GENETIC VARIABILITY FOR YIELD AND YIELD RELATED CHARACTERS IN EARLY TO MEDIAM MATURING YELLOW MAIZE (*Zea may s* L.) AT CHIRO, ETHIOPIA.

M Sc. THESIS

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GENETIC VARIABILITY FOR YIELD AND YIELD RELATED CHARACTERS IN EARLY TO MEDIAM MATURING YELLOW MAIZE (*Zea mays* L.) AT CHIRO, ETHIOPIA

A Thesis Submitted to the College of Natural and Computational Sciences,Department of Biology, School of Graduate Studies

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By

FEKADU ERAGO

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As Thesis Research advisor, I hereby certify that I have read and evaluated this thesis prepared, under my guidance, by Fekadu Erago entitled **Genetic Variability for Yield and Yield Related Characters in Early to Medium Maturing Yellow Maize (*Zea mays L.*) at Chiro, Eastern Ethiopia.**

I recommend that it be submitted as fulfilling the Thesis requirement.

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As member of the Board of Examiners of the M.Sc Thesis Open Defense Examination, We certify that we have read, evaluated the Thesis prepared by Fekadu Erago and examined the candidate. We recommended that the Thesis be accepted as fulfilling the Thesis requirement for the Degree of Master of Science in Biology (Genetics).

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External Examiner Signature Date

DEDICATION

I dedicate this thesis manuscript to my Brother, Mr. Tsdeka Erago and for nursing me with affection and for their dedicated partnership in the success of my life.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my genuine work and that all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for an advanced M.Sc degree at Haramaya University and is deposited at the University Library to be made available to borrowers under rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the reward of any academic degree, diploma or certificate. Brief quotations from this thesis are allowable without special permission provided that accurate acknowledgement of source is made. Requests for permission for extended quotation or reproduction from this manuscript in whole or in part may be granted by the head of the major department or the Dean of the School of Graduate Studies when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

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BIOGRAPHICAL SKETCH

The author was born at Hosanna, Hadiya zone, SNNPR, Ethiopia, on 20th January, 1987. He attended Elementary school at Number three (No.3) Primary school from 1996-2004 and secondary school at Wachemo Secondary School and preparatory from 2005 to 2008. Then he joined Samara University in 2009 and graduated with a B. Sc, Degree in Biology in Jun 2011.

Soon after graduation, he was employed by the Hadiya zone education Bureau as a Biology teacher at Ecclesia Secondary School for one year. Then he was employed by Ethiopian Somalia regional Education Bureau as Biology teacher at Mullu Secondary School where he is still serving. He joined Haramaya University in July 2012 to pursue his postgraduate study in Genetics.

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LIST OF ABBREVIATIONS/ACRONYMS

ANOVA	Analysis of Variance
CSA	Central Statistics Authority
CV	Coefficient of Variation
df	Degrees of freedom
EARO	Ethiopian Agricultural Research Organization
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agricultural Organization statistic
GA	Genetic Advances
GAM	Genetic Advance as Percent of the Mean
GCV	Genotypic Coefficient of Variation
ha	Hectare
HU	Haramaya University
m.a.s.l	Meter above sea level
OPV	Open Pollinated Varieties
PCV	Phenotypic Coefficient of Variation
PC	Principal Component

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ABSTRACT

Twenty five maize (Zea mays L) genotypes were evaluated in randomized complete block design for genetic variability and association between agronomic traits at Haramaya University at Chiro campus. Data were collected on 20 quantitative traits. The analysis of variance showed that the mean squares due to genotype were highly significant (p<0.01) for all trait studied, which indicates the existence of sufficient genetic variability and the potential for selection and improvement of the traits. High phenotypic and genotypic coefficients of variations were observed for plant height, ear height and grain yield and aboveground biomass. Also the difference between genotypic and phenotypic coefficients of variation were low in the traits for days to75% maturity, leaf width, ear diameter, number of rows per ear and harvest index indicating less environmental influence on these traits. High heritability estimates were obtained from days to75% maturity, days to silking, plant height, leaf width, number of nodes per plant, 1000-kernels weight, kernels texture, above ground biomass, grain yield per hectare and internodes length. These traits, therefore, may respond positively due to selection. Estimates of genetic advances as percent of mean at 5% selection intensity ranged from 3.6% for number of plant at harvest to 76.4% for above ground biomass. Genotypic correlation coefficients were found to be higher in magnitude than that of phenotypic correlation coefficients, which clearly indicated the presence of inherent association among various traits. At phenotypic level, days to silking, days to maturity, plant height, ear height, number of ears at harvest, internodes length, ear length, days to anthesis, leaf width and number of nodes per hectare was observed to have positive and highly significant (P<0.01) correlation with grain yield per hectare and negative and highly significant (P<0.01) correlation with harvest index. Path coefficient analysis at phenotypic level based on grain yield as dependent variable revealed that days to anthesis, days to maturity, ear height, leaf width, number of nodes per plant, number of ears at harvest, above ground biomass and harvest index showed positive direct effect. The genotypic path analysis also indicated that above ground biomass and harvest index showed positive and significant correlation, therefore, these traits are more important than other traits for the genetic improvement of maize for yield.

Key words: Genetic variability, Heritability, and Genetic advance

1. INTRODUCTION

The center of origin of maize is the Mesoamerican region probably in the Mexican highlands, from where it spread to the rest of the world (Paliwal, 2000 and Farnham, 2003). Archaeological records and phylogenetic analysis suggest that domestication began at least 6,000 years ago (Piperno and Flannery, 2001; Matsuuka, 2002). Maize spread around the world particularly to the temperate zones after European discovery of the Americas in the 15th century, (Paliwal, 2000 and Farnham, 2003).

Maize is one of the most important cereal crops in the world. It is used as a human food and livestock feed. Moreover it is used to produce different alcoholic and non-alcoholic drinks, construction materials and fuel. It is also used to produce medicinal products such as glucose and used as ornamental plant (Bekric and Radosavljevic, 2008).

Maize was introduced to Ethiopia by the Portuguese in the 16th or 17th century (Haffnagel, 1961). Since its introduction, it has gained importance as a main food and feed crop.

Maize growing areas in Ethiopia are broadly classified into four ecological zones based on altitude and annual rainfall. These are the high altitude moist zone, which receive 1200 to 2000mm annual rainfall with an altitude of 1700 to 2400 meters above sea level (m.a.s.l), the mid-altitude moist zone (1200-2000 mm annual rainfall with an altitude of 1000 to 1700 m.a.s.l), the low–altitude moist zone with less than 1000 m.a.s.l and 1200 -1500 mm annual rainfall), and the moisture stress zone with 500 to 1800 m.a.s.l and less than 800 mm annual rainfall. Currently, maize is a major crop in Ethiopia in terms of production, consumption and income generation for human beings. The total annual production and productivity exceed all other cereal crops, though it is surpassed by teff in area coverage (EARO, 2000).

Maize breeding in Ethiopia has been ongoing since the 1950's and has passed through three distinctive stages of research and development (CIMMYT, 1998). These are from 1952 to 1980, the main activities were the introduction and evaluation of maize materials from different part of the world for adaptation to local condition, from 1980 to 1990, the work was focused on evaluation of inbred lines and development of hybrid and open-pollinated varieties. From 1990 to the present, the main activities were (a) extensive inbreeding and hybridization, (b) development of early maturing or drought tolerant cultivars, and (c) collection and improving of maize with adaptation to highland agro ecologies. As a result, various improved hybrids and open-pollinated varieties were released for large-scale production, especially for mid-altitude zones. The high land maize breeding program was also started in 1998 in collaboration with the international maize and wheat improvement center (CIMMYT, 1998).

The main goal of all maize breeding programs is to obtain new open pollinated varieties (OPVs), inbred lines and from them hybrids and synthetics that will outperform the existing cultivars with respect to a number of traits. In working toward this goal, attention needs to be paid to grain yield as the most important agronomic trait (CIMMYT, 1998).

Grain yield is a complex quantitative trait that depends on a number of factors. It's highly influenced by environmental conditions; has complex mode of inheritance and low heritability. Because of this, during selection for grain yield, attention is given first to determine mean values, components of variance and the heritability of yield related traits in order to establish the best selection criteria (Mohamed, 1993)

Besides, knowing the correlations between the traits is also of great importance for success in selection to be conducted in breeding programs, and analysis of correlation coefficient is the most widely used one among numerous methods (Yagdi and Sozen, 2009).

Success in any crop improvement or breeding program depends upon the selection of suitable parents, a thorough knowledge of genetic variability, heritability and type of gene action. In addition, traits upon which selection of parents is based should be known. Relatively higher estimates of genotypic coefficient of variation for grain weight, plant height, ear placement, kernel rows per ear and number of grains per row along with high heritability suggest that the selection can be effective for these traits (Rezaei, 2004).

A number of studies in maize have been conducted to elucidate the nature of association between yield and its components which identified traits like ear length, ear diameter, kernels per row, ears per plant, 100-seed weight and rows per ear as potential selection criteria in breeding programs aimed at high yield (Rezaei, 2004).

According to Yoseph (2005) who reported in his study on phenotypic diversity for morphological and agronomic traits in traditional Ethiopian highland maize accessions, highland maize varieties may be grouped into a number of completely or partially isolated populations, which may be adapted to different highland conditions. Legesse (2007) also reported in his study on genetic diversity of maize inbred lines by AFLP Markers that seven pairs of AFLP primers identified 499 scorable fragments out which 81.7% were polymorphic and the diversity varying from 0.35 to 0.71. The above are among the limited studies made on maize genetic diversity in Ethiopia. The currently proposed study involves maize germplasm which were not used by other researchers for similar studies and would contribute positively to the area of study. Thus, this study was undertaken to find out the nature and magnitude of genetic variability for different traits in maize genotypes with specific objectives to:-

- Estimate the nature and magnitude of genetic variability for the yield and yield related traits in maize genotypes.
- Estimate the phenotypic and genotypic coefficient of variation, heritability and genetic advance of some agronomic traits.
- Assess the extent of association between traits among themselves and yield.

2. REVIEW LITRATURE

2.1. Origin and Production of Maize

Maize (Zea mays L.) belongs to the family Poaceae (Gramineae), tribe Maydeae. While maize comes in five phenotypes (sweet, pop, floury, dent, and flint), all its forms derive from a single ancestor domesticated in central Mexico about 7000 years ago (McCann, 2005). It was the principal food plant of the Indians when Columbus arrived, and it is still the most important cereal food crop in Mexico, Central America and many countries in South America and Africa. Two locations have been suggested as possible centre of origin of maize, namely the highlands of Peru, Ecuador and Bolivia, and the region of Southern Mexico and Central America. Many types of maize have been found in both areas (Poehlman, 1995).

Though the exact date and circumstances of *Zea mays* first cultivation is a mystery, by 1500 A.D. the Aztec and Mayan civilization had long called the descendants of that plant “maize,” literally “ that which sustains life,” and claimed that the crop was flesh and blood. In the modern economies of the U.S., East Asia, and Europe, however, it is an important/legible industrial row material: agribusiness uses its starch and cellulose for fuel, fodder, paints, plastic, and penicillin (McCann, 2005).

Maize is one of the most productive species of food plants. It has the highest potential for carbohydrate production per unit area and is an important cereal in many developing and developed countries of the world. In developing countries maize is generally used as food, while in the developed world it is used widely as major source of carbohydrate in animal feed and as industrial raw materials for wet and dry milling (Paliwal, 2000). Apart from a strong demand for starches and sweeteners, there has been exponential growth in maize-based ethanol production, fuelled by rapid increases in world energy and petrol prices (FAO Food Outlook, 2006).

Maize is a widely cultivated crop throughout the world. The United States produces almost half of the world’s production. Other top producing countries are China, Brazil, France, Indonesia and South Africa. In India, maize is the fourth most important cereal crop next to rice, wheat and sorghum. India ranks fourth in maize production with 12.7 million tones grown on an area of

6.20 million hectares with productivity of 20.48 quintals per hectare during 2005-2006 (Kumar, 2008)

Maize is believed to have been introduced Ethiopia by the Portuguese in the 16th or 17th centuries (Haffanagel, 1961). Since its introduction it has gained importance as a food and feed crop. As Ethiopia is a diverse or heterogeneous country in terms of altitude, temperature, rain fall and soil types, maize can grow in areas ranging from sea level up to 2800 m above sea level (IAR, 1980). It is grown on light soils and wide ranges of temperature and rain fall, which indicates its potential for wider adaptation.

Currently, maize is the second most important crop exceeded only by teff [*Eragrostis tef (Zucc) Trotter]* in terms of production area. However, it is the first in total production and yield per unit area among all the cereals which accounts for about 80% of the annual crop production in Ethiopia. It is cultivated on about 1.7 million ha, accounting for about 20% of the land allocated for all cereals **(**CSA, 2011).

In Ethiopia, currently maize grows in all parts of the country with high production in Western, South-western, Southern regions and Eastern and Western Highland of Hararghe. In the country, about 2.0 million hectares of land was covered with maize in 2009 / 2010 with an estimated production of about 4.936 million tons (CSA, 2011). However, the national average yield (2.54 t/ha) is still far below the world average 5.12 t/ha (FAOSTAT, 2011).

2.2. Genetic Variability, Heritability, and Genetic Advance.

2.2.1. Genetic variability

The amount of variability that exists in the germplasm collections of any crop is of at most importance towards breeding for better varieties, particularly genetic variability for a given trait is a basic prerequisite for its improvement by systematic breeding (Engida *et al.,* 2007).

Assessing the origin and magnitude of variation is the key to success in crop improvement program as difference will always exist among individuals in a plant population. Selection in breeding programs is based in measurement of phenotypic traits, while genotypic variability is measured through analysis of variance, simple measurements like arrangement standard deviation and coefficient of variation and estimation of diversity (Singh, 1990 as cited in Tamrat, 2004).

