1.1	1.1	1.0	1.1
	C2	1.1	1.0	1.0	1.0	1.0
	C3	1.3	1.3	1.3	1.0	1.2
	C4	1.1	1.0	1.0	1.1	1.1
	C5	1.1	1.1	1.1	1.0	1.1
H611	C0	1.0	1.0	1.0	1.0	1.0
	C1	1.0	1.0	1.0	1.0	1.0
	C2	1.0	1.0	1.0	1.0	1.0
	C3	1.0	1.0	1.0	1.0	1.0
	C4	1.0	1.1	1.0	1.0	1.0
	C5	1.0	1.0	1.0	1.0	1.0
KCA (E)	C0	1.0	1.0	1.0	1.0	1.0
	C2	1.0	1.2	1.1	1.0	1.0
	C4	1.0	1.0	1.0	1.0	1.0
	C6	1.0	1.1	1.0	1.0	1.0
	C8	1.0	1.0	1.0	1.0	1.0
	C10	1.0	1.0	1.0	1.0	1.0
H 614C		1.0	1.0	1.0	1.0	1.0
H 622		1.0	1.0	1.1	1.0	1.0
Mean		1.0	1.0	1.0	1.0	1.0

Table 37. Average rust scores obtained at three locations in maize populations.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined Mean
K S II(R)	C0	1.3	1.3	1.3	1.0	1.2
	C1	1.6	1.3	1.4	1.2	1.3
	C2	1.4	1.8	1.6	1.3	1.5
	C3	1.5	1.7	1.5	1.3	1.5
	C4	1.7	1.5	1.7	1.3	1.5
	C5	1.4	1.8	1.5	1.3	1.5
Ec 573(R)	C1	1.4	1.0	1.2	1.3	1.2
	C2	1.2	1.0	1.1	1.1	1.1
	C3	1.0	1.0	1.0	1.0	1.0
	C4	1.1	1.0	1.0	1.0	1.0
	C5	1.2	1.0	1.1	1.1	1.1
H611	C0	1.3	1.0	1.1	1.0	1.1
	C1	1.2	1.0	1.1	1.1	1.1
	C2	1.1	1.0	1.0	1.0	1.1
	C3	1.3	1.1	1.2	1.3	1.3
	C4	1.3	1.3	1.2	1.1	1.2
	C5	1.0	1.0	1.0	1.1	1.0
KCA (E)	C0	1.2	1.1	1.1	1.0	1.1
	C2	1.3	1.3	1.3	1.2	1.3
	C4	1.2	1.3	1.2	1.1	1.2
	C6	1.3	1.4	1.2	1.1	1.3
	C8	1.3	1.2	1.1	1.1	1.2
	C10	1.2	1.1	1.1	1.1	1.1
H 614C		1.1	1.3	1.1	1.0	1.1
H 622		1.6	1.6	1.5	1.3	1.5
Mean		1.3	1.2	1.2	1.1	1.2
L.S.D. 5%		0.3	0.3		0.2	0.2
L.S.D. 1%						0.3
C.V.		21.4	21.9		17.4	

There was no significant curve which could fit the average rust scores in KS II, Ec 573, H611 and KCA (Table 38).

4.20. Shelling percent.

The mean values of shelling percent for different populations and coefficients of variation are shown in Table 39. No noticable change was observed in shelling percentage in KS II, Ec 573 and H611. The improvement in shelling percentage in KCA from C0 to C10 was significant at 5% level.

The slight decline in shelling percentage in KS II, Ec 573 and H611 as well as increase in KCA did not fit any response curve (Table 40).

4.21. Total biological yield.

The mean values for total biological yield in different population at three locations, combined means and coefficients of variation are summarised in Table 41. There was a decline in the total biological yield in KS II and Ec 573 after five cycles of reciprocal recurrent selection. In KS II C5 the decrease was significant at 5% level compared to C0 while Ec 573 C5 was not significantly different in total biological yield from C1. The total biological

Table 38. Combined analysis of variance table for average rust scores in maize.

Source	d.f.	ms	F
Replicates	10	0.34	2.17
Locations	1	0.70	4.38*
Genotypes	24	0.50	3.10**
Between populations	4	2.14	13.38**
Cycles within KSII (R)	5	0.29	1.81
Cycles within EC 573 (R)	4	0.05	0.31
Cycles within H611	5	0.09	0.56
Cycles within KCA (E)	5	0.08	0.50
Within checks	1	0.84	5.25*
Genotypes x locations	24	0.16	1.49
Error	240	0.11	
Total	299	0.15	

* Significant at 5% level.

** Significant at 1% level.

Table 39. Mean shelling percent values obtained at three locations in maize populations.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined mean
K S II(R)	C0	77.0	81.6	79.4	82.7	80.4
	C1	79.7	80.6	80.2	81.5	80.6
	C2	79.0	80.6	79.8	82.6	80.7
	C3	76.9	76.7	76.8	81.6	78.4
	C4	79.2	81.3	80.2	84.7	81.7
	C5	79.5	79.0	79.3	80.8	79.8
Ec.573(R)	C1	80.9	84.2	82.6	84.5	83.2
	C2	83.6	83.3	83.4	83.8	83.6
	C3	83.2	85.7	84.5	85.3	84.7
	C4	82.5	84.0	83.3	81.3	82.6
	C5	82.9	84.1	83.5	84.2	83.7
H611	C0	82.6	82.8	82.7	85.7	83.7
	C1	82.0	83.0	82.5	84.7	83.2
	C2	82.3	83.4	82.9	84.6	83.4
	C3	81.7	82.6	82.2	84.3	82.9
	C4	84.1	83.4	83.7	85.5	84.3
	C5	82.7	81.2	82.0	83.5	82.5
KCA (E)	C0	79.9	82.5	81.2	83.4	81.9
	C2	82.8	83.1	82.5	85.0	83.6
	C4	82.8	83.1	82.9	85.0	83.6
	C6	83.0	83.5	83.2	83.2	83.2
	C8	81.9	80.4	81.2	82.6	81.6
	C10	81.8	84.5	83.1	86.2	84.2
H 614C		84.1	83.0	83.5	83.3	83.5
H 622		81.0	83.6	82.3	83.7	82.8
Mean		81.5	82.4	81.9	83.8	82.5
L.S.D. 5%		3.2	2.8		3.5	1.9
L.S.D. 1%						2.5
C.V.		3.4	2.9		3.7	

Table 40. Combined analysis of variance table for shelling percentage in maize.