The breeding methodology to be adopted for the improvement of a crop mainly depends upon the amount of genetic variability present in the crop. It is of immense importance that the hybrids are obtained only from desirable parental combinations. Therefore, it is very important to select the desirable parents that could transmit high yield and other economic traits to their progenies analysis of combining ability would help in the selection of parents and crosses for improvement of the crop (Habtamu and Hadji, 2010).

According to Mansir (2010) who studied on genetic variability of maize, the phenotypic coefficients of variations (PCV) were higher than the genotypic coefficients of variations (GCV) for all the traits studied. Thousand seed weight had the highest GCV and the trait days to silk had the highest PCV. The highest genetic gain was obtained for plant height and the lowest genetic gain was recorded for the trait number of leaves per plant. This suggests broader genetic base for number of leaves per plant among the genotypes studied.

Genetic knowledge of germplasm diversity among local populations has a significant impact on the improvement of plant and is a valuable source of useful traits but also a bank of highly adapted genotypes. Germplasm, which is a prerequisite for any breeding program serves as a valuable source material as it provides scope for building of genetic variability. Study of variability and genetic advance in the germplasm will help to ascertain the real potential of the genotype. Further, efficiency of selection in any breeding program mainly depends upon the knowledge of association of traits. Phenotypic correlation indicates the extent of the relation between two traits, while genotype correlation provides an estimate of inherent association between the genes controlling two traits. For formulating selection indices for genetic improvement of yield, the cause and effect of the trait is very essential and can be done by path analysis (Singh and Chaudhary, 1977).

2.2.2. Heritability

The effectiveness of selection is dependent upon the variability present in the germplasm and the extent to which it is heritable. Heritability values that give the proportion of the total phenotypic variation that is due to all genetic factors are known as broad sense heritability. Heritability in broad sense gives useful indications of the relative value of selection in the material at hand. Thus information on the extent of heritability is very important to plant breeders since it gives an indication on the effectiveness with which selection of genotypes can be based on phenotypic performance of qualitative traits (Allard, 1999).

Theoretically, heritability can range from one where all variation is due to genetic, to zero where all the variation results from the environment. Actual heritability value will fall somewhere between these extreme values. It is difficult to determine the amount or types of genetic variability if phenotypic expressions are strongly influenced by the environment (Welsh, 1990 as cited in Basazen, 2006).

The importance of epitasis for gene controlling grain yield in the breeding population of maize is not well understood. Most statistical models for estimating zone effects assume epitasis to be of importance. This assumption has been used in the estimation of heritability and the number of genes affecting quantitative traits. Theoretical comparisons have shown that estimates of genetic parameters may be biased greatly if epitasis is present and expectations based on such parameters may lead to erroneous expectations of response to selection (Welsh, 1990 as cited in Basazen, 2006).

Yasien (1993) found that yield of maize (*Zea mays Z)* is considered as a complex inherited trait, therefore direct selection for yield perse may not be the most efficient method for its improvement. But indirect selection for other yield related traits which are closely associated with yield and high heritability estimates will be more effective. Yasien (1993) found that the narrow sense heritability estimates were 65% for plant height, 51% for ear length, 63% for ear diameter, 44% for number of rows per ear, 66% for number of kernel for row, 42% for 100 kernel weight and 27% for grain yield.

Many investigators determined the association among different traits in maize Moursi *et al.* (1975) mentioned that number of kernels per row; ear diameter and 1000-kernel weight had consistent positive and significant correlations with grain yield.

Yoseph (2005) found that analysis of variance revealed highly significant differences among accessions for all of the traits suggesting that there was a high degree of phenotypic diversity among the accessions. Grain yield, plant and ear height and days to maturity showed wide variation, while number of leaves, leaf width and ear diameter showed a narrower range of phenotypic variation.

Number of rows per ear also appears to be important in the first PC. In the second PC, which explained 12.6% of the total variation, predominant traits were ear traits (yield, ear length, ear diameter and kernels/row) and foliage rating. The third PC, which accounted for 10.5% of the total variation, was dominated by traits such as number of leaves, ear diameter, yield and ear length, number of leaves was important delineating traits associated with the fourth principal component, which accounted for 6.7% of the total variation (Yoseph, 2005).

2.2.3 Genetic advances

Genetic advances measure the expected genetic progress that would result from the best performing genotypes for the trait being evaluated (Allard, 1999). Heritability and Genetic advance should be considered simultaneously because it is not always true that high heritability will always be associated with high genetic advances (Johnson, 1955).

Improvement in the performance of selected plant over the original population can be termed as genetic advance. The ultimate goal of the plant breeder is to have higher genetic advance for the material selected since it is an indicator for the genetic improvement made in a population under selection. The genetic gain can be expected for a particular trait through selection. The genetic gain that can be expected for a particular trait through selection is the product of heritability, phenotypic standard deviation and selection differential (Kassaye, 2006). It is clear that the heritability estimated either “Broad sense” or Narrow sense” are usefull only for the population or genotypes under consideration as these estimates vary with the set of genotypes considered.

The estimates of genetic advance help in understanding the type of gene action involved in the expression of various polygenic traits (Kassaye, 2006).

According to Devi *et al*., (2001) genetic advance (GA) expressed as percentage of mean for grain yield per plant, plant height, ear height, ear length and ear diameter was higher showing that these parameters were under the control of additive genes. These observations are in confirmation with the findings of Mani *et al.* (1999). Number of kernels per row had significant correlation with seed yield followed by plant height, ear height, diameter and length of ear. These data confirm the findings of (Khatun *et al.*1999).

2.3. Association of Traits

2.3.1. Correlation coefficient

Correlation coefficient is the linear association between two variables (Gomez and Gomez, 1984). Knowledge of correlations that exist between important characters may facilitate the interpretations of the result obtained and provide the basis for planning more efficient program for the future (Johnson, 1955).

The identification and manipulation of traits contributing to grain yield is important as this increases breeding efficiency. Thus, giving emphasis to easily measurable trait with high heritability and having useful relationship with grain yield are of paramount importance to practice indirect selection for high yield (Falconer and Mackay, 1996).

Generally, three types of correlations are discussed in quantitative genetics and these are phenotypic, genotypic and environmental correlations. The association between two traits that can be directly observed is the correlation of phenotypic values or phenotypic correlations (r_p). Phenotypic correlations measure the extent to which the two observed traits are linearly related. It is determined from measurements of the two traits in a number of individuals of the populations. Genotypic correlation (r_g) is the associations of breeding values (i.e., additive genetic variance) of the two traits. Genetic correlations measure the extent to which the same genes or closely linked genes cause co-variation (simultaneous variations) in two different traits.

The correlations of environmental deviations together with non-additive genetic deviations (i.e., dominance and epistatic genetic deviations) are referred to as environmental correlations (r_e) (Singh and Chaudhary, 1977).

Studies on genotypic and phenotypic correlations among traits of crop plants are useful in planning, evaluating and setting selection criteria for the desired traits in breeding program (Johnson, 1955). Correlation measured by correlation coefficient is important in plant breeding because it measures the degree of association, genetic or non-genetic, between two or more traits. If genetic association exists, selection for one trait will cause changes in the other traits (Hallauer and Miranda, 1988).

Genetic correlation may be attributed to pleiotropism and/or linkage disequilibrium (Hallauer and Miranda, 1988). Pleiotropic occurs when one gene affects simultaneously several physiological traits. Linkage disequilibrium refers to genes, which show a tendency to being transmitted together with in a population. When genes are not linked, linkage disequilibrium is not an important cause of correlation between traits in random mated populations. In such cases the existence of genetic correlations is mostly attributed to pleiotropic effect. Environmental correlation also exists because measurements of several traits are taken from the same individual or from the same family. According to Hallauer and Miranda (1988) Positive environmental correlation is expected to occur between plant height the average (or total) of a family, the environmental deviation in a given plot containing the given family affects all individuals of that plot and causes environmental correlation of traits among them.

Correlation coefficient indicates whether or not relationships exist between two variables. It is a single summary that gives a good idea about how closely one variable is related to another variable. In plant genetics and breeding studies, correlation is used to determine the relationship between any two types of measurements made on the same individuals. The identification of correlated traits is very crucial for three chief reasons: 1) in connection with the genetic causes of correlation through the pleiotropic action of genes, 2) in connection with the changes brought about by selection, and 3) in connection with natural selection. The first point is important because pleiotropy is the common property of major genes while the second and third points are important in order to know how improvement of one trait causes simultaneous change in another trait and to understand the relationship between metric traits and fitness (Falconer and Mackay, 1996).

Since grain yield in maize is quantitative in nature and polygenic ally controlled, effective yield improvement and simultaneous improvement in yield components are imperative (Bello and Olaoye, 2009). Selection on the basis of grain yield trait alone is usually not very effective and efficient. However, selection based on its component traits could be more efficient and reliable (Mohammadi *et al*., 2003). Knowledge of association between yield and its component traits and among the component parameters themselves can improve the efficiency of selection in plant breeding. Correlation coefficient measures the mutual association between a pair of variables independent of other variables to be considered. Where more than two variables are involved, correlation coefficient alone does not give complete picture of the interrelationship (Fakorede and Opeke, 1985).

To determine relationships, correlation analyses are used such that the values of two traits are analyzed on a paired basis, results of which may be either positive or negative. The result of correlation is of great value in the evaluation of the most effective procedures for selection of superior genotypes. When there is positive association of major yield traits, breeding would be very effective but when these traits are negatively associated, it would be difficult to exercise simultaneous selection for them in developing a variety (Nemati et al., 2009).

Several workers have estimated correlation coefficient among yield and other quantitative traits in maize. Robinson *et al*. (1958) found that yield components that had the highest correlation with yield in maize were the number of ears per plant, followed by plant height and ear height while ear diameter and ear length having very small correlation with yield. Singh and Chawdhari (1972) also reported positive and significant correlation of yield with ear length, thousand-kernel weight, ear diameter, number of kernel rows per ear, number of kernels per row, plant height and number of ears per plant. They also noted significant negative correlation between yield and days to silking and maturity.

Habtamu and Hadji (2010) found positive and significant association between grain yield and ear height, plant height, ear length, ear diameter, number of kernels per row, days to maturity and thousand kernel weights, while negative and significant association with days to silking at phenotypic level. Plant height and ear height were also positively and highly correlated with each other in their study. They also found positive and highly significant associations of grain yield with plant height, ear length and number of kernels per row at genotypic level.

Dagne (2008) found positive and highly significant phenotypic correlation between grain yield and plant height, ear height, ear diameter, ear length, number of kernel rows per ear and thousand kernel weights at Bako under optimum and low nitrogen conditions. He also reported negative and highly significant phenotypic correlation between grain yield and days to silking and days to anthesis at Bako under both conditions.

Mandefro (1998) also reported positive and significant correlation of grain yield and other agronomic traits (days to anthesis, silking and maturity, plant and ear height and number of kernels per row) both at genotypic and phenotypic level and suggested that improving one of these traits can result in the improvement of grain yield, but path analysis should be done to determine the direct and indirect effects of each of these traits in relation to grain yield.

Mandefro (1998) also noted significant and positive environmental correlation between days to tasselling and silking, plant height and ear height, thousand-kernel weight and grain yield, and plant height and grain yield. He concluded from this result that any environment that favors the expression of one trait also favors the expression of the associated trait. Abedon *et al*. (1999) reported positive and significant phenotypic correlation between ear height and plant height, plant height and days to silking and between days to tasselling and silking. Habtamu and Hadji (2010) also found positive and significant environmental correlations between grain yield and plant height, ear height, ear length, ear diameter and number of kernels per row. Pixley and Bjarnason (2002) observed positive and significant correlation between ear height and grain yield.

Correlation of the association of grain yield with other traits was estimated by genotypic and phenotypic coefficients, plant height was correlated positively and significantly with all the traits at genotypic level. Grain yield per plant was correlated positively and significantly with plant height at genotypic level and positively and non-significantly at phenotypic level. A correlation coefficient tells that whether there is relationship between two variables and whether the relationship is positive or negative and how strong or weak the relationship (Bello and Igze *et al.,* 2010).

Devi *et al.* (2001) reported that ear length, number of row per ear, number of seeds per row and 1000-seed weight had direct influence on grain yield and indirect on several other components. Yusuf *et al.* (2001) reported that grain yield per plant had positive correlation with plant height, number of kernels rows per ear and number of kernels per row. The highest correlation was observed between plant height and ear height (Neto *et al.,* 2001).

Phenotypic and genotypic correlations have been computed by calculating the appropriate components of covariance and variance. Correlation coefficient provides a measure of the associations between traits (Cerna and Beaver, 1990). Thus, the information on genotypic and phenotypic correlation coefficients among various plant traits helps to ascertain the degree to which these are associated with economic productivity. The association between two traits can directly be observed as phonotypic correlation while genotypic correlation expresses the extent to which two traits are genetically associated. Both genotypic and phenotypic correlations among and between pairs of agronomic traits provide scope for indirect selection in a crop breeding program (AL-Ahmad, 2004, Aydin *et al.* 2007).

In selecting high yield genotypes correlation studies supply reliable information on the nature extent and direction of selection. The knowledge of correlation coefficient between different yield attributes helps the maize breeder to find out the nature and magnitude of the association between these traits which are mostly used to attain better yield of the crop Najeeb *et al.,* (2009).

AL-Ahmad, (2004), Aydin *et al.* (2007) and Najeeb *et al., (*2009) indicated that the correlation values were positive and significant between grain yield and each of ear diameter, ear length, and number of kernels per row.

Values of phenotypic correlation coefficient estimated for all pairs of the studied traits including grain yield and leaf area index gave significant and positive correlation, with ear diameter, ear height, plant height and silking date (Salama *et al.,* 1994, and Sadek *et al.,* 2006). Katta (2002) found positive correlation between grain yield and plant height, number of rows per ear, number of kernel per row and 100- kernel weight and emphasized the role of these traits in selection of high grain yield in maize.