Source	d.f.	ms	F
Replicates	10	12.63	1.72
Locations	1	63.30	8.62**
Genotypes	24	38.49	5.24**
Between populations	4	179.39	24.42**
Cycles within KSII (R)	5	19.46	2.65*
Linear	1	1.88	0.26
Quadratic	1	5.55	0.75
Remainder	3	29.96	4.08*
Cycles within Ec573 (R)	4	5.63	0.77
Cycles within H611	5	4.63	0.63
Cycles within KCA (E)	5	10.81	1.47
Within checks	1	9.25	1.26
Genotypes x locations	24	7.34	1.09
Error	240	6.76	
Total	299	9.74	

* Significant at 5% level.

** Significant at 1% level.

Table 41. Mean values in kg/plot of total biological yield obtained at three locations in maize populations.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined Mean
K S II(R)	C0	7.9	8.4	8.2	3.5	6.6
	C1	7.2	7.7	7.5	3.8	6.2
	C2	6.4	7.6	7.0	3.5	5.8
	C3	6.2	7.2	6.7	3.8	5.7
	C4	6.9	8.2	7.5	4.5	6.5
	C5	6.3	6.6	6.5	3.6	5.5
Ec 573(R)	C1	6.2	7.4	6.8	4.7	6.1
	C2	7.4	7.0	7.2	3.9	6.1
	C3	5.3	6.6	6.0	5.4	5.8
	C4	6.4	7.3	6.9	3.7	5.8
	C5	6.5	6.4	6.4	4.9	5.9
H611	C0	9.5	9.8	9.7	6.1	8.5
	C1	8.1	9.1	8.6	6.1	7.8
	C2	8.6	10.5	9.5	4.6	7.9
	C3	8.1	9.5	8.8	6.0	7.9
	C4	8.8	10.7	9.8	7.1	8.9
	C5	9.8	10.4	10.1	7.1	9.1
KCA (E)	C0	6.6	7.2	6.9	3.1	5.6
	C2	7.7	8.2	8.0	4.3	6.7
	C4	7.4	9.1	8.3	5.4	7.3
	C6	7.1	9.2	8.2	4.6	7.0
	C8	8.0	9.1	8.5	6.5	7.8
	C10	7.2	9.2	8.2	5.8	7.4
H 614C		8.1	9.1	8.6	6.0	7.7
H 622		6.2	6.6	6.5	3.4	5.4
Mean		7.4	8.3	7.8	4.9	6.8
L.S.D. 5%		1.1	1.4		1.2	1.0
L.S.D. 1%						1.3
C.V.		13.0	14.6		20.7	

yield in KCA increased after 10 cycles of modified ear-to-row selection: H611 did not show significant increase in total biological yield. KCA showed an increase in total biological yield from C0 to C10 which was significant at 1% level.

The decline in total biological yield in KS II had a linear trend which was significant at 1% level, while in Ec 573 it did not fit any response curve. The increase in total biological yield in H611 fitted a quadratic curve at 5% significant level. The increase in total biological yield observed in KCA had a linear trend which was significant at 1% level and a quadratic curve at 5% level (Table 42 and Figure 13).

4.22. Harvest index. The mean crop index percent values in different populations at three locations and coefficients of variation are summarised in Table 43. KS II and Ec 573 showed an increase in harvest index though it was not significant. The increase of crop index observed in H611 from C0 to C5 was significant at 5% level. KCA showed a significant increase in harvest index from C0 to C10 at 1% level.

Table 42. Combined analysis of variance table for total biological yield (kg/plot) in maize.

Source	d.f.	ms	F
Replicates	10	5.90	4.66**
Locations	1	7.11	56.63**
Genotypes	24	16.39	13.05**
Between populations	4	73.37	58.40**
Cycles within KSII (R)	5	4.60	3.66*
Linear	1	12.75	10.15**
Quadratic	1	1.57	1.25
Remainder	3	2.90	2.31
Cycles within Ec573 (R)	4	2.72	2.17
Cycles within H611	5	3.83	3.05*
Linear	1	3.78	3.01
Quadratic	1	6.83	5.44*
Remainder	3	2.86	2.28
Cycles within KCA (E)	5	3.81	3.03*
Linear	1	10.42	8.29**
Quadratic	1	6.76	5.38*
Remainder	3	0.63	0.50
Within checks	1	27.73	22.07**
Genotypes x locations	24	1.26	1.05
Error	240	1.20	
Total	299	2.81	

* Significant at 5% level.
** Significant at 1% level.

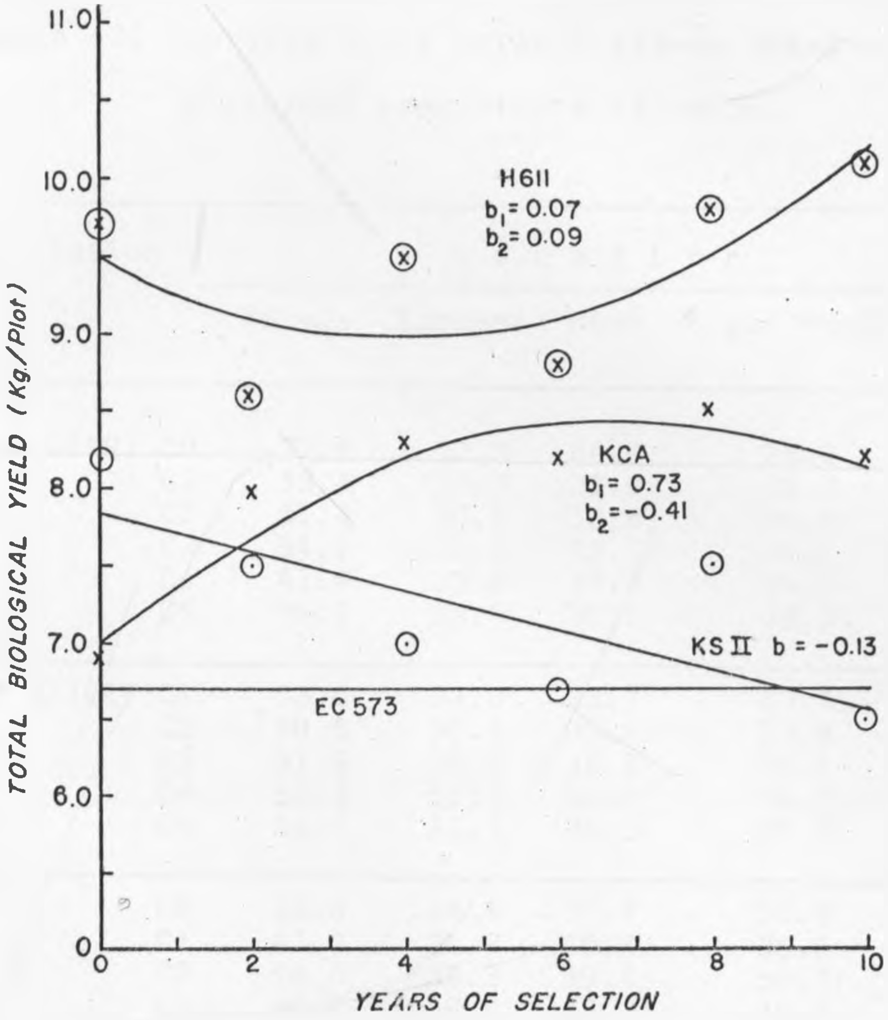

Figure 13. Response of total biological yield in KSII, Ec573, H611 and KCA maize populations to recurrent selection.

Table 43. Harvest index percent values obtained in different populations of maize.

Population		Location				
		Kitale	Sabwani	Mean	Elgon Rock	Combined mean
K S II(R)	C0	37.5	32.3	34.9	28.2	32.7
	C1	33.4	32.3	32.9	29.7	31.8
	C2	35.4	30.1	32.8	35.8	33.8
	C3	34.7	32.7	33.7	29.9	32.4
	C4	41.4	33.0	37.2	36.5	37.0
	C5	36.5	33.8	35.2	38.3	36.2
Ec 573(R)	C1	33.5	34.0	33.7	33.3	33.6
	C2	30.5	30.5	30.4	23.9	28.2
	C3	37.9	39.9	38.9	32.6	36.8
	C4	33.8	31.3	32.5	32.0	32.4
	C5	38.9	33.7	36.3	35.5	36.0
H611	C0	36.6	34.8	35.7	31.9	34.4
	C1	41.0	39.7	40.4	36.6	39.1
	C2	40.6	38.2	39.4	38.7	39.2
	C3	46.6	39.9	43.3	45.9	44.1
	C4	43.6	39.4	41.5	46.6	43.2
	C5	39.7	38.5	39.1	48.7	42.3
KCA (E)	C0	25.9	30.2	28.0	22.4	26.2
	C2	38.8	35.9	37.4	33.5	36.1
	C4	37.4	35.8	36.6	42.9	38.7
	C6	39.4	34.8	37.1	33.1	35.8
	C8	37.0	35.3	36.2	36.6	36.3
	C10	39.1	38.4	38.8	37.5	38.3
H 614C		43.9	42.8	43.4	43.2	43.3
H 622		41.8	44.3	43.0	40.8	42.3
Mean		37.8	35.7	36.7	35.8	36.4
L.S.D. 5%		4.9	5.1		9.3	6.5
L.S.D. 1%						8.7
C.V.		11.4	12.4		22.8	

The increases observed in KS II and Ec 573 did not fit any response curve. The increase observed in H611 fitted a quadratic response curve at 1% significant level (Figure 14). The increase observed in KCA had a linear trend which was significant at 1% level as well as a quadratic response curve at 5% significant level (Table 44).

Table 44. Combined analysis of variance table for for harvest index in maize.

Source	d.f.	ms	F
Replicates	10	36.76	1.49
Locations	1	332.22	13.45**
Genotypes	24	187.36	7.59**
Between populations	4	628.07	25.43**
Cycles within KSII (R)	5	34.83	1.41
Cycles within Ec573 (R)	4	132.10	5.35**
Linear	1	63.51	2.57
Quadratic	1	0.41	0.02
Remainder	2	232.23	9.40**
Cycles within H611	5	78.63	3.18*
Linear	1	101.92	4.13
Quadratic	1	212.02	8.59**
Remainder	3	26.40	1.07
Cycles within KCA (E)	5	177.58	7.19**
Linear	1	438.77	17.77**
Quadratic	1	169.13	6.85*
Remainder	3	93.33	3.78*
Within checks	1	0.84	0.03
Genotypes x locations	24	24.69	1.29
Error	240	19.16	
Total	299	34.74	

* Significant at 5% level.

** Significant at 1% level.

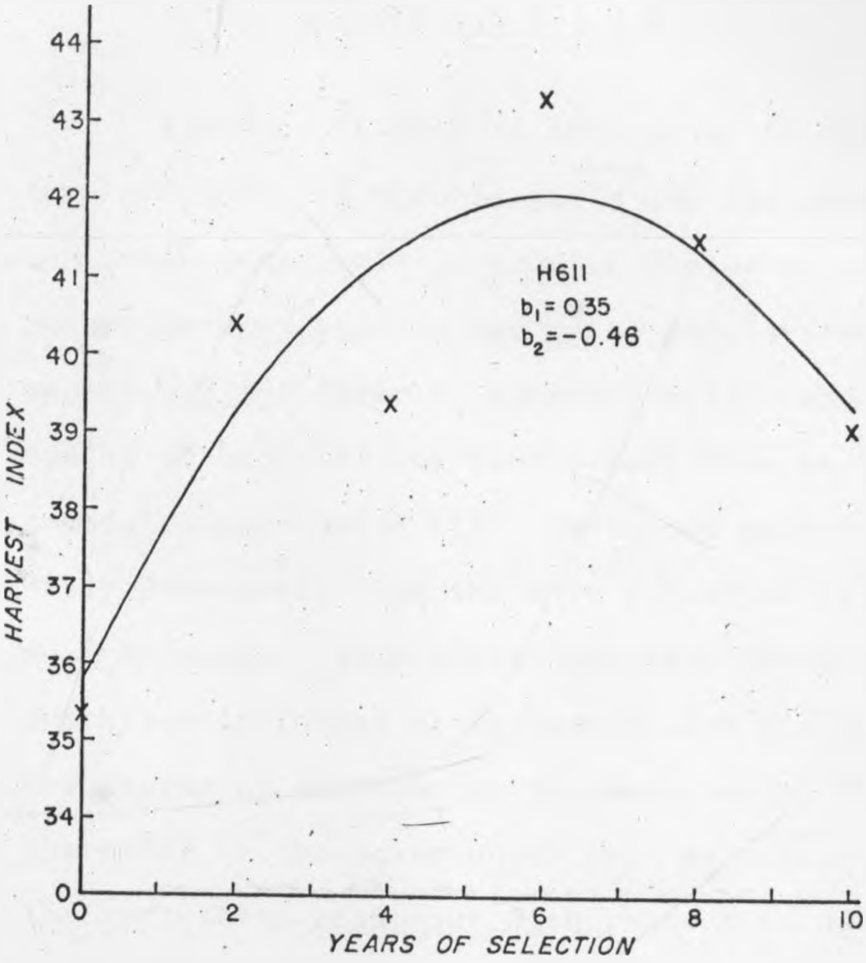

Figure 14. Response of harvest index in H611 maize population to recurrent selection.