Components of variance revealed a wide range of variability for all the traits. Variances arising due to differences among genotypes were highly significant for all the traits (Mohan *et al*. 2002). This result showed that simple regression coefficient is not enough for selection of traits which affect grain yield. Indirect effect of traits showed that only ear length had highly significant effect (0.35) on grain yield through number of seed per ear and indirect effect of other traits was not important. Then, number of seed per ear and 100- seed weight significantly affected grain yield and could be used as selection index for selection of maize hybrids with high grain yield. Ear length was important after number of seed per ear and 100- seed weight and affected yield directly and inherently by number of seed per ear. This trait could be used for increasing yield (Mohan *et al.*2002).

Indirect effect of this trait through 100- seed weight (r = 0.146), ear length (r = 0.144) was positive and correlation coefficient was significant. Indirect effect of number of seed per ear through of ear height (r = 0.0321) was negative. Direct and indirect effect of 100- seed weight (r = 0.41) was 265 through other traits. This trait through number of seed per ear (r = 0.18), ear length (r = 0.08), and ear height had direct effect on grain yield. Direct and indirect effects of 100- seed weight on grain yield produced highly significant correlation coefficient (r = 0.68). Direct and indirect effect of ear length on grain yield was thought all of studied traits. Maximum and minimum indirect effect on yield was through number of seed per ear (r = 0.35), ear height (r = 0.02) and 100- seed weight (r = -0.16) traits (Mohan *et al.,* 2002).

Correlation between ear length and grain yield was through indirect effect of number of seed per ear (r = 0.35). Ear height was last trait that explained by path analysis and had positive indirect effect on grain yield by ear length (0.04) and number of seed per ear (0.13) and negative indirect effect 100 -seed weight (r = -0.06) correlation between traits. This trait with grain yield was non significant (r= -0.014) (Mohan *et al.,* 2002).

2.3.2. Path coefficient analysis

Phenotypic and genotypic correlation coefficients could further be analyzed by path coefficient analysis, which involves the partitioning of the correlation coefficients into direct and indirect effects through alternate traits or path ways. Such analysis leads to identification of important component traits useful in indirect selection for higher yield. Estimation of simple correlation coefficient helps the breeders to determine the association between traits, but they do not provide the real picture of direct and indirect influence of each trait associated with the other trait. This weakness of correlation analysis can therefore be overcome by path coefficient analysis (Bhatt, 1973).

Studies of correlation and path coefficient analysis would be very important to design appropriate breeding strategies for improvement in yield through selection and to have better understanding of the relationship among yield-related traits (Dewey and Lu, 1959). Yield, being a complex trait, has been observed to be associated with a number of component traits. Grain yield in maize, specifically, is the result of a number of complex morphological and physiological traits. For full understanding of the complex relationships between grain yield and other traits, the computation of direct and indirect effects of these traits on grain yield is essential. Path coefficient analysis is used to standardize the data, determine simple correlations between independent factors, and to regress all the independent factor separately in order to obtain the direct effects in the form of partial regression coefficients (path coefficients) (Cramer *et al*., 1999).

Partitioning the correlation coefficients into components of direct and indirect effects and assessment of the relative importance of each causal factor affecting yield are possible through the path-coefficient analysis. When the correlation coefficient between a causal factor and the effect (e.g. grain yield) is almost equal to its direct effects, correlation explains the true relationship and a direct selection through this trait (causal factor) will be effective. If the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effects seem to be cause of correlation and in such situations; the indirect causal factors are to be considered simultaneously for selection (Singh and Chaudhary, 1977).

On the other hand, Singh and Kakar (1977) suggested that, under the circumstances of negative correlation coefficient but positive and high direct effect, a restricted simultaneous selection model is to be followed. That is, restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effects.

Sadek *et al.,* (2006) found that, specific leaf weight exhibited significant and positive correlation with cob-kernel weight while, it exhibited significant and negative correlations with specific leaf area and number of rows per ear confirmed the positive association between specific leaf weight and 100-kernel weight. Specific leaf area showed significant and positive correlation with number of rows per ear on the other hand; it appeared significant and negative correlations with 100-kernel weight. The association among traits may be measured by genotypic and/or phenotypic coefficients of correlation depending on the type of studied material and the kind of experimental design used (Sadek *et al.,* 2006).

Positive significant genotypic and phenotypic correlation coefficient for days to 50% silking with grain yield per plant under normal spring season was recorded by Shakoor *et al.,* (2007). Asra-ur-Rehman *et al.,* (2007) also concluded that days to 50% silking had positive and significant association with each other and grain yield per plant under drought condition. After getting information from the results of regression and correlation analysis, the path coefficient analysis was done to determine direct and indirect effects of traits on grain yield (Asra-ur-Rehman *et al.,* (2007).

Path analysis plays an important role in determining the degree of relationship between yield and its components. Studies of correlation and path analysis have recently been conducted in groundnut by Izge *et al., (*2004); in sorghum by Ezeaku and Mohammed, (2006).

Khatun *et al.* (1999) reported that grain yield per plant was positively and significantly correlated with number of grains per ear, and 1000-grain weight and ear height. Orlyan *et al.* (1999) and Gautam *et al.* (1999) suggested that most important traits in improving maize grain yield are number of grains per row, number of grain per ear and plant height. However, Mohammadi *et al.* (2003) determined the interrelationship between grain yield and its components from eighteen maize lines/hybrids, using genotypic correlation and path coefficient analysis. Grain yield was positively and significantly associated with plant and ear height, ear diameter, number of grains per ear, number of grains per row and 1000-grainweight.

Geetha and Jayaraman (2000) studied direct and indirect effects of different quantitative traits on grain yield in 90 hybrids and reported that number of grains per ear exerted a maximum direct effect on grain yield. They therefore suggested that selection of number of grains per ear could be highly effective for improvement of grain yield. In their study on maize Habtamu and Hadji (2010) found positive and significant direct effects of ear height, ear length, ear diameter, number of kernels per row, days to maturity and thousand kernels weight on grain yield and correlated also positively and significantly with grain yield at phenotypic level. At genotypic level, they found positive and significant direct effects of plant height and ear length on grain yield but negative and significant direct effects of ear height on grain and correlated positively and significantly with grain yield in both cases. Research conducted on path coefficient analysis to investigate the direct and indirect effects of maturity traits on yield revealed that plant height influences the grain yield considerably (Odongo *et al*., 1989).

3. MATERIALS AND METHODS

3.1. Description of the study Area.

West Harerge Zone is one of the 17 Zones in Oromia National Regional State, geographically located between 70 32' - 90 47'N latitude and 410 24' - 430 48'E longitudes (between 70 52' 15'' - 9028'43'' North latitude and 400 03' 33'' - 40034'13'' East longitudes. The capital town of the Zone is Chiro, which is located at a distance of 326 km East of Addis Ababa. The area coverage of the Zone is 1,723,145ha (17,231km2), comprising of 14 districts with a combined population of 1,871,706, of whom 912,845 are women. While 160,895 or 9.36% are urban inhabitants, a further 10,567 or 0.56% are pastoralists. West Hareerghe is subdivided in to three major climatic zones known to be Temperate tropical highland locally known as *dega* (12.49%), Semi-temperate/Tropical rainy mid land or woinadega (38%), and Semi-arid/Tropical dry or kola International Journal of Environmental Monitoring and Analysis 2013; (49.5%). The topography of the zone is characterized by steep slopes in the highlands and mid plains in the lowland areas. The ecological zones are set based on the differences in altitude variation ranging between 500 up to 3500 meters above sea level 1500 m a.s.l), *woinadega* (1500 - 2300 m (2300 - 3500 m a.s.l). The mean monthly minimum temperature ranging from 160C to 200 maximum is 240C to 280C. Rainfall is dispersed the year into two rainy seasons *belg* February-April and *meher* or main season rains fall from June-September with small showers in dry months. Annual rainfall averages range from below 700 mm for the lower *kolla* to nearly 1,200 mm for the higher elevations of *woinadega* and *dega* areas. The rainfall is variable from year to year both in terms of intensity and distribution during the growing seasons causing a wide range of climatic hazards.

3.2. Experimental Material

Twenty five to 36 maize genotypes will be used for the study. The source of the genotypes is Haramaya University, maize research project. The description of the genotypes is depicted in Table 1.

3.3. Experimental Design and Trial Management

The experiment was carried out in a randomized complete block design with three replications. Each plot consisted of 4 rows of 5.1m in length with row to row spacing of 75cm and within row spacing of 25 cm. Agronomical practice including pest control, weeding and observation were made as required. Other cultural practices were carried out as recommended for the area.

3.4. Data Collection

Days to 50% anthesis: The number of days from emergence to when 50% of the plants started shedding pollen.

Days to 50% silking: The number of days from emergence to when 50% of the plants in the plot produced 3cm long silk.

Table : Description of Genotypes

No.	Name
1	Al 205 X CML 157
2	Al 205 X CML 316
3	AL 206 X AL 99 CML 79A
4	AL 206 X CML 316
5	AL 206 X CML 44
6	Al 99 AL 281 X CML 157
7	Al 99 AL 281 X CML 44
8	Al 99 CML 270 X Al 99 CML 79A
9	Al 99 CML 270 X CML 44

10	Al 99 CML 300A X AL 99 CML 79A
11	Al 99 CML 300A X CML 44
12	Al 99 CML 370 X AL 205
13	Al 99 CML 39A X AL 99 CML 79A
14	Al 99 CML 39A X CML 316
15	Al 99 CML 39A X CML 44
16	Al 99 CML 79A X CML 316
17	Al 99 CML 79A X CML 44
18	CML 306 X CML 44
19	CML 126 X CML 157
20	CML 126 X CML 316
21	CML 157 X AL 99A 79A
22	CML 157 X CML 316
23	CML 157 X CML 44
24	CML 161 X CML 165
25	CML 306 X CML 157
26	CML 306 X CML 316
27	CML 316 X CML 44
28	CML 32 X AL 99 CML 79A
29	CML 32 X CML 44
30	CML 44 X CML 157
31	TL 99 AL 1505-35 X CML 316
32	Birkata
33	Bukuri
34	Melkassa 1
35	Mnelkassa 7
36	Yellow Pop

Source: Haramaya University, College of Agriculture

Days to 90% maturity: The number of days from emergence to when 90% of the plants in the plot reached physiological maturity.

Plant height (cm): heights of five randomly taken plants from each plot measured from the ground level to the base of tassel and the average was recorded.

Ear height (cm): Ear heights of five randomly taken plants from each plot were measured from the ground level to the node bearing the upper useful ear and the average was recorded.

Ear length (cm): Length of five randomly taken ears from each plot was measured and the average was recorded.

Leaf width (cm): Width of two leaves below and two leaves above the upper most useful ear from each five randomly taken plants were measured and the mean was recorded.

No. of nodes per plant: The numbers of nodes from five randomly taken plants were counted and the average was recorded.

Internode length (cm): Internodes of five randomly taken plants from each plot were measured and the average was recorded**.**

No. of ears at harvest: Number of ears taken from all plants of each plot was counted and the average was recorded.

No. of ears per plant: Number of ears per plant from five randomly taken plants of each plot was counted and the average was recorded.

No. of plants at harvest: The number of plants/plot were counted immediately before harvesting and recorded.

Ear diameter (cm): Diameter of five randomly taken ears from each plot was measured using caliper and the average was recorded.

No. of kernels per row: The number kernels/row from five randomly taken ears/plot was counted and the mean was recorded.

No. of rows per ear: The number of rows/ear from five randomly taken ears from each plot was counted and the mean was recorded.

1000 kernel weight: Thousands of kernels from each plot were counted by automatic seed counter and were weighed using a sensitive balance after adjusting the moisture content to 12.5%.

Adjusted yield (kg/plot): The yield of grain of each plot were weighed and adjusted to 12.5% moisture. Adjusted yield per plot= (FW×0.81) × (100-MMR)/ (100-12.5)

Grain yield (kg/ha): This was calculated by converting plot yield into hectare basis. GY= (Yield per plot (g) / Plot size) X 10000 m^2

Aboveground biomass yield (kg/ha): The total aboveground biomass was weighed per plot and later was converted to ha basis.

Harvest index: This was calculated as the ratio between grain yield and aboveground biomass yield

$$\text{Harvest Index} = \frac{\textit{Grain yield (kg)}}{\textit{Above ground biomass yield (kg)}}$$ (Debouck and Hidalgo, 1986)

3.5. Qualitative data

Table 2. The following qualitative characteristics was be recorded used the proposed scales for each trait separately as indicated in the table 2 below.

Trait	Scoring Scale
Tassel anther glumes color	
Pink	1
Green	2
Light purple	3
Purple	4
Silk color at emergence	
Green	1
Pink	2

Red	3
Purple	4
Stalk color	
Yellowish green	1
Light green	2
Green	3
Dark green	4
Purple	5
Leaf color	
Yellowish green	1
Light green	2
Green	3
Dark green	4
Leaf midrib color	
Yellowish green	1
Light green	2
Green	3
Dark green	4
Purple	5
Leaf pubescence	
Absent	0
Present	1
Ear shape	
Cylindrical	1
Cylindrical-Conical	2
Conical	3
Round	4
Kernel color	
White	1
Yellow	2
Purple	3
Variegated	4
Brown	5
Orange	7
White cap	8
Red	9
Kernel texture	
Flat	1
Beaked	2
Round	3
Kernel shape	
Shrunken	1
Round	2
Indented	3
Pointed	4

3.6. Statistical Analysis

3.6.1. Analysis of variance

Analysis of variance (ANOVA) was carried out for the quantitative traits as per the procedure outlined by Gomez and Gomez (1984), which were known as MSTAT, SAS and SPSS.

Table 3: Analysis of Variance (ANOVA)

Source of variation	Degrees of freedom	Mean square	Expected mean
Replication	r-1	M_{sr}	$\sigma_e^2 + g\sigma_r^2$
Genotypes	g-1	M_{sg}	$\sigma^2 e + g\sigma^2 g$
Error	(r-1) (g-1)	M_{se}	$\sigma^2 e$
Total	gr-1		

Where r = number of replication

g = number of genotypes

$\sigma^2 g$ = genotypic variance

Ms_g = Mean square due to genotype

Ms_r = Mean square due to replicati*on*

M_{se} = Error mean square

σ^2_e = environmental variance

3.6.2. Estimation of genetic parameters

The amount of genotypic and phenotypic variability that exist in a species is essential in developing better varieties and in initiating a breeding program. Genotypic and phenotypic coefficients of variation are used to measure the variability that exists in a given population (Burton and Devane, 1953).