CHAPTER V

DISCUSSION

Attempt was made in this study to understand the correlated changes in yield and its components and other characters after five cycles of reciprocal recurrent selection in two maize populations, KSII and Ec.573 and their F_1 hybrids, H611; and ten cycles of modified ear-to-row selection in the composite population KCA (advanced generation of H611). Grain yield was the only selection criteria in both cases. Some characters were found associated and hence increased or decreased with yield. However, the degree of increase or decrease varied from character to character under both selection procedures. The correlated responses with respect to each character are discussed below.

Grain yield and its components

5.1. Grain yield.

After 10 years of reciprocal recurrent selection in parental populations KSII and Ec.573, there was a similar yield improvement in their hybrid H611 (C5) as that of modified ear-to-row selection in KCA

(C10). H611 (C5) significantly outyielded the current commercial check H614C while the yield of KCA (C10) was significantly below that of H614C. H611 (C5) outyielded highly significantly KCA (C10) at 1% level (Table 1). H611 (C0) outyielded KCA (C0) by 62% and after improvement H611 (C5) outyielded KCA (C10) by 30% in grain yield.

After ten cycles of modified ear-to-row selection, KCA (C10) attained grain yield levels of 66.3 q/ha which were equivalent to the starting point in H611 (C0) with grain yield level of 67.7 q/ha.

The parental populations KSII and Ec 573 are of diverse genetic stock which when crossed expressed substantial amount of heterosis in their Hybrids, H611; particularly for grain yield. Such increase was not witnessed in composite populations KCA. This suggests that the advantage of heterosis could not be exploited in composite populations even after 10 cycles of modified ear-to-row selection. KSII showed inbreeding depression while increasing the frequency of favourable alleles as indicated by negative quadratic response curve.

H611 showed an increase of 5.41% (2.07 q/ha) per cycle of selection. Such increases in heterosis by reciprocal recurrent selection were also reported by other workers. Darrah et al. (1978) reported significant gain in yield using reciprocal recurrent selection in Ec 573 (0.97 q/ha) and H611 (2.09 q/ha) per cycle. The rate of gain in the H611 was 7% per cycle. The higher gain per cycle of 7% reported by Darrah et al. (1978) seems to be inflated on the higher side as compared to 5.41% in the present study because they evaluated the populations in different seasons. Penny and Eberhart (1971) found a gain of 1.7% per cycle in the variety cross of BSSS X BSCB1. A 3.5% per cycle gain from reciprocal recurrent selection was reported by Moll and Stuber (1971) in the variety cross of "Jarvis" x "Indian Chief." Evaluation of reciprocal recurrent selection in BSSS and BSCB1 by Eberhart et al. (1973) showed the variety cross gain to be 4.6% per cycle. The heterosis increased from 15% in the C0 x C0 to 37% for BSSS (R) C5 x BSCB1 (R) C5.

The improvement by reciprocal recurrent selection in the population hybrids without much improvement in the parental populations is consistent with expectations from changing gene frequencies at loci involving over-dorminant (or pseudo -over-dominant) gene action. Moll and Stuber (1971) stated that reciprocal recurrent selection is designed to capitalise upon gene combinations that enhance hybrid performance, such as many loci showing complete dominance and over-dominance and certain kinds of epistasis. This is evident from the present study in which heterosis increased from 37% in the H611 (C0) to 81% for H611 (C5) above the mid-parent. Reciprocal recurrent selection was effective in increasing the frequency of favourable alleles and complementary gene frequencies which were responsible for high yields in crosses of KSII and Ec 573 as showed by the highly significant linear response in H611 (Table 3). Comstock et al. (1949) pointed out that, the greater the difference in the initial gene frequencies for such loci, the faster the progress from reciprocal recurrent selection. The F_1 hybrids between two populations KSII and Ec 573 was highly heterotic indicating the differences in their gene frequencies.

Heterosis is a function of dominance effects and the square of the differences in gene frequencies (Falconer, 1960). Douglas et al. (1961) reported that reciprocal recurrent selection was proposed by Comstock, Robinson and Harvey (1949) and is designed to place selection pressure on both specific and general combining abilities. It is theoretically effective regardless of the type of gene action that is involved in conditioning hybrid vigour, but is most effective for those loci showing complete or partial dominance.

The improved parental populations KSII and Ec 573, should therefore be good sources of inbred lines for future production of commercial hybrids.

KCA showed a significant gain in yield 5.38% (2.03 q/ha) per cycle of modified ear-to-row selection. KCA (CO) gave very low yields due to poor stand count whereby inflating the per cent gain per cycle. Darrah *et al*. (1978) reported gain in yield of 2.6% per cycle (1.22 q/ha per cycle per year^{-1}). Modified ear-to-row in "Nebraska Hays Golden" by Compton and Bahadur (1977) showed a gain in yield of 5.3% per cycle.

Modified ear-to-row selection was effective in accumulating desirable additive gene effects as indicated by the highly significant linear response in KCA (Table 3). Modified ear-to-row selection was suggested by Lonnquist (1964) and it utilises additive genetic effects. Lonnquist and Webel (1967) suggested that it is useful in intra-population improvement prior to the extraction of inbred lines for development of hybrids. Yield levels of the F_1

hybrids derived from improved KSII and Ec 573 could have been different if modified ear-to-row selection was applied in both populations separately before obtaining the F_1 hybrids. Modified ear-to-row selection in KCA in the present study did not result in comparable high yield as compared to H611. This may be due to the:

(i) exploitation of additive genetic effects

(ii) inbreeding depression, which would mask selection response, and

(iii) natural selection in opposition to selection for higher yield (Moll and Stuber, 1971).

Darrah et al. (1978) pointed out that although three seasons of random mating were completed in KCA before selection, linkage equilibrium probably was not achieved or even approached. They hypothesized that intense selection with inadequate recombination between cycles may tend to maintain large linkage blocks and hinder progress from selection. This problem may be more severe in the advanced generation of variety cross between diverse varieties, but it may be important in other populations also. Favourable effects of irradiation on selection for increased yield have been reported by Gardner (1961 and 1968). Selection in irradiated populations could be of significant importance in the future breeding programmes most probably because of increased variability and recombinations.

5.2. Number of usable ears per 100 plants.

Apparently, there were no substantial increases in the number of usable ears per 100 plants in the parental populations, KSII and Ec 573 after five cycles of reciprocal recurrent selection. However, their F_1 hybrid H611 showed heterosis by significantly increasing the number of ears per 100 plants. KCA showed a highly significant increase in the number of ears per 100 plants which showed a highly significant linear response after ten cycles of modified ear-to-row selection. Thus, it appears that reciprocal recurrent selection in H611 exploited non-additive gene effects while modified ear-to-row selection in KCA utilized the additive gene effects. However, H611 (C0) outyielded KCA (C0) by 36% while after improvement H611 (C5) outyielded KCA (C10) by 11% in the number of ears per 100 plants. Therefore, it seems that much of the gains in grain yield improvement in H611 and KCA was a consequence of increased number of ears per 100 plants. Similar conclusions were made by other authors. Darrah *et al*. (1978) reported that reciprocal recurrent selection in Ec 573 showed a significant gain in ears per 100 plants. Yield gains in H611 were associated with significant increases in ears per 100 plants. Gardner (1968) reported rapid progress in yield improvement by selecting for prolificacy. Compton and Bahadur (1977) reported that modified ear-to-row selection resulted in significant increase in number of ears per 100 plants in "Hays Golden." Moll and Robinson (1966) reported that it is not particularly surprising that number of ears per plant show a rather consistent response associated with selection for high yield since it is a component of yield. Lonnquist and Webel (1967) while selecting for number of ears per plant reported increases in grain yield of 3.93% and 6.28% per cycle, respecively, in mass selection experiments. Ogada (1975) reported that full-sib selection for prolificacy showed correlated response resulting in increasing grain yield.

5.3. 1000-kernel weight (g).

The highly significant negative linear response observed in KSII, indicates that there was more reduction in 1000-kernel weight in KSII than in Ec 573, after five cycles of reciprocal recurrent selection. Although H611 showed heterosis in increasing 1000-kernel weight. Modified ear-to-row selection in KCA on the other hand resulted in non-significant reduction in 1000-kernel weight. The reduction in 1000-kernel weight perhaps was due to smaller or less filled kernels than those kernels from the original or previous populations. This observation indicates that there was a shortage of assimilates relative to the increased sink size (i.e. increased number of kernels per plant). Ogada (1975) also reported that selection in Kitale Composite B and E had lowered the 1000-kernel weight. Leng (1954) pointed out that the final limits of kernel weight are not set until the grain reaches physiological maturity.

5.4. Number of rows per ear.

Apparently, there was no significant change in number of rows per ear in KSII, Ec 573 and H611. Similar results were reported by Leng (1954) who reported that the number of rows per ear was one of the components of yield least affected by heterosis. KCA showed significant increase in number of rows per ear which showed a highly significant linear response after ten cycles of modified ear-to-row selection. Leng (1954) reported that row number is fixed at or shortly after the time when differentiation of the ear shoot begins. This occurs within 35 to 40 days after planting. Tomozei

(1970) showed heritability was greatest for number of rows per ear.

5.5. Number of kernels per row.

There was no outstanding reduction in number of kernels per row in KSII and Ec 573 after five cycles of reciprocal recurrent selection. This was caused by significant decrease in ear length observed in both KSII and Ec 573. H611 showed heterosis in increasing the number of kernels per row due to increased ear length. There was a significant increase in number of kernels per row due to substantial increase in ear length in KCA after ten cycles of modified ear-to-row selection. This indicates that the number of kernels per row was closely linked with ear length. This trend was also observed by many workers. Leng (1954) pointed out that kernels per row (ear length) is the only primary yield component in which largely positive effects of heterosis are manifested consistently. Johnson (1973) reported that yield response to dominance effects was due to kernels per row. Johnson (1974) reported that kernels per row are positively associated with ear length which, along with total leaf area and plant height are an indicator of general plant vigour. Leng (1954) reported that the maximum expression of the number of kernels per row is not finally fixed until fertilization of the ovules has been completed.

5.6. Weight of kernels per ear (g).

There was more reduction in weight of kernels per ear in KSII than in Ec 573 after five cycles of reciprocal recurrent selection. The significant decrease in weight of kernels per ear in KSII showed a highly significant linear negative response. The decrease in weight of kernels per ear was due to decrease in 1000-kernel weight and number of kernels per ear. However, H611 showed heterosis in increasing the weight of kernels per ear, due to increase in 1000-kernel weight and number of kernels per ear. KCA after ten cycles of modified ear-to-row selection showed a highly significant linear response in increasing the weight of kernels per ear, due to increase in number of kernels per ear.

5.7. Number of kernels per ear.

Apparently, there was substantial reduction in number of kernels per ear in KSII, while in Ec 573 it was not significant, after five cycles of reciprocal recurrent selection. The decrease of number of kernels per ear observed in KSII and Ec 573 was due to decrease in number of kernels per row. The increase in number of kernels per ear observed in H611 was due to the increase in number of kernels per row. KCA after ten cycles of modified ear-to-row selection showed a highly significant increase, due to increase in number of kernels per row. The number of kernels per ear per plant determine the sink size of the plant.

5.8. Ear diameter (cm).

Ear diameter is determined by the number of rows per ear. Apparently the increase or decrease in ear diameter in KSII, Ec 573 and H611 was due to increase or decrease in kernel size as showed in 1000-kernel weight because the number of rows per ear almost remained unchanged. In KCA the increase in ear diameter was due to the increase in the number of rows per ear. Krivosheya and Zozulya (1974) reported weak correlation between yield and ear diameter.