Phenotypic and genotypic variance components and of phenotypic and genotypic coefficients of variation were calculated by the methods suggested by Burton and Devance (1953).

Genotypic variance (σ_g^2) = $\frac{\text{Msg}-\text{Mse}}{\text{r}}$

Phenotypic Variance (σ^2 p) = σ^2 g +σ^2 e

Environmental Variance (σ^2 e) = Mean Square error

Where Msg = mean square due to genotype

Mse = environmental variance

R = the number of replication

Phenotypic coefficient of variation (PCV)

$$\text{PCV} = \frac{\sqrt{\sigma^2 p}}{\bar{x}} \text{x } 100$$

Genotypic coefficient of variation (GCV)

$$\text{GCV} = \frac{\sqrt{\sigma^2 g}}{\bar{x}} \times 100 \qquad \text{Where } \bar{x} = \text{trait means}$$

PCV and GCV values were categorized as low, moderate and high values as indicated by Sivasubramaniah and Menon (1973) as follows.

0-10 % = Low

10-20% = Moderate

>20 = High

Heritability in Broad sense for all traits was computed using the formula given by Falconer and Mackay (1996)

Heritability (H) = $\frac{\sigma_g^2}{\sigma_p^2} \times 100$

Where (H) = heritability in broad sense

σ_p^2= phenotypic variance

σ_g^2= genotypic variance

The heritability percentage was categorized as low, moderate and high as followed by Robinson *et al*., (1949), as follows.

0-30% = Low

30-60% = Moderate

>60% = High

Genetic advances under selection (GA) expected genetic advances for each trait at 5% selection intensity was computed by the formula described by Johnson *et al*., (1955).

Genetic advances (GA) = K. σ^2 p. H

Where K= constant (selection differential where K= 2.056 at 5% selection intensity)

σ_p = phenotypic standard deviation

H= heritability in broad sense

Genetic advances as percent of means was calculated to compare the extent of predicated advances of different traits under selection using the formula.

GAM= (GA /$\bar{x}$) x 100

Where GAM= genetic advances as percent of mean

GA= Genetic advances under selection

$\bar{x}$ = mean of population in which selection was employed.

The GA as per cent of mean was categorized as low, moderate and high as described by Johnson *et al.* (1955) as follows.

0-10 % = Low

10-20% = Moderate

20 and above = High

3.6.3. Association of traits and path coefficient analysis

3.5.3.1. Correlation coefficient (r)

Genotypic and phenotypic coefficients of correlation between two traits were determined by using variance and covariance components as suggested by Weber and Moorthy (1952).

$$r_g(\mathrm{xy}) = \frac{\boldsymbol{covg(xy)}}{\boldsymbol{\sigma_g^{\frac{1}{2}}(x)\,\sigma_p^{\frac{1}{2}}(y)}}$$

$$\boldsymbol{r_p}\ (\mathbf{xy}) = \frac{\boldsymbol{covp(xy)}}{\boldsymbol{\sigma_g^{\frac{1}{2}}(x)\,\sigma_p^{\frac{1}{2}}(y)}}$$

Where r_g(xy) and r_p are genotypic and phenotypic correlation coefficients, respectively.

cov_g(xy) and cov (xy) are genotypic and phenotypic covariance of xy.

$\sigma_g^{1/2}$(x) $\sigma_p^{1/2}$(x) and $\sigma_g^{1/2}$(y), $\sigma_p^{1/2}$(y) are genotypic and phenotypic standard deviations of x and r, respectively.

These, coefficients of correlation were tested for their statistically significance by using t- test as:

$$t = \frac{r\sqrt{(n-1)}}{\sqrt{(1-r2)}}$$

Where n= number of treatments

The calculated value of t was compared with "t" table value are n-2 degrees of freedom at 1 and 5 percent level of significance.

3.6.3.2. Path coefficient analysis

Path coefficient analysis was estimated with the formula given by Dewey and Lu *et al*., (1959).

$R_{ij} = p_{ij} + \sum rik\ Pjk$

Where: rij is association between independent variables (i) and dependent variable j as measured by phenotypic and genotypic correlation coefficient.

Pij is component of direct effect of independent variable (j) as measured by the phenotypic and genotypic path coefficients and

$\sum rik\ pjk$ *is* the summation of components of indirect effect of a given independent variable (i)on a given dependent variable (j) via all other independent variables.

The residual factor (P^2R) was calculated as described by Dewey and Lu *et al*., (1959):

$1 = P^2R + \sum Pij\ rij$

Small P^2R value (P^2R, nearly zero) indicates that the dependent trait considered (grain yield) is fully explained by the variability in the independent traits.

Higher P^2R value indicates that some other factors which have not been considered need to be included in the analysis to account fully for the variation in the dependent trait.

4. RESULT AND DISCUSSION

4.1. Quantitative Traits

4.1.1 Analysis of variance

The result of the analysis of variance is presented in (Table 5). The mean squares due to genotype were highly significantly different ($p < 0.01$) for all the traits studied except for the number of plant at harvest, which indicates the existence of sufficient genetic variability. Similarly, Mansir Yusuf (2010) reported significant difference in thousand seed weight and days to silk in maize varieties; and he also reported that the highest genetic gain was obtained for plant height and the lowest genetic gain for number of leaves per plant. Ihsan *et al., (*2005); Nazir *et al*., (2010); Salami *et al*., (2007) and Naushad *et al*., (2007) also reported similar results in their study on maize.

4.1.2. Range and mean values

The range means and standard errors of the 20 traits studied are shown in (Table 5). Wide ranges were recorded for aboveground biomass (7009-21375), 1000kernel weight (185.67-382.33) day to 90% maturity(153-160.66) Plant height (125-180) and day to 50% silking (74.6-92). Similarly, days to 50% anthesis (71.667-89), ear height (54-85.67), no. of kernels per row (27-38) and no. of ears at harvest (15.33-32.66), no. of plants at harvest (15-21.33), ear length (12.26-16.71), no. of rows per era (10.4-13.86) and no. of nodes per plant (10.2-13.2) had wide ranges. Grain yield per hectare ranged from 3709 tons for AL99CML39AX AL99CML 79A to 10347 tons for Al 99 CML 39A X AL 99 CML 79A. Maximum grain yield per hectare was obtained in AL99CML270XAL99CML79A (10347t), AL206XCML316 (9770t), CML126XCML316 (9594t), CML32XAL99CML79A (8470t), CML126XCML157 (8433t), AL99CML370AL205 (8236), AL99AL281 XCML44 (8456t), Al99CML270XAl99CML 79A (7314t), AL206 X AL99CML79A (7432t), CML 157 X CML 316 (6735t), Al 99 CML 79A XCML 44 (6660t), CML 161 X CML 165 (6652), Al 99 CML79A X CML 316 (5972t). While low yield were obtained for Al 99 CML 270 X CML 44, Yellow Pop, CML 306 X CML 44, Mnelkassa 7 and Al 99 CML 79A X CML 316, 3709, 4717, 5512, 5805, 5972 respectively (App.Table 1).

The range for number of ears per plant was 0.86 for CML 306 X CML 316 to 2.13 for CML 157 X CML 316, Nemati *et al*. (2009) reported that the components of variance revealed a wide range of variability for traits such as number of rows per ear, kernels per row, kernels per ear, ear length, ear diameter, 100-kernels weight and plant height. Plant height ranged from 125 cm Al 99 CML 270 X CML 44 to 180cm for Yellow Pop (App. Table 1).

Yoseph (2005) also reported that grain yield, plant height, ear height and days to maturity showed wide range of variation, while number of leaves, leaf width and ear diameter showed a narrower range of phenotypic variation of maize in Ethiopia.

In the present study the average number of ears at harvest showed a wide range of variability in that the minimum was recorded for CML 32 X CML 44 (9.787) and maximum for Al 99 CML 39AXAL 99 CML 79A (32.667). In general, range and mean values in this study suggested the existence of sufficient variability among the tested genotypes for the majority of the traits studied and their considerable potential in the improvement of maize.

Table 4**:** Mean squares from analysis of variance of the 36 maize genotypes evaluated.

Source of variation	Df	DT	DM	DS	PH	EH	EL
Genotype	35	34.72^{**}	8.33^{**}	35.2^{**}	509.8^{**}	159.0^{**}	3.74^{**}
Replication	2	6.58	9.89	4	1540	241.22	1.7
Error	70	13.51	3.9	13.68	531.9	101.9	2.54
Total	107	54.81	22.12	52.8	2581.7	502.13	7.98
C.V		4.6	1.26	2.45	15.23	14.84	10.75
R square		0.56	0.53	0.53	0.36	0.45	0.43
LSD at 5%		5.98	3.22	6.02	37.55	16.44	2.59
Grand mean		79.77	155.89	82.78	152.42	67.98	14.82
SE		3.67	1.97	33.51	23.06	10.09	1.59

DT=days of teaseling, DM=days of maturity, DS=days of silking, PH=plant height, EH=ear height, EL=era length, C.V=coefficient of variation, LSD=least significant digit, SE=standarderror,Df=degreeoffreedom.*Significantat5%,**significanceat1%.

Table 4: . . . . .

Source of variation	Df	LW	NO	IN	ET	PE	PL	ED
Genotype	35	1.52**	1.79**	6.51**	46.57**	1.68**	7.29**	5.84
Replication	2	10.96	21.3	13.6	86.33	0.01	19.34	67.62
Error	70	1.31	1.54	5.33	35.93	0.78	7.47	6.09
Total	107	13.79	24.63	25.44	168.83	2.47	34.1	79.55
C.V		13.58	10.66	19.6	23.3	7	14.9	53
R square		0.44	0.49	0.4	0.41	0.51	0.36	0.44
LSD at 5%		6.34	2.02	3.76	9.76	1.44	4.45	4.01
Grand mean		8.44	11.65	11.75	25.66	12.54	18.23	4.65
SE		1.14	1.24	2.3	5.9	0.88	2.73	2.46

KR= No. of kernels per row, EP=number of ears per plant, KW=1000kernel weight, AY= a jested yield (Kg/plot),GY= grain yield(Kg/ha),AB=aboveground biomass yield, HI= harvest index, C.V=coefficient of variation, LSD=least significant digit, SE=standard error, Df =degree of freedom. *Significantat5%, **Significancantat1%.

Table 4; . . . .

Source of variation	Df	KR	EP	KW	AY	GY	AB	HI
Genotype	35	24.02	0.14	4312.6	1.099	5393060	21952700	0.0037
Replication	2	17.34	0.02	1411.17	0.01	304091	1459335.4	0.00044
Error	70	11.83	0.1	2250.7	0.4	385478	13007028	0.0033
Total	107	53.19	0.26	7974.47	1.509	6082629	36419063	0.00744
C.V		10.51	22.6	14.3	25.44	27.5	26.9	10.79
R square		0.51	0.41	0.49	0.53	0.41	0.45	0.36
LSD at 5%		5.6	0.52	77.25	1.11	3197.1	5873.1	0.09
Grand mean		32.71	1.41	331.57	2.69	7138.56	13361.4	0.53
SE		3.44	0.32	47.44	0.68	1963.28	3606.52	0.05

KR= No. of kernels per row, EP=number of ears per plant, KW=1000kernel weight, AY= a jested yield (Kg/plot),GY= grain yield(Kg/ha),AB=aboveground biomass yield, HI= harvest index, C.V=coefficient of variation, LSD=least significant digit, SE=standard error, Df =degree of freedom. *Significant at 5%, **Significancantat1%.

4.1.2. Phenotypic and genotypic variations

Estimated variance components, phenotypic coefficient of variation (PCV) and genotypic Coefficient of variation (GCV) of the traits studied are presented in Table 5. The high phenotypic coefficient of variation was observed for ear diameter (51.82), interned length (47.84), adjusted yield (38.66), aboveground biomass yield (35), grain yield (32.52), no.of ears at harvest (26.57), no. of ears per plant (26.24). On the other hand, relatively moderate values were observed for1000kernelweight (19.8), ear height (18.34),plant height(15.12), leaf width (14.57), no.of plants at harvest (14.81), no. of kernels per row (14.94), ear length (13.02), harvest index (11.32), no. of nodes per plant (11.41), no. of rows per ear (10.28). The remaining traits depicted low phenotypic coefficient of variation. According to Majid (2011), traits having high GCV indicate high potential for effective selection.

The genotypic coefficient of variation was high for harvest index (37.73), grain yield (31.34), adjusted yield (30.85) and aboveground biomass yield (22.38). These effects were also detected from high heritability estimates for these traits (Table 5). On the other hand, relatively lower genotypic coefficient of variation was observed for number of rows per ear (7.49), ear length (7.35), leaf width (5.33), number of nodes per plant (4.29), days of 50% anthesis (3.25), days to 50% siliking (3.22), number of plants at harvest (2.3), plant height (1.78) and days to 90% maturity (0.77). Relatively moderate genotypic coefficient variation were observed for inter node(19.8), number of ears per plant (14.18), 1000 kernel weight (13.69), number of ears at harvest (12.7), ear height (11.1), ear diameter (10.75), number of kernels per row (10.63). In this study, it was found that phenotypic coefficients of variation were higher than genotypic coefficients of variation for all traits though the phenotypic coefficient of variation were greater than genotypic coefficient of variation .This might be due to the fact that of the trial management and soil condition of the experimental plot has been more or less uniform. This observation was in conformity with that of Mansir Yusuf (2010) who reported similar result in his study on maize.