5.9. Ear length (cm).

The highly significant negative linear response observed in KSII, indicates that there was more reduction in ear length in KSII than in Ec 573, after five cycles of reciprocal recurrent selection. Ear length of H611 remained almost the same throughout. On the other hand KCA showed a significant increase in ear length. Thus, modified ear-to-row selection in KCA favoured the selection of longer ears. It appears that reciprocal recurrent selection in H611 exploited non-additive gene effects while modified ear-to-row selection in KCA utilized the additive gene effects. It was observed that increase or decrease in ear length was accompanied by increase or decrease in number of kernels per row. Therefore ear length is an important component of yield because it determines the number of kernels per row. Similar observations were made by other workers such as Leng (1954) and Johnson (1974) who reported that ear length is closely linked with the number of kernels per row. Krivosheya and Zozulya (1974) reported that there was moderate correlation between yield and ear length.

Other chracters affecting grain yield.

5.10. Ear height (cm).

Apparently, the highly substantial reduction in ear height observed in KSII, indicates that there was more reduction in ear height in KSII than in Ec 573, after five cycles of reciprocal recurrent selection. H611 showed small increase in ear height. The reduction in ear height in KSII and Ec 573 was achieved through selecting for low ear placement in the nursery. Modified ear-to-row selection resulted in significant increase in ear height in KCA. Similar observations were reported by other authors. Compton and Bahadur (1977) reported that modified ear-to-row selection resulted in significant increase in ear height. Darrah *et al*. (1978) reported that in Ec 573 and KCA, ear height decreased significantly. Ear height is moderately positively correlated with yield (Krivosheya and Zozulya 1974 and Jain *et al*. 1976).

5.11. Plant height (cm).

Apparently, plant height was reduced in KSII, while in Ec 573 it increased after five cycles of reciprocal recurrent selection. However, plant height increased in H611 and KCA. KSII and Ec 573 were shorter compared to H611 and KCA. KSII, H611 and KCA showed highly significant quadratic response curves. The increase or reduction in plant height appears to have resulted from increase or decrease in number of internodes per plant as measured by the number of leaves per plant and shortening of the internodes. However, in all populations studied no selection was made to reduce the plant height drastically. In case of selection to reduce plant height yield loss was expected as reported by Robinson _et al_. (1951) who found that appreciable genetic association with yield and plant height and ear height. Krivosheya and Zozulya (1974) reported that plant height, was moderately positively correlated with yield. Muchena (1972) reported that in practice, the problem of how to select for high yield in populations segregating for height, is central to modern plant breeding and still unsolved.

5.12. Root lodging.

The selection pressure against the root lodged plants per cent in the nursery, resulted in significant decrease in root lodged plants per cent in KSII. Root lodging resistance was increased in Ec 573 and H611. KCA showed a highly significant reduction in root lodged plants per cent after ten cycles of modified ear-to-row selection. Both breeding methods were equally effective in exploiting favourable genes for root lodging resistance. Darrah _et al_. (1978) reported that Ec 573 and

and H611 showed significant gain in root lodging resistance.

5.13. Stalk lodging.

Despite selection, stalk lodged plants per cent in KSII, Ec 573 and H611 were not significantly reduced, while there was a slight increase in KCA. These results were not surprising considering that no effort was made to select those plants which had stronger rind to support increased number of big ears per plant.

5.14. Number of bare tipped ears.

Selection against number of bare tipped ears per cent in the nursery produced significant reduction in KSII, while they were not significant in Ec 573 and H611. However, KCA showed a highly significant increase in number of bare tipped ears per cent after ten cycles of modified ear-to-row selection. Thus, reciprocal recurrent selection was more effective in reducing the number of bare tipped ears per cent than modified ear-to-row selection. Darrah *et al*. (1978) reportea significant reduction in bare tips per cent in Ec 573.

5.15. Days to 50% tasselling.

Although, selection for earliness in days to 50% tasselling was carried out, still Ec 573 was significantly late in flowering. H611 (C5) was significantly earlier in days to 50% tasselling than H611 (CO). KSII and KCA maintained almost same number of days to 50% tasselling throughout the selection cycles. Both breeding methods were equally effective in exploiting favourable genes for earliness. Darrah et al. (1978) reported that there was significant decrease in days to 50% tasselling in KCA. Lanza and Dionigi (1974) found that a close negative correlation existed between earliness and yield.

5.16. Number of leaves per plant.

Apparently, the number of leaves per plant were significantly reduced in KSII, while they were not significant in Ec 573, after five cycles of reciprocal recurrent selection. H611 and KCA maintained almost constant number of leaves per plant throughout the selection cycles. The increase or reduction in number of leaves per plant was accompanied by increase or decrease in plant height. The number of nodes per plant is reflected by the number of leaves per plant. The number of leaves per plant is essential in utilization of radiant energy in photosynthesis to produce assimilates for the plant and to fill the sink size (i.e. number of kernels per ear per plant). Many authors such as Smith (1909), Chase and Nanda (1967) reported that leaf number (or number of internodes) is a stable character, which controls the duration of growth period. Early maturing genotypes are associated with reduced number of leaves.

5.17. Diseased ears per cent.

The elimination of diseased ears in the nursery produced slight improvement in the selected populations in KSII, Ec 573 and KCA. On the contrary, there was a slight increase in the number of diseased ears per cent in H611. It is most probably because of the increased number of ears per plant.

5.18. Leaf blight and rust scores.

Selection for blight and rust resistance in KSII and Ec 573 was carried out in the nursery. Ec 573 showed a small gain in resistance to leaf blight. There was little or no variation of blight scores in the other three populations for this trait.

All the populations showed stable reaction to leaf rust attack. Darrah *et. al*. (1978) reported that KSII and Ec 573 had high levels of resistance to leaf blight and leaf rust because of prior mass or natural selection.

5.19. Shelling percentage.

Despite the improvement in grain yield, there was no noticeable change in shelling percentage in KSII, Ec 573 and H611 after five cycles of reciprocal recurrent selection. However, KCA showed a significant increase in shelling percentage after ten cycles of modified ear-to-row selection. There was an increase in shelling percentage in KCA because of increased weight of kernels per ear due to increased number of kernels per ear.

5.20. Total biological yield.

Apparently, there was more reduction in total biological yield in KSII than in Ec 573 after five cycles of reciprocal recurrent selection. However, H611 showed small increase in total biological yield. This seems to indicate that those plants with good specific combining ability in the parental population for example KSII and Ec 573, had less total biological yield. KCA showed a highly significant increase in total biological yield after ten cycles of modified ear-to-row selection. Those genotypes which were more efficient in dry matter production were favoured during selection in both breeding methods. Jain et al. (1976) reported that biological yield showed significant positive correlation with grain yield. Biological yield has been found to make greater contribution to grain yield than harvest index.