In the present study the difference between GCV and PCV were low in the traits of days to 90%maturity, days to 50% silking, grain yield per hectare, number of rows per ear and days to50% anthesis. Inter node length, number of ears at harvest, number of ear per plant, number of plant at harvest, ear diameter, above ground biomass yield and harvest index had moderate genotypic and phenotypic coefficients of variation, and hence these traits provide practically average chance for selection. Days to90%maturity, days to 50% siliking, days to 50% anthesis, leaf width, number of rows per ear, 1000kernel weight, number of nodes per plant, adjusted yield, and grain yield had the least phenotypic and genotypic coefficients of variation, and hence these traits provide practically less chance for selection.

Table 5; Estimates of ranges, Standard error (SE), Phenotypic (σ^2p) and Genotypic (σ^2g) variance, Phenotypic coefficient variability (PCV) and Genotypic Coefficient of variability (GCV), Broad sense heritability (H), Expected genetic advances (GA) and Genetic advance as percent of mean (GAM).

Trait	Range	Mean	**SE**	(σ^2e)	(σ^2g)
DT	71.667-89	79.77778	3.67	13.51	7.07
DM	153-160.66	155.69	1.97	3.91	1.47
DS	74.6-92	82.78	33.51	13.68	7.17
PH	125-180	151.42	23.06	531.9	0.36
EH	54-85.67	67.98	10.09	101.91	57.11
EL	12.26-16.71	14.82	1.59	2.54	1.2
LW	6.34-9.44	8.44	1.14	1.31	0.21
NO	10.2-13.2	11.65	1.24	1.54	0.25
IN	9.68-18.4	11.75	2.3	5.33	1.18
ET	15.33-32.66	25.66	5.9	35.93	10.64
PE	10.4-13.86	12.54	0.88	0.7	0.9
PL	15-21.33	18.23	2.73	7.47	0.18
ED	3.46-7.76	4.65	2.46	6.09	0.26
KR	27-38	32.71	3.44	11.83	12.17
EP	0.86-2.13	1.41	0.32	0.1	0.04
KW	185.67-382.33	331.1	47.44	2250.73	2061.9
AY	0.86-3.96	2.69	0.68	0.46	0.69
GY	3709-10347	1.33	1963.28	3854478	5007582
AB	7009-21375	13361.4	3606.52	13007028	8945672
HI	0.48-0.61	0.53	0.95	0.0035	0.0004

DT=days of teaseling, DM=days of maturity, DS=days of silking, PH=plant height, EH=ear height, EL=era length, LW= leaf width, NO=No. of node, IN= inter node length, ET=No. of ears at harvest, PE=No. rows per ear, PL=No. of plants at harvest, ED=ear diameter, KR= No. of kernels per row, EP=number of ears per plant, KW=1000kernel weight, AY= a jested yield (Kg/plot),GY= grain yield(Kg/ha),AB=aboveground biomass yield, HI= harvest index. SE=Standard error.

Table 5; . . . . .

Trait	(σ^2 p)	GCV	PCV	h~~%~~	GA	GAM
DT	20.59	3.25	5.68	34.59	3.2	4.01
DM	5.37	0.77	0.19	27.37	1.3	0.833
DS	20.85	3.22	5.51	34.39	3.23	3.9
PH	524.54	1.78	15.12	1.4	0.66	0.43
EH	159.01	11.1	18.34	35.9	9.33	13.72
EL	3.74	7.35	13.02	32.08	1.27	8.56
LW	1.52	5.33	14.57	13.81	0.35	4.14
NO	1.79	4.29	11.41	13.96	0.38	3.26
IN	6.51	19.8	47.84	18.12	0.31	0.05
ET	46.57	12.7	26.57	22.84	3.21	12.52
PE	1.68	7.49	10.28	90.02	14.25	1.13
PL	7.29	2.3	14.81	1.46	0.13	0.71
ED	5.84	10.75	51.82	1.09	0.22	4.76
KR	24	10.63	14.94	79.9	5.11	15.63
EP	0.14	14.18	26.24	28.57	0.21	15.46
KW	4312.6	13.69	19.8	47.81	64.779	19.53
AY	1.09	30.85	38.66	82	1.37	51.22
GY	5393060	31.34	32.52	92.85	4447.89	62.3
AB	21952700	22.38	35	40.74	3938.83	29.47
HI	0.0037	37.73	11.32	10.81	0.013	2.52

DT=days of teaseling, DM=days, DT= days of 50% anthesis, DM=days90% of maturity, DS=days50% of silking, PH=plant height, EH=ear height, EL=era length, LW= leaf width, NO=No. of node, IN= inter node length, ET=No. of ears at harvest, PE=No. rows per ear, PL=No. of plants at harvest, ED=ear diameter, KR= No. of kernels per row, EP=number of ears perplant,KW=1000kernelweight,AY=ajestedyield(Kg/plot),GY=grainyield(Kg/ha),AB=abovegr ound biomass yield, HI= harvest index. SE=Standard error.

4.1.3. Heritability estimates

Broad sense heritability (h^2), an estimate of the total contribution of the genotypic variance to the total phenotypic variance ranged from 1% for ear diameter to 92.85% for grain yield (Table 5). High heritability estimates were obtained for grain yield (92.85), number of rows per ear (90.02), adjusted yield (82), number of kernels per row (79.9),1000kernel weight (47.81), above ground biomass yield (40.74), ear height (35.9), days to50%anthesis (34.59%), days to 50% silking (34.39%), ear length (32.08%), number of ears per plant (28.57%), days to 90% maturity (27.37%),number of ears at harvest (22.84%), inter node length (18.12%), number of nodes per plant (13.96%), leaf width (13.81%), harvest index (10.81), plant height (1.4%), number of plants at harvest (1.46%), ear diameter (1%) indicating that these traits may respond positively to phenotypic selection.

These observations are in agreement with the findings of AL- Ahmad (2010) who reported high heritability estimates for grain yield (92%), number of rows per ear (90.02%) adjusted yield (82%), number of kernels per row (79.9%), emphasizing that the additive genetic variation was the major component of genetic variation in the inheritance of these traits and the effectiveness of selection in the early segregating generations of the genotypes for improving these traits. Mani *et al.* (1999) and Kumar (2008) also observed in their study on maize high heritability estimates for the traits such as grain yield per plant (96.80%), ear height (92.77%), days to 50 per cent tasseling (89.27%), days to 50 per cent silking (88.57%), plant height (93.53%), cob length (85.97%), number of kernels per row (72.80%) and 1000-kernels weight (84.43%).

4.1.4. Estimates of expected genetic advance

The genetic advances as percent of the mean (GAM) at 5% selection intensity is presented in Table 5. It ranged from 0.05% for inter node length to 62.3%grain yield. There was relatively high genetic advance expressed as percentage of mean for almost half of the traits, i.e. for grain yield (62.3%), adjusted yield (51.22%), above ground biomas yield (29.47%), 1000kernelweight (19.53%), number of kernels per row (15.63%), number of ears per plant (15.46%), ear height

(13.72%), number of ears at harvest (12.52%) showing that these parameters were under the control of selective genes.
Genetic advance (GA) as percentage of mean for grain yield per hectare, plant height, ear height and ear diameter were highly showing that these parameters were under the control of additive genes. These observations were in agreement with the findings of Mani *et al.* (1999) who reported similar results in their study on maize genotypes.

Low estimates of genetic advances expressed as percentage of mean were observed for ear length (8.56%), leaf width (4.14%), days to 50%anthsis (4.01%), ear diameter (4.76%), days to 50%siliking (3.9%), number of nodes per plant (3.26%), harvest index (2.52%), number of rows per ear (1.13%), daysto90%maturity (0.83%), number of plants at harvest (0.71%), plant height (0.43%), and inter node length (0.05%). The low genetic advances for traits like, days to 50% anthesis, leaf width, number of nods per plant, ear diameter and days to50%silking in spite of their heritability value which is more than 60%. This finding shows the presence of low genetic variability for these traits which are also reflected by their respective low genotypic and phenotypic variation. This in turn shows the importance of genetic variability in improvement through selection.

4.2.1. Association of traits

Genotypic correlation coefficient and phenotypic correlation coefficient values are depicted in Table 6. It can be seen that in most cases the genotypic coefficient of correlation values are slightly greater in magnitude than that of phenotypic correlation coefficients indicating the presence of inherent association among the various traits.

4.2.2. Correlation of grain yield with yield related traits

Genotypic and phenotypic correlations among the 36 traits are presented in Table 6. At phenotypic level, days to silking (r_p= 0.245), plant height (r_p= 0.932), ear height (r_p = 0.907) ,number of ear at harvest (r_p = 0.429), internodes length (r_p = 0.543), ear length (r_p= 0.487), days to anthesis (r_p= 0.235), leaf width (r_p = 0.597) and number of nodes per plant (r_p = 0.781) were observed to have positive and highly significant ($P < 0.01$) correlation with grain yield per hectare and have negative and highly significant ($P < 0.01$) correlation with harvest index ($r_p = -0.275$). Similarly, Bullo (2010) reported that grain yield had positive and highly significant phenotypic associations with plant height, ear height, number of nodes per plant, internodes length, ear length, ear diameter, number of kernel rows per ear and stand count at harvest.

Table 6: Genotypic Coefficient of Correlation (above diagonal) and Phenotypic Coefficient of Correlation (below diagonal) of 36 maize genotypes studied.

Variable	DT	DS	DM	PH	EH	LW	NO	GY	AB	HI
DT		0.867**	0.956**	0.511**	0.488**	0.536**	0.474**	0.584**	0.532**	-0.141
DS	0.874**		0.767**	0.392**	0.376**	0.485**	0.548*	0.676**	0.625*	-0.124
DM	0.865**	0.780**		0.435*	0.268	0.466**	0.409*	0.651*	0.471*	0.006
PH	0.277**	0.287**	0.221*		0.880**	0.813**	0.820**	0.789**	0.820**	-0.848**
EH	0.283**	0.280**	0.224*	0.872**		0.730**	0.785**	0.763**	0.803**	-0.837**
LW	0.249*	0.247*	0.189*	0.793**	0.734**		0.744**	0.717**	0.793**	-0.624*
NO	0.238*	0.230*	0.171	0.919**	0.899**	0.809**		0.632**	0.853**	-0.670**
GY	0.235**	0.245**	0.201*	0.932**	0.907**	0.599**	0.781**		0.963**	-0.575**
AB	0.223*	0.239*	0.186	0.969**	0.946**	0.584**	0.613	0.865**		-0.673**
HI	-0.049	-0.059	0.007	-0.518**	-0.487**	-0.320**	-0.431**	-0.275**	-0.543**	
ET	0.127	0.137	0.097	0.171	0.187*	-0.005	0.143	0.429**	0.475**	-0.016
IN	0.432*	0.331**	0.247**	0.773**	0.754**	0.487**	0.555**	0.543**	0.561**	0.426**
EP	-0.170	-0.182	-0.144	0.080	0.092	0.0983	0.037	0.148	0.107	0.023
PL	0.028	0.043	0.031	0.190	0.242*	-0.093	0.087	0.273*	0.283	-0.175
EL	0.307**	0.437**	0.313**	0.578**	0.556**	0.376**	0.489**	0.487**	0.527**	-0.352**
ED	-0.122	-0.117	-0.093	0.104	0.103	0.102	0.070	0.136	0.113	0.002
KR	0.373**	0.517**	0.349**	0.009	-0.002	0.072	0.080	-0.019	-0.018	-0.076
AY	0.321	0.421**	0.043	0.122	0.032	0.421	0.0342	0.0821	0.0341	0.121
PE	-0.194	-0.186	-0.148	0.081	0.081	0.083	0.044	0.130	0.130	0.011
KW	0.592**	0.581**	0.677**	0.014	0.057	-0.070	-0.014	0.019	0.019	0.008

DT=Days to 50% anthesis, DS=Days to 50% silking, DM=Days to 75% maturity , PH= plant height , EH = ear height ,LW= Leaf width , NO= No. of nodes per plant , EP = No. of ears per plant , LP = No. of plant at harvest , EL =Ear length , ED = Ear diameter , KR = No. of kernels per row , PE = No. of row per ear , KW = 1000-Kernel weight , AB = Above ground biomass per hectare , GY= Grain yield per hectare, HI =Harvest index , ET = No. of ear at harvest ,IN = Inter node length and [*]= significant at the 0.05 probability level,[**]= highly significant at the 0.01 Probability level and ns = non-significant.

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Table 6... …

Variable	ET	IN	EP	PL	EL	ED	KR	AY	PE	KW
DA	0.457**	0.452**	0.057	0.266	0.767**	0.055	0.371	0.456**	-0.002	0.570**
DS	0.581	0.538*	0.064	0.297	0.751**	0.061	0.341*	0.312	0.012	0.587**
DM	0.553	0.463	-0.044	0.340	0.718**	0.004	0.241	0.021	-0.064	0.586**
PH	0.386	0.957**	0.151	0.427	0.887**	0.164	0.082	0.032	0.131	0.135
EH	0.438	0.911**	0.170	0.535	0.865**	0.172	0.064	0.611	0.147	0.173
LW	0.034	0.816**	0.222	-0.016	0.675**	0.231	0.041	0.152	0.317	-0.041
NO	0.213	0.907**	0.083	0.311	0.813**	0.124	0.281	0.034	0.787	0.106
GY	0.593	0.775**	0.183	0.488*	0.856**	0.200	0.044	0.531	0.175	0.149
AB	0.551	0.838**	0.125	0.537*	0.883**	0.143	0.077	0.063	0.105	0.177
HI	-0.004	-0.904**	0.140	-0.426	-0.684**	0.1178	-0.175	0.331	0.106	-0.081
ET		0.227**	-0.181	0.511*	0.532*	-0.227	0.394	0.421	-0.354	0.554*
IN	0.330		-0.239	0.321	0.877**	-0.226	0.488*	0.362	-0.328	0.406
EP	-0.235	-0.48		-0.275	-0.238	0.887**	-0.724**	0.434	0.895**	-0.735**
PL	0.341**	0.357	-0.243**		0.416*	-0.145	0.025	0.052	-0.174	0.492**
EL	0.344	0.786**	-0.487**	0.358		-0.215	0.393*	0.22	-0.253	0.504**
ED	-0.286	-0.472	0.883**	-0.206*	-0.464**		-0.725**	0.054	0.883**	-0.734**
KR	0.107	0.373	-0.457**	0.087	0.411**	-0.421**		0.022	-0.750**	0.754*
AY	0.361	0.412	0.110	0.041	0.721	0.261	0.312		0.541	0.451
PE	-0.283*	-0.483	0.895**	-0.224	-0.485**	0.870**	-0.463*	0.323		-0.760**
KW	0.303	0.317	-0.483**	0.307	0.396**	-0.438**	0.470**	0.462	-0.492**	

DT=Days to 50% anthesis, DS=Days to 50% silking, DM=Days to 75% maturity , PH= plant height , EH = ear height ,LW= Leaf width , NO= No. of nodes per plant , EP = No. of ears per plant , LP = No. of plant at harvest , EL =Ear length , ED = Ear diameter , KR = No. of kernels per row , PE = No. of row per ear , KW = 1000-Kernel weight , AB = Above ground biomass per hectare , GY= Grain yield per hectare, HI =Harvest index , ET = No. of ear at harvest ,IN = Inter node length and [*]= significant at the 0.05 probability level,[**]= highly significant at the 0.01 Probability level and ns = non-significant.

In line with the results obtained in this study, Habtamu and Hadji (2010) reported positive and significant associations of grain yield with ear height, plant height, ear length, ear diameter, number of kernels per row and thousand kernels weights. Similarly, Dagne (2008) also found positive and highly significant phenotypic correlations between grain yield and plant height, ear height, ear diameter, ear length, number of kernels per row and thousand kernels weights. Hence, the positive associations of the above mentioned traits with grain yield indicated that these traits are the most important ones to be considered for indirect selection to improve grain yield.

Number of ears per plant had highly significant ($p < 0.01$) and negative phenotypic correlation with ear length ($r_p = -0.487$), number of kernels per row ($r_p = -0.457$), 1000-kernels weight ($r_p = -0.483$) and number of plant at harvest ($r_p = -0.243$). This trait had highly significant ($p < 0.01$) and positive phenotypic correlation with ear diameter and number of rows per ear. These results are in agreement with the findings of Sadek *et al*, (2006). Grain yield had insignificant phenotypic correlations with ears per plant, ear diameter, number of kernels rows per ear and also showed negative non- significant correlation with1000-kernels weight, kernels texture and number of kernels per row indicating that selection for increased level of these traits may not bring significant change in grain yield. Habtamu and Hadji (2010) also found positive and significant correlation of grain yield with days to maturity.

Days to silking showed positive and highly significant phenotypic associations with days to anthesis ($r_p = 0.874$), days to maturity ($r_p = 0.780$), 1000-kernels weight (0.581), number of kernel per row ($r_p = 0.517$), ear length ($r_p = 0.437$), plant height ($r_p = 0.287$), inter node length ($r_p = 0.331$), ear height ($r_p = 0.280$), adjusted yield ($r_p =0.421$) and grain yield ($r_p =0.245$).

Similarly, Mandefro (1998) and Abedon *et al.* (1999) reported that days to silking and days to anthesis showed positive and highly significant correlation with each other (0.92). Days to anthesis indicated positive and highly significant associations with days to maturity ($r_p = 0.865$), day to anthesis ($r_p = 0.874$), grain yield per hectare ($r_p = 0.235$), ear length ($r_p = 0.307$), adjusted yield ($r_p = 0.321$), plant height ($r_p = 0.277$), ear height ($r_p = 0.283$) and 1000-kernels weight ($r_p = 0.592$), showed positive and significant associations with leaf width ($r_p = 0.249$), number of node per plant ($r_p = 0.238$), inter node length ($r_p = 0.432$), and above ground biomass ($r_p = 0.223$).

Plant height indicated positive and highly significant associations with ear height, number of nodes per plant, internodes length, ear length, leaf width and above ground biomass per hectare and negative and highly significant correlation with harvest index. Similarly, Mandefro (1998) reported positive and significant correlation of plant height and ear height with each other. Habtamu and Hadji (2010) also reported positive and highly significant association between plant height and ear height. The positive and highly significant correlation between ear height and plant height indicates the possibility to improve these two traits simultaneously.

At genotypic level days to anthesis showed positive and highly significant genotypic association with grain yield/ha ($r_g = 0.584$), days to maturity ($r_g = 0.956$), days to silking ($r_g = 0.867$), ear length ($r_g = 0.767$), thousand kernels weight ($r_g = 0.572$), leaf width ($r_g = 0.536$), above ground biomass ($r_g = 0.527$), plant height ($r_g = 0.511$), adjusted yield(0.456), inter node length ($r_g = 0.452$), ear height ($r_g = 0.488$), number of node per plant ($r_g = 0.474$), and number of ears at harvest(0.457).

Similarly ears per plant had positive and highly significant ($p < 0.01$) correlation with ear diameter ($r_g = 0.887$) and number of rows per ear ($r_g = 0.895$) adjusted yield ($r_g = 0.434$), and also it had negative and highly significant ($p < 0.01$) correlation with kernels per row ($r_g = -0.724$) and 1000-kernels weight ($r_g = -0.735$), number of plants at harvest ($r_g = -0.275$) and ear length ($r_g = -0.238$).

On the other hand 1000-kernels weight showed highly significant genotypic correlation with days to anthesis, days to silking, days to maturity, number of plant at harvest and ear length and it had significant genotypic coefficient with number of kernels per row. Number of rows per ear showed highly significant correlation with ears per plant and ear diameter at the genotypic level and highly significant correlation at phenotypic level with number of ears per plant and ear diameter.

From the results obtained in this study it may be concluded that improvement in genotypes of maize studied can be made by simultaneous selection of number of kernel rows per ear and 1000-kernels weight. Physiological maturity had highly significant ($p < 0.01$) and positive association with ear length, 1000-kernels weight and leaf width also had significant and positive association with plant height, number of node per plant, grain yield per hectare and above ground biomass. Similar findings were reported by Ahsan (1999); Mohammadi *et al*., (2003); Ojo *et al*., (2006); Sadek *et al*., (2006) and Abou-Deif (2007).

The highly significant positive correlations between grain yield and plant height, ear height, internodes length, ear length, leaf width, above ground biomass and harvest index at genotypic and phenotypic level indicated that these traits contributed positively towards yield, and should be considered when selecting for high grain yield.

Generally, grain yield was positively correlated with ear height, plant height, and leaf width, number of nodes per plant at both phenotypic and genotypic level. In general, the existence of positive associations in the present study between grain yield and number of kernels per row, ear length, plant height and ear height suggests that an increment of production maybe achieved upon improving either one or more of these traits.

4.2.3. Correlation among agronomic traits

Correlation among yield and yield components and other quantitative traits help to identify traits needed by maize genotypes to grow successfully under certain ecological conditions and also to identify and avoid traits that have little or no importance in the selection program. Many interesting associations were observed among yield related traits (Table6). The phenotypic and genotypic associations between days to anthesis and days to maturity were highly significant and positive ($r_p = 0.865$ and $r_g = 0.956$).This indicates that selection based on these traits will lead to early maturing genotypes.

Plant height was positively and highly significantly correlated with days to anthesis, days to silking, ear height, number of nodes per plant, leaf width, grain yield per hectare, above ground biomass, ear length and inters node length at phenotypic and genotypic levels. It is negatively and highly significantly correlated with harvest index. This indicates that taller genotypes tend to have higher biomass and takes longer time for days to anthesis and maturity but has large proportion of grain. On the other hand, plant height had highly significant and negative correlation with harvest index at genotypic level. This indicates that taller genotypes take long time to days to anthesis and less proportion of small and big maize.

Above ground biomass per plant showed highly significant and positive phenotypic correlation with plant height, leaf width, ear height, number of ear at harvest, grain yield per hectare, inter node length and ear length (Table 6). However; above ground biomass yield showed negatively and highly significantly phenotypic correlation with harvest index.

According to this finding, genotypic correlation of above ground biomass yield had positive and strong association with grain yield, ear length, plant height, ear height, leaf width, and inter node length. Days to anthesis, plant height, leaf width, ear height, and number of node per plant, inter node length and ear length had positive and highly significant association with grain yield.

The genotypic and phenotypic correlations between days to anthesis and days to maturity were Strong and positive ($r_g = 0.956$ and rp = 0.865), this indicates that genotypes that anthesis early were also early in maturing. Date of anthesis was positively correlated with ear length in both genotypic and phenotypic level ($r_g = 0.767$ and $r_p = 0.317$) respectively. Positive correlation between two traits implies better prospects for improving one trait. Most of the traits correlated positively among themselves, which ranged from low to high-level of correlation. Those traits with positive and significant correlation with each other and with grain yield per plant indicated that such traits were probably equally important in determining maize yield per plant.

In agreement with this study, Rangaswamy (1995) who reported that correlation among yield and yield components and other quantitative traits help in understanding the independence of the traits. Negative correlation between two traits implies selection for improvement of one trait will likely cause decrease in the other trait and vice versa.

4.2.4. Path coefficient analysis

Correlations in phenotypic and genotypic terms were further analyzed by path coefficient analysis technique, which involved partitioning of the correlation coefficient into direct and indirect effects via alternative traits or path. Path coefficient analysis specifies the cause and measures the relative importance of traits, while correlation measures only mutual associations without considering causation (Dewey and Lu, 1959). Path analysis has proven useful in providing additional information that describes cause and effect relationships, such as between yield and yield components, it is therefore, essential to assess the importance as well as degree of association of various quantitative traits in order to initiate an effective selection program aimed at genetic improvement of crop yield.

4.2.4.1. Phenotypic direct and indirect effects of various traits on grain yield

The path coefficient analysis at phenotypic level based on yield as dependent variable revealed that days to anthesis, days to maturity, ear height, leaf width, no. of node per plant, number of ear at harvest, above ground biomass and harvest index showed positive direct effect (Table 7). Compared to the simple correlation analysis, path analysis of maize yield and its traits demonstrated that, above ground biomass and ear height showed the highest direct influence, 0.95,and 0.382, respectively.

Additionally, 1000-kernels weight, number of node per plant and leaf width had positive and moderate direct effect on maize yield with magnitude of 0.108, 0.183, and 0.107 respectively. Days to anthesis, days to silking, plant height, number of kernels per row, 1000-kernels weight had indirect negative effect on maize yield. In addition to its maximum direct effect on maize yield, above ground biomass exhibited positive indirect effects through days of maturity, ear height, leaf width, number of node per plant, number of ear at harvest ,inter node length, ear length , number of row per ear, number of kernels per row and 1000-kernels weight.

Besides its direct effect on maize yield, harvest index, exhibited maximum favorable indirect effects on days to anthesis, days to silking, days to maturity, plant height, internodes length, number of plant at harvest, number of kernels per row, number of rows per ear and 1000-kernels weight. Negative indirect effect on above ground biomass yield with plant height, days to anthesis, days to silking and harvest index were observed.

Above ground biomass yield, 1000-kernels weight, ear length, number of plants at harvest, harvest index, number of nodes per plant, leaf width and ear height contributed their major effects as direct effects. Therefore, these traits could be considered as major components of selection in a breeding program for obtaining higher maize yield. Phenotypic path coefficient analysis also revealed that days to maturity, days to anthesis, leaf width, ear length, and number of rows per ear and 1000-kernels weight exerted low and direct effects on maize yield. They had also positive and significant correlation with maize yield.

Negative direct effects were recorded for days to silking (-0. 181), plant height (-0.846), number of plant at harvest (-0.148), and number of kernels per row (-0.01). Plant height and days to silking was positively and significantly correlated with grain yield per plant and its negative direct effect on grain yield was counterbalanced by its positive indirect effect via days to maturity, ear height, above ground biomass, leaf width, number of ear at harvest, internode length and number of node per plant.

Therefore, it is evident from the result of this study that high consideration should be placed on days to maturity, ear height, above ground biomass, leaf width, and number of ears at harvest, internode length and number of nodes per plant to improve maize yield potential, since they showed positive direct effect; specially harvest index and above ground biomass. This finding is in agreement with (Sattar *et al.*2007) who reported that plant height and biomass yield contributed directly to grain yield indicating their importance as selection index for yield improvement.

Table 7: Phenotypic direct effect (bold face) and indirect effect (off diagonal) of various traits on maize yield per hectare evaluated.

Trait	DT	DS	DM	PH	EH	LW	NO	AB
DT	**0.022**	-0.04	-0.028	-0.008	-0.008	-0.006	-0.006	-0.006
DS	-0.177	**-0.181**	-0.183	-0.053	-0.057	-0.047	-0.033	-0.034
DM	0.028	0.029	**0.022**	0.008	0.008	0.007	0.005	0.0054
PH	-0.226	-0.211	-0.177	**-0.846**	-0.836	-0.535	-0.73	-0.757
EH	-0.115	0.114	0.096	0.291	**0.382**	0.234	0.208	0.321
LW	-0.035	0.035	0.021	0.083	0.077	**0.107**	0.083	0.07
NO	-0.045	0.044	0.021	0.17	0.153	0.139	**0.183**	0.138
AB	0.234	0.273	0.205	0.003	0.867	0.763	0.927	**0.95**
HI	-0.008	-0.009	0.001	-0.083	-0.077	-0.045	-0.058	-0.084
ET	0.045	0.039	0.027	0.049	0.058	-0.002	0.04	0.117
IN	0.047	0.035	0.034	0.085	0.08	0.077	0.068	0.068
PL	-0.003	-0.0048	-0.004	-0.028	-0.037	0.012	-0.014	-0.044
EL	0.025	0.037	0.028	0.048	0.047	0.031	0.041	0.047
KR	-0.0047	-0.005	-0.004	-0.0001	0.00002	-0.0007	-0.0008	0.000
PE	-0.008	-0.008	-0.0053	0.004	0.003	0.003	0.002	0.003
KW	0.074	0.074	0.078	0.001	0.007	-0.007	-0.0014	0.002

Dt=Days to 50% anthesis, DS=Days to 50% silking, DM=Days to 75% maturity , PH= plant height , EH = ear height, LW= Leaf width , NO = No. of nodes per plant , Et = No. of ears at harvest , Pl = No. of plant at harvest , EL =Ear length , KR = No. of kernels per row , PE = No. of row per ear , KW = 1000-Kernel weight, HI =Harvest index, IN = Internode length ,AB = Above ground biomass per hectare

Table 7…...