5.21. Harvest index.

Despite, the improvement in grain yield, there was no increase in harvest index in Ec 573 after five cycles of reciprocal recurrent selection. H611 and KCA however, showed significant increase in their harvest index. This was caused by the substantial increases in grain yield at the expense of biological yield both in the hybrids and composites. However, H611 had higher harvest index values than in the KCA at each corresponding cycle of selection. Therefore, reciprocal recurrent selection was more effective than modified ear-to-row selection in selection of those genotypes that were superior in increasing grain yield (i.e. economic yield) instead of biological yield. Jain et al. (1976) stated that the efficiency of a maize plant can be measured on the basis of the relationship between production of grain yield and stover.

CHAPTER VI

CONCLUSION

Reciprocal recurrent selection was found to be very effective in improving the grain yields of hybrids after each cycle of selection. Similarly, modified ear-to-row selection procedure was effective in increasing the grain yields of the composite population KCA. Higher levels of grain yields obtained in H611 than those in KCA was due to high degree of heterosis in H611. It is apparent that reciprocal recurrent selection exploited the non-additive gene effects while the modified ear-to-row selection utilized the additive gene effects. During reciprocal recurrent selection increase in grain yield was accompanied by increase in most of the yield components except number of rows per ear which remained stable. During modified ear-to-row selection, most of the yield components, except 1000-kernel weight accompanied the increase in grain yield. H611 was more efficient in partitioning of assimilates to improve grain yield at the expense of biological yield than KCA. Among the yield components the number of ears per 100 plants and weight of kernels per ear were found to be closely associated with increase in grain yield. Hence, the number of ears per plant, i.e. prolificacy and weight of kernels per ear appeared to be the most reliable components of grain yield which could be used as effective criteria of selection. Similarly, harvest index though not a direct component of grain yield, also was found to be closely associated with increase in grain yield and hence could be considered as an important selection criterion.

Suggestions for further research.

1. There is a scope for further improvement in yields of hybrids by improving the parental populations, KSII and Ec 573.
2. In addition to reciprocal recurrent selection which has given outstanding results in Kenya maize breeding programme, it is suggested that the parental populations, KSII and Ec 573 be improved separately by modified ear-to-row selection. The improved populations could then be used for making suitable hybrids.

3. The composite KCA (advance generation cross of KSII x Ec 573) even after ten cycles of modified ear-to-row selection, did not give comparable yields to F_1 hybrids (H611). It is therefore, suggested that the genetically diverse populations, namely KSII and Ec 573 be maintained and improved separately and hybrids developed from improved populations, if high grain yield is the main objective.

4. Further studies are required to construct selection indices based on genetic correlations and find out the contributions of main yield components related to grain yield.

REFERENCES

Bagshaw, F.M. (1964). Inheritance of prolificacy and maturity in crosses of southern and northern maize germplasm. Diss. Abstr. 1964: 25: Order No. 64-9722: Page 2141.

Brown, A.H. and Allard, R.W. 1971. Effects of reciprocal recurrent selection for yield on isozyme polymorphisms in maize (Zea mays L.) Crop Sci. 11: 888-893.

Chase, S.S. and Nanda, D.K. 1967. Number of leaves and maturity classification in (Zea mays L.) Crop Sci. 7: 431-432.

Comstock, R.E., Robinson, H.F. and Harvey, P.H. 1949. A procedure designed to make maximum use of both general and specific combining ability. J. Am. Soc. Agron. 41: 360-367.

Compton, W.A. and Bahadur, Khan. 1977. Ten cycles of progress from modified ear-to-row selection in corn (Zea mays L.) Crop Sci. 17: 378-380.

Compton, W.A. and Comstock, R.E. 1976. More on modified ear-to-row selection in corn. Crop. Sci. 16: 122.

Cornelius, P.L. and Dudley, J.W. 1976. Genetic variance components and predicted response to selection under selfing and full sib mating in a maize population. Crop Sci. 16: 333-339.

Cross, H.Z. and Zuber, M.S. 1973. Interelationships among plant height, number of leaves and flowering dates in maize. Agron. 65: 71-74.

Darrah, L.L., Eberhart, S.A. and Penny, L.H. 1972. A maize breeding methods study in Kenya. Crop Sci. 12: 605-608.

Darrah, L.L. and Penny, L.H. 1975. Inbred line extraction from improved breeding populations. E. Afr. Agric. For. J. 41: pl-8.

Darrah, L.L. and Mukuru, S.Z. 1976. Annual report of the maize Division, E.A.A.F.R.O. Unpublished report, P.O. Box 450, KITALE.

Darrah, L.L., Eberhart, S.A. and Penny, L.H. 1978. Six years of maize selection in Kitale Synthetic II, Ecuador 573 and Kitale Composite A, using methods of the comprehensive breeding system. Euphytica 27: 191-204.

Darrah, L.L. and Mukuru, S.Z. 1977. Recurrent selection for maize improvement: the east African experience. E.A. Agric. and For. R.O. Unpublished.

Daynard, T.B. and Duncan, W.G. 1969. The black layer and grain maturity in corn. Crop Sci. 9: 473-476.

Douglas, A.G., Collier, J.W., El-Ebrashy, M.F. and Rogers, J.S. 1961. An evaluation of three cycles of reciprocal recurrent selection in corn improvement program. p. 157-161.

Dornescu, A., 1973 a. Heterosis of yield components in maize Cerecetari agronomice in Moldora 6: 63-66. (Rumania).

Dornescu, A., 1973 b. Analysis of yield components in maize by means of correlation and path coefficients. Institutul Agronomic "Ion Ionescu de la brad", Iasi, p. 51-57. (Rumania).

Eberhart, S.A., Harrison, M.N. and Ogada, F. 1967. A comprehensive breeding system. Der Zuchter 37: 169-174.

Eberhart, S.A., Debela Seme and Hallauer, A.R. 1973. Reciprocal recurrent selection in the BSSS and BSCB1 maize population and half-sib selection in BSSS. Crop Sci. 13: 451-456.

Falconer, D.S. 1960. Introduction to quantitative genetics. Ronald Press. New York. p. 247-263.