Trait	HI	ET	IN	PL	EL	KR	PE	KW
DA	0.003	-0.00	-0.0104	-0.0009	-0.0137	-0.014	0.007	-0.019
DS	0.011	-0.033	-0.073	-0.0073	-0.093	-0.087	0.033	-0.113
DM	0.003	0.004	0.009	0.0008	0.0086	0.011	-0.005	0.02
PH	0.282	-0.123	-0.529	-0.1274	-0.448	-0.007	-0.078	-0.0088
EH	-.181	0.087	0.253	0.0848	0.213	-0.0009	0.047	0.022
LW	-.033	-0.001	0.05	-0.0962	0.049	0.008	0.0086	-0.007
NO	-.072	0.027	0.109	0.0193	0.085	0.014	0.009	-0.0035
AB	-0.718	0.434	0.771	0.3303	0.73	-0.022	0.148	0.022
HI	**0.13**	-0.003	0.059	-0.027	-0.049	-0.0084	0.002	0.0014
ET	-.005	**0.202**	0.081	0.1334	0.084	0.042	-0.078	0.007
IN	0.059	0.034	**0.129**	0.0457	0.086	0.0349	-0.078	0.04
PL	0.027	0.045	-0.039	**-0.148**	-0.038	-0.014	0.033	-0.032
EL	-.028	0.038	0.058	0.022	**0.084**	0.027	-0.04	0.025
KR	0.008	-0.001	-0.003	-0.0008	-0.004	**-0.01**	0.005	-0.005
PE	0.003	-0.011	-0.017	-0.0068	-0.017	-0.018	**0.029**	-0.053
KW	0.001	0.022	0.034	0.0327	0.023	0.052	-0.053	**0.108**

Dt= Days to 50% anthesis, DS =Days to 50% silking, DM=Days to 75% maturity , PH = plant height , EH = ear height, LW = Leaf width , NO = No. of nodes per plant , Et = No. of ears at harvest , Pl = No. of plant at harvest , EL = Ear length , KR = No. of kernels per row , PE = No. of row per ear , KW = 1000-Kernel weight, HI = Harvest index, IN = Inter node length, AB = Above ground biomass per hectare

4.2.4.2. Genotypic direct and indirect effects of various traits on grain yield

The genotypic direct and indirect effects of sixteen yield related traits on grain yield are shown in Table 8. The maximum positive genotypic direct effect on grain yield was observed in above ground biomass yield (1.036) followed by harvest index (0.332), inter node length (0.083), leaf width (0.057), number of ears at harvest (0.054) and number of rows per ear (0.033), Above ground biomass also showed positive and indirect influence on date of anthesis, days to maturity, plant height, leaf width, number of nodes per plant, number of row per ear, 1000-kernels weight and number of ears at harvest. The positive indirect effect nullified the negative indirect effects on grain yield via days to silking, ear height, number of plants at harvest, harvest index, and number of kernels per row. Though plant height showed strong and highly significant association with grain yield, its positive direct effect on yield was counterbalanced by its indirect effect through all traits, except ear length. Habtamu and Hadji (2010) also found plant height exerted positive direct effect and positive association with grain yield that agreed with this result.

Negative direct effects were recorded for days to silking (-0.037), number of kernels per row (-0.016), number of plant at harvest (-0.013) and ear height (-0.053). Though, days to silking and ear height were positively and highly significantly correlated with grain yield, it showed minimum negative direct effect on grain yield. Besides the negative direct effect of days of silking and ear height on grain yield, all traits except harvest index and number of row per ear exerted negative indirect effect on grain yield via days to silking.

The genotypic path analysis indicated that above ground biomass and harvest index showed positive and highly significant correlation, therefore, these traits are more important than other traits for the genetic improvement of maize.

Table 8: Genotypic direct effect (bold face) and indirect effect (off diagonal) of various traits on maize yield per hectare evaluated.

Trait	DA	DS	DM	PH	EH	LW	NO	AB
DA	**0.018**	0.019	0.017	0.010	0.008	0.010	0.008	0.010
DS	-0.037	**-0.037**	-0.004	-0.018	-0.017	-0.019	-0.016	-0.020
DM	0.003	0.003	**0.004**	0.003	0.001	0.002	0.002	0.003
PH	0.013	0.011	0.008	**0.024**	0.024	0.018	0.022	0.031
EH	-0.027	-0.025	-0.018	-0.052	**-0.053**	-0.037	-0.036	-0.048
LW	0.030	0.003	0.028	0.037	0.043	**0.058**	0.048	0.040
NO	0.008	0.008	0.007	0.014	0.012	0.012	**0.025**	0.014
AB	0.544	0.540	0.394	0.832	0.835	0.827	0.982	**1.036**
HI	-0.043	-0.040	0.002	-0.240	-0.247	-0.179	-0.213	-0.214
ET	0.025	0.027	0.024	0.015	0.017	0.002	0.011	0.034
IN	0.033	0.033	0.027	0.073	0.070	0.054	0.070	0.054
PL	-0.002	-0.004	-0.003	-0.005	-0.007	0.000	-0.004	-0.007
EL	0.004	0.004	0.004	0.005	0.005	0.003	0.003	0.005
KR	-0.007	-0.008	-0.005	-0.001	-0.001	-0.001	-0.003	-0.001
PE	-0.034	0.000	-0.001	0.002	0.004	0.003	0.015	0.002
KW	0.012	0.012	0.012	0.004	0.004	0.000	0.002	0.003

Dt =Days to 50% anthesis, DS = Days to 50% silking, DM = Days to 75% maturity , PH = plant height , EH = ear height, LW = Leaf width , NO = No. of nodes per plant , Et = No. of ears at harvest , Pl = No. of plant at harvest , EL = Ear length , KR = No. of kernels per row , PE = No. of row per ear , KW = 1000-Kernel weight, HI = Harvest index, IN = Internode length ,AB = Above ground biomass per hectare

Table 8…..

Trait	HI	ET	IN	PL	EL	KR	PE	KW
DA	-0.003	0.008	0.008	0.004	0.014	0.014	0.100	0.012
DS	0.005	-0.018	-0.017	-0.009	-0.025	-0.016	-0.001	-0.023
DM	0.000	0.002	0.003	0.001	0.004	0.001	-0.203	0.002
PH	0.017	0.008	0.020	0.007	-0.019	0.002	0.004	0.004
EH	0.037	-0.019	-0.043	-0.023	-0.040	-0.003	-0.007	-0.008
LW	-0.477	0.003	0.042	-0.001	0.044	0.002	0.013	0.002
NO	-0.010	0.004	0.013	0.004	0.011	0.004	0.014	0.002
AB	-0.784	0.482	0.894	0.458	0.920	0.091	0.111	0.165
HI	**0.332**	-0.001	0.259	-0.105	-0.182	0.058	0.033	-0.027
ET	0.000	**0.054**	0.013	0.023	0.024	0.017	-0.014	0.028
IN	-0.070	0.017	**0.083**	0.017	0.059	0.028	-0.018	0.024
PL	0.005	-0.007	-0.003	**-0.013**	-0.007	0.000	0.002	-0.008
EL	-0.004	0.004	0.005	0.003	**0.007**	0.002	-0.002	0.004
KR	0.004	-0.004	-0.007	0.000	-0.007	**-0.016**	0.010	-0.010
PE	0.002	-0.004	-0.004	-0.003	-0.004	-0.012	**0.033**	-0.014
KW	-0.002	0.012	0.007	0.008	0.012	0.013	-0.013	**0.022**

Dt = Days to 50% anthesis, DS = Days to 50% silking, DM = Days to 75% maturity, PH = plant height , EH = ear height, LW = Leaf width , NO = No. of nodes per plant , Et = No. of ears at harvest , Pl = No. of plant at harvest , EL = Ear length , KR = No. of kernels per row , PE = No. of row per ear , KW = 1000-Kernel weight, HI = Harvest index, IN = Inter node length ,AB = Above ground biomass per hectare

5. SUMMARY AND RECOMMENDATIONS

5.1. Summary

The progress of crop improvement program depends on the choice of the breeding material, the extent of variability and the knowledge of quantitative traits with yield and yield related traits. In view of this, a study was conducted with the objective to assess the genetic variability and association between agronomic traits in some maize genotypes.

Analysis of variance showed the presence of highly significant differences among the tested genotypes for the 20 traits considered which indicates the existence of sufficient genetic variability and there was less coefficient of variation in all of the traits indicating good precision of the experiment.

The ranges of mean values for most of the traits were large showing the existence of variation among the tested genotypes. Phenotypic coefficients of variation (PCV) were found to be higher than genotypic coefficients of variation (GCV) for all traits. The two values differed slightly indicating less influence of the environmental factors. Days to 90%maturity, days to 50% silking, grain yield per hectare, number of rows per ear and days to50% anthesis. Inter node length, number of ears at harvest, number of ear per plant, number of plant at harvest, ear diameter, above ground biomass yield and harvest index had moderate genotypic and phenotypic coefficients of variation .Days to90%maturity, days to 50% siliking, days to 50% anthesis, leaf width, number of rows per ear, 1000kernel weight, number of nodes per plant, adjusted yield, and grain yield had the least phenotypic and genotypic coefficients of variation.

High heritability estimates were obtained for grain yield, number of rows per ear, adjusted yield, number of kernels per row,1000kernel weight, above ground biomass yield, ear height, days to50% anthesis, days to 50% silking, ear length, number of ears per plant, days to 90% maturity, number of ears at harvest, inter node length, number of nodes per plant ,leaf width, harvest index, plant height, number of plants at harvest, ear diameter, indicating that these traits may respond positively to phenotypic selection.

Genetic advance expressed as percentage of mean (GAM) was high for grain yield ,adjusted yield, aboveground biomass yield, 1000kernel weight, number of kernels per row, number of ears per plant, ear height, number of ears at harvest. Low estimates of genetic advances expressed as percentage of mean were observed for internodes length, plant height, days to 90% maturity, number of nodes per plant, days to 50% siliking, days to 50% anthesis, number of plants at harvest and ear diameter. The path coefficient analysis at phenotypic level based on grain yield as dependent variable revealed that days to anthesis, days of maturity, ear height, leaf width, number of node per plant, number of ear at harvest, above ground biomass and harvest index showed positive direct effect.

The maximum positive genotypic direct effect in grain yield was observed in above ground biomass yield followed by harvest index, inter node length, number of kernels per row, number of ears at harvest and leaf width. The genotypic path analysis also indicated that negative direct effects were recorded for days of silking, number of kernels per row, number of plant at harvest and ear height.

5.2. Conclusion

There were significant genetic differences among the genotypes for all the traits, which suggested huge scope of selection for genotypes with desirable characters. The traits which revealed high magnitude of heritability and genetic advance were controlled by fixed genetic factors which advocated that they might be improved through selection. The characters positively and significantly associated with grain yield could be reliable selection criteria for grain yield in maize(*Zea Mays L.*) for this group of genotypes. The genetic variability among genotypes observed should be utilized for future maize improvement program.

Thus, based on the results obtained the following could be recommended.

- Plant height, maturity traits, above ground biomass should be used as selection criteria for yield improvement in maize.
- The genetic variability among genotypes observed should be utilized for future maize improvement program.

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7. APPENDICES

Appendix 1: Mean performance 20 quantitative traits of 36 maize genotypes.

No	Trait	DT	DM	DS	PH
1	Al 205 X CML 157	78.667^{FHDEG}	154.667^{GFDE}	$81.667^{EJDIHGF}$	153.33^{EBDAC}
2	Al 205 X CML 316	78.667^{FhHDEG}	154.333^{GFE}	$81.667^{EJDIHGF}$	132.67^{EDC}
3	AL 206 X AL 99 CML 79A	79.333^{FHDECG}	156.333^{FDEC}	$82.333^{EJDIHGCF}$	160^{EBDAC}
4	AL 206 X CML 316	82.333^{FBDEC}	156.667^{FDEC}	$85.667^{EBDAGCF}$	176^{BA}
5	AL 206 X CML 44	78.667^{FHDEG}	155.333^{GFDEC}	81.667^{EJDIHG}F	157.67^{EBDAC}
6	Al 99 AL 281 X CML 157	75^{HI}	154^{GF}	78^{KJ}	149.33^{EBDAC}
7	Al 99 AL 281 X CML 44	79.333^{FHDECG}	156^{GFDEC}	$81.667^{EJDIHGF}$	160.67^{EBDAC}
8	Al 99 CML 270 X Al 99 CML 79A	76.333^{HIG}	154^{GF}	79.333^{KJI}	142^{EBDC}
9	Al 99 CML 270 X CML 44	86.333^{AB}	160^{BA}	89.333^{BA}	125^{E}
10	Al 99 CML 300A X AL 99 CML 79A	83.667^{BDAC}	156.333^{FDEC}	87^{BDAC}	152.67^{EBDAC}
11	Al 99 CML 300A X CML 44	77.667^{FHEG}	155.667^{GFDEC}	$81.333^{EJDIHGF}$	160^{EBDAC}
12	Al 99 CML 370 X AL 205	77.333^{FHEI}	154.333^{GFE}	80.333^{KJIHGF}	133^{EDC}
13	Al 99 CML 39A X AL 99 CML 79A	76.333^{HIG}	154.667^{GFDE}	79.333^{KJI}	169^{BAC}
14	Al 99 CML 39A X CML 316	77^{FHIG}	155.333^{GFDEC}	80^{KJIHG}	143.33^{EBDAC}
15	Al 99 CML 39A X CML 44	71.667^{I}	153^{G}	74.667^{K}	134.33^{EDC}
16	Al 99 CML 79A X CML 316	79^{FHDEG}	155.333^{GFDEC}	$82^{EJDIHGCF}$	144.67^{EBDAC}
17	Al 99 CML 79A X CML 44	83.667^{BDAC}	158^{BAC}	86.667^{EBDAC}	166^{BDAC}
18	CML 306 X CML 44	81.333^{FBDECG}	156.667^{FDEC}	$84.677^{EBDIHGCF}$	163.67^{BDAC}
19	CML 126 X CML 157	77.667^{FHEG}	155^{GFDEC}	$80.667^{EKJIHGF}$	143.33^{EBDAC}
20	CML 126 X CML 316	77.667^{FHEG}	154.667^{GFDE}	$80.667^{EKJIHGF}$	157.33^{EBDAC}
21	CML 157 X AL 99A 79A	76.333^{HIG}	154^{GF}	79.667^{KJIH}	148.67^{EBDAC}
22	CML 157 X CML 316	77^{FHIG}	154.333^{GFE}	80^{KJIHG}	142.67^{EBDAC}
23	CML 157 X CML 44	78^{FHDEG}	154.667^{GFDE}	$81^{EJDIHGF}$	155.33^{EBDAC}
24	CML 161 X CML 165	80.333^{FHDECG}	155.667^{GFDEC}	$83.667^{EBJDIHGCF}$	158.67^{EBDAC}