Gardner, C.O. 1968. Mutation studies involving quantitative traits. "The present state of mutation breeding." Gamma Field Symposia No. 7: 57-87.

Gardner, C.O. 1961. An evaluation of effects of mass selection and seed irradiation with thermal neutrons on yield of corn. Crop Sci. 1: 241-245.

Hallauer, A.R., 1970. Genetic variability for yield after four cycles of reciprocal recurrent selections in maize. Crop Sci. 10: 482-485.

Hayes, H.K. and Johnson, I.J. 1939. The breeding of selfed lines of corn. J. Amer. Soc. Agron. 31: 710-724.

Harrison, M.N. 1970. Maize improvement in East Africa, Common Agric. Sur, Farnham Royal. P. 21-59.

Jain, H.K., Mukherjee, B.K., Singh, R.D. and Agrawal, K.N., 1976. The present basis and future possibilities of breeding for yield in maize. Z. pflanzenauchtg 76: 90-101.

Jenkins, M.T. 1929. Correlation studies with inbred and cross bred strains of maize. J. Agric. Res. 39: 677-721.

Johnson, D.R. and Tanner, J.W. 1972. Calculation of the rate and duration of grain filling in corn (Zea mays L.) Crop Sci. 12: 485-486.

Johnson, G.R. 1973. Relationships between yield and several yield components in a set of maize hybrids. Crop Scie. 13: 649-651.

Johnson, G.R. 1974. Analysis of the genetic relationship between several yield components of maize and leaf area at specific leaf positions. Crop Sci. 14: 559-561.

Jorgensen, L. and Brewbaker, H.E. 1927. A comparison of selfed lines of corn and first generation crosses between them. J. Amer. Soc. Agron. 19: 819-830.

Kotova, G.P., Shakhor, N.F., and Mustafin, I. 1976. Correlations between some characters in lines and single hybrids of maize. Polosy 11 (3) p. 47 - 52 . (Poland).

Krivosheya, L.K., Zozulya, A.L. 1974. The interrelation of characters in maize hybrids, Kukuruza No. 12: 27-28 (U.S.S.R.)

Kumar, S. 1974. Correlation between yield and yield components and their combining abilities in maize (Zea mays L) Madras Agric. J. 61: 111-117.

Kyle, C.H. and Stoneberg, H.F. 1925. Associations between number of kernel rows, productiveness and deleterious characters in corn. J. Agric. Res. 31: 83-99.

Lanza, F. and Dionigi, A. 1974. Correlation between earliness and yield in maize. Instituto sperimentale agronomico 5: 383-403 (Italy).

Law, R. 1975. Applied maize breeding research. Annual report for 1974. Unpublished. P.O. Box 450, KITALE.

Law, R. and Fisher, M.N. 1975. A comprehensive growth analysis of three Kenyan maize varieties (unpublished). Report N.A.R.S. KITALE.

Leng, E.R. 1954. Effects of heterosis on the major components of grain yield in corn. Agron. Jour. 46: 502-506.

Lonnquist, J.H. 1953. Heterosis and yield of grain. Agron. Jour. 45. 539-542.

Lonnquist, J.H. 1964. A modification of the ear-to-row procedure for the improvement of maize populations. Crop Sci. 5: 227-228.

Lonnquist, J.H. and Webel, O.D. 1967. An evaluation of modified ear-to-row in selection in a population of corn. Crop Sci. 7: 651-655.

Martin, G.O. and Salvioli, R.A. 1971. A study of the association between yield components and a selection index in maize (Zea mays L.) Revista agronomica del noroeste Argentino 8: 391 -410.

Mason, L. and Zuber, M.S. 1976. Diallel analysis of maize for leaf angle, leaf area, yield and yield components. Crop Sci. 16: 693-396.

Moll, R.H. and Robinson, H.F. 1966. Observed and expected response in four selection experiments in maize. Crop Sci. 6: 319-324.

Moll, R.H. and Stuber, C.W. 1971. Comparison of response to alternative selection procedures initiated with two populations of maize (zea mays L.) Crop Sci. 11: 706-711.

Moll, R.H. Stuber, C.W. and Hanson, W.D. 1975. Correlated responses and responses to index selection involving yield and ear height of maize. Crop Sci. 15: 243-248.

Muchena, S.C. 1972. An evaluation of mass selection and S_1 testing for grain yield in two maize populations of diverse origin. M.Sc. Thesis, Makerere University Library. Kampala, Uganda.

Ogada, F. 1975. The effect of selection for prolificacy in two composite populations of *Zea mays* L. Ph.D. Thesis, Makerere University Library, Kampala, Uganda.

Penny, L.H., W.A. Russell, G.F. Sprague, and A.R. Hallauer. 1963. Recurrent selection. p. 352-367. In W.D. Hanson and H.F. Robinson (ed.) Stat. genet. and plant breeding NAC-NRC Pub. 982.

Penny, L.H. and Eberhart, S.A. 1971. Twenty years of reciprocal recurrent selection with two synthetic varieties of maize (Zea mays L.) Crop Sci. 11: 900-903.

Robinson, H.F., Comstock, R.E. and Harvey, P.H. 1951. Genotypic and phenotypic correlation in corn and their implications in selection. Agron. J. 43: 283-287.

Sharkov, N.F. 1975. Analysis of the correlation in inbred maize between yield components and other characters. Druzhby Narodor Instituta Rastenierodstra Imeni N.I. Vavilira No. 53: 21-23.

Sharma, R.K. 1974. Components of yield in sweet and pop-corn Madra Agric. J. 61: 381-385.

Smith, L.H. 1909. The effect of selection upon certain physical characters in the corn plant. Univ. III Agric. Exp. Sta. Bull 132.

Tomozei, I. 1970. Heritability of the main yield components of maize. Institutul agronomic "Ion Ionescu de la Brad", 1: 185-193.

Torregroza, M., Aris, E., Diaz, C, and Arboleda, F. 1972. Evaluation of reciprocal recurrent selection in germplasm sources of highland Latin American maize. Am. Soc. of Agron. 20: 301-304. (Colombia).

Vera, G.A. and Crane, P.L. 1970. Effects of selection for lower ear height in synthetic populations of maize. Crop. Sci. 10: 286-288.

Zinsly, J.R. and Moro, J.R. 1974. Reciprocal recurrent selection in sib-families of two composites of maize (Zea mays L.) 253 Instituto de Genetica, ESALQ, Piracicaba, Brazil.