Appendix 1…

No	Trait	DT	DM	DS	PH
25	CML 306 X CML 157	82.667^{FBDEC}	158^{BAC}	$85.667^{EBDHGCF}$	153.33^{EBDAC}
26	CML 306 X CML 316	89^{A}	160.66^{7A}	92^{A}	131.33^{ED}
27	CML 316 X CML 44	85^{BAC}	158^{BAC}	88^{BAC}	132^{EDC}
28	CML 32 X AL 99 CML 79A	80.333^{FHDEC}	155.667^{GFDEC}	$83.333^{EBJDIHGCF}$	157.33^{EBDAC}
29	CML 32 X CML 44	77.333^{FHE}I	155^{GFDEC}	80.333^{KJIHGF}	136.33^{EDC}
30	CML 44 X CML 157	79^{FHDEG}	155^{GFDEC}	$82^{EJDIHGCF}$	144.33^{EBDAC}
31	TL 99 AL 1505-35 X CML 316	80^{FHDECG}	156.667^{FDEC}	$82^{EJDIHGCF}$	164.33^{BDAC}
32	Birkata	81.333^{FBDECG}	156.333^{FDEC}	$84.333^{EBDIHGCF}$	159.67^{EBDAC}
33	Bukuri	80^{FHDECG}	156.333^{FDEC}	$82.333^{EJDIHGCF}$	158^{EBDAC}
34	Bukuri	83^{bBDEC}	157.333^{BDEC}	86.333^{EBDCF}	157.67^{EBDAC}
35	Mnelkassa 7	83^{BDEC}	156.667^{FDEC}	$86^{EBDAGCF}$	147.33^{EBDAC}
36	Yellow Pop	82^{FBDECG}	157.667^{BDAC}	$85^{EBDIHGCF}$	180^{A}

Appendix 1…

No	Trait	EH	EL	LW	NO
1	Al 205 X CML 157	85.667^{A}	$14.687^{EBDHAGCF}$	8.44^{BAC}	11.267^{EBDAC}
2	Al 205 X CML 316	78.667^{BA}	13.593^{EDHGF}	8.24^{BAC}	11.267^{EBDAC}
3	AL 206 X AL 99 CML 79A	77^{BAC}	$14.987^{EBDAGCF}$	8.2^{BDAC}	12.6^{BAC}
4	AL 206 X CML 316	76.667^{BAC}	$14.733^{EBDHAGCF}$	9.246774^{BA}	13.2^{A}
5	AL 206 X CML 44	75.333^{BDAC}	16.067^{BDAC}	9.44^{A}	12.133^{EBDAC}
6	Al 99 AL 281 X	75.333^{BDAC}	16.3^{BAC}	9.0067^{BA}	10.2^{E}

	CML 157				
7	Al 99 AL 281 X CML 44	75.333^{BDAC}	14.78^{EDHGF}	8.8867^{BAC}	12.4^{BDAC}
8	Al 99 CML 270 X Al 99 CML 79A	73.667^{EBDAC}	15.533^{EBDACF}	9.22^{BA}	10.933^{EB}
9	Al 99 CML 270 X CML 44	73.667^{EBDAC}	12.267^{H}	7.0733^{DC}	11.467^{EBDAC}
10	Al 99 CML 300A X AL 99 CML 79A	73.333^{EBDAC}	12.967^{HGF}	7.76^{BDAC}	12.067^{EBDAC}
11	Al 99 CML 300A X CML 44	72.867^{EBDAC}	16.713^{A}	9.033^{BA}	12.533^{BAC}
12	Al 99 CML 370 X AL 205	72.^{333EBDAC}	15.6^{EBDAC}	9.22^{BA}	11.6^{EBDAC}
13	Al 99 CML 39A X AL 99 CML 79A	72.333^{EBDAC}	16.66^{BA}	9.34^{BA}	13.067^{A}
14	Al 99 CML 39A X CML 316	71^{EBDAC}	14.8^{EBDHAGCF}	7.52^{BDC}	11^{EBDC}
15	Al 99 CML 39A X CML 44	70.333^{EBDAGCF}	15.013^{EBDAGCF}	8.4933^{BAC}	10.933^{EBDC}
16	Al 99 CML 79A X CML 316	69.667^{EBDAGCF}	15.133^{EBDACF}	8.5267^{BAC}	11.267^{EBDAC}
17	Al 99 CML 79A X CML 44	69.667^{EBDAGCF}	15.227^{EBDACF}	8.1067^{BDAC}	12^{EBDAC}
18	CML 306 X CML 44	69.333^{EBDAGCF}	16.1^{BDAC}	8.82^{BAC}	12.333^{BDAC}
19	CML 126 X CML 157	69^{EBDGCF}	14.067^{EBDHAGCF}	9.0733^{BA}	11.467^{EBDAC}
20	CML 126 X CML 316	67.333^{EBDGCF}	14.833^{EBDHAGCF}	9.1333^{BA}	11.533^{EBDAC}
21	CML 157 X AL 99A 79A	66^{EBDGCF}	16.153^{BDAC}	9.36^{BA}	10.733^{EDC}
22	CML 157 X CML 316	65.333^{EBDGCF}	16.033^{BDAC}	8.3133^{BAC}	11.467^{EBDAC}
23	CML 157 X CML 44	65.333^{EBDGCF}	15.513^{EBDACF}	8.6733^{BAC}	11.467^{EBDAC}
24	CML 161 X CML 165	65.333^{EBDGCF}	15.733^{EBDAC}	8.1867^{BDAC}	12.2^{EBDAC}

Appendix 1…

No	Trait	EH	EL	LW	NO
25	CML 306 X CML 157	65^{EBDGCF}	15.633^{EBDAC}	8.36^{BAC}	11.4^{EBDAC}
26	CML 306 X CML 316	63^{EBDGCF}	14.067^{EBDHAGCF}	6.3467^{D}	10.933^{EDC}
27	CML 316 X CML 44	61.667^{EDGCF}	12.453^{HG}	7.5067^{BDC}	10.267^{E}
28	CML 32 X AL 99 CML 79A	61^{EDGCF}	13.2^{EHGF}	9.06676^{BA}	12^{EBDAC}
29	CML 32 X CML 44	61^{EDGCF}	15.04^{EBDAGCF}	8.5733^{BAC}	11^{EBDC}
30	CML 44 X CML 157	59.667^{EDGF}	14.347^{EBDHAGCF}	8.4067^{BAC}	10.4^{ED}
31	TL 99 AL 1505-35 X CML 316	59.667^{EDGF}	15.133^{EBDACF}	8.7067^{BAC}	12.2^{EBDAC}
32	Birkata	59.333^{EDGF}	14.7^{EBDHAGCF}	7.5867^{BDAC}	12.333^{GDAC}
33	Bukuri	59.067^{EDGF}	14.533^{EBDHAGCF}	8.6667^{BAC}	12.8^{BA}
34	Bukuri	58.333^{EGF}	14.507^{EBDHAGCF}	8.2467^{BAC}	12.2^{EBDAC}
35	Mnelkassa 7	55.667^{GF}	13.593^{EDHGF}	7.6667^{BDAC}	12^{EBDAC}
36	Yellow Pop	54^{G}	13.89^{EDHGCF}	7.6^{BDAC}	10.733^{EDC}

Appendix 1…

No	Trait	IN	ET	EP	PL	ED
1	Al 205 X CML 157	12.293^{B}	26^{EBDAC}	1.4^{BDC}	18.667^{EBDAC}	7.213^{BA}
2	Al 205 X CML 316	10.46^{B}	$24^{EBDAGCF}$	1.2333^{BEDC}	19^{EBDAC}	3.887^{BA}
3	AL 206 X AL 99 CML 79A	12.06^{B}	22.667^{EBDGCF}	1.4^{BDC}	16.333^{EBDC}	4.147^{BA}
4	AL 206 X CML 316	13.027^{B}	29.667^{BDAC}	1.5667^{BC}	19^{EBDAC}	4.273^{BA}
5	AL 206 X CML 44	13.34^{B}	28^{EBDAC}	1.6333^{BAC}	17.333^{EBDAC}	3.813^{BA}
6	Al 99 AL 281 X CML 157	12.6^{B}	27.667^{EBDACF}	1.5^{BDC}	18.667^{EBDAC}	3.767^{BA}
7	Al 99 AL 281 X CML 44	12.82^{B}	29.667^{BDAC}	1.4667^{BDC}	20^{BAC}	7.76^{A}
8	Al 99 CML 270 X Al 99 CML 79A	12.233^{B}	30.333^{BBAC}	1.5333^{BDC}	19.667^{BDAC}	6.580^{BA}
9	Al 99 CML 270 X CML 44	9.68B	19.667^{EGF}	13^{BEDC}	15^{E}	3.467^{B}
10	Al 99 CML 300A X AL 99 CML 79A	18.44^{A}	$23.667^{EBDAGCF}$	1.4667^{BDC}	16.333^{EBDC}	7.067^{BA}
11	Al 99 CML 300A X CML 44	12.053^{B}	$23.333^{EBDAGCF}$	1.4667^{BDC}	16^{EDC}	3.94^{BA}
12	Al 99 CML 370 X AL 205	11.66^{B}	26^{EBDACF}	1.2667^{BEDC}	20.667^{BA}	4.153^{BA}
13	Al 99 CML 39A X AL 99 CML 79A	12.46^{B}	32.667^{A}	1.5333^{BDC}	21.333^{A}	4.073^{BA}
14	Al 99 CML 39A X CML 316	11.873^{B}	27.333^{EBDACF}	1.4667^{BDC}	18.33^{EBDAC}	3.467^{B}
15	Al 99 CML 39A X CML 44	11.967^{B}	$24^{EBDAGCF}$	1.5^{BDC}	16.33^{EBDC}	3.827^{BA}
16	Al 99 CML 79A X CML 316	10.327	$23^{EBDAGCF}$	1.3667^{BEDC}	17.33^{EBDAC}	3.89^{BA}
17	Al 99 CML 79A X CML 44	11.82^{B}	22.33^{EBDGCF}	1.2^{BEDC}	18.67^{EBDAC}	6.53^{BA}
18	CML 306 X CML 44	12.627^{B}	20.333^{EDGF}	1.167^{EDC}	17.67^{EBDAC}	4.13^{BA}
19	CML 126 X CML 157	13.007^{B}	25.667^{EBDAC}	1.33^{BEDC}	19.3^{EBDAC}	4.12^{BA}
20	CML 126 X CML 316	10.507^{B}	29.667^{BDAC}	1.7^{BA}	17.3^{EBDAC}	7.46^{BA}
21	CML 157 X AL 99A 79A	12.327^{B}	27.33^{EBDACF}	1.7^{BA}	16^{EDC}	4^{BA}
22	CML 157 X CML 316	12.26^{B}	31^{BAC}	2.1333^{A}	15.333^{ED}	3.713^{B}
23	CML 157 X CML 44	12.007^{B}	25.667^{EBDAC}	1.5^{BDC}	17.3^{EBDAC}	3.667^{B}
24	CML 161 X CML 165	11.173^{B}	26.333^{EBDAC}	1.433^{BDC}	18.3^{EBDAC}	3.88^{BA}
25	CML 306 X CML 157	11.687^{B}	22^{EBDGCF}	1.267^{BEDC}	18.3^{EBDAC}	7.25^{BA}
26	CML 306 X CML 316	10.247^{B}	15.333^{G}	0.8667^{E}	17^{EBDAC}	3.48^{B}
27	CML 316 X CML 44	10.253^{B}	26.333^{EBDAC}	1.467^{BDC}	17.67^{EBDAC}	3.81^{BA}
28	CML 32 X AL 99 CML 79A	11.073^{B}	29.333^{EBDAC}	1.467^{BDC}	19.67^{BDAC}	4.27^{BA}
29	CML 32 X CML 44	9.787^{B}	27.67^{EBDACF}	1.433^{BDC}	19.67^{BDAC}	3.94^{BA}
30	CML 44 X CML 157	11.133^{B}	31.667^{BA}	1.7^{BA}	19^{EBDAC}	3.493^{B}
31	TL 99 AL 1505-35 X CML 316	12.053^{B}	30^{BDAC}	1.6^{BC}	18.67^{EBDAC}	3.87^{BA}
32	Birkata	11.467^{B}	26^{EBDACF}	1.2667^{BEDC}	21^{A}	3.86^{BA}
33	Bukuri	10.68^{B}	21.333^{EDGCF}	1.1667^{EDC}	19^{EBDAC}	6^{BA}
34	Bukuri	11.267^{B}	26.333^{EBDAC}	1.267^{BEDC}	20^{BAC}	3.913^{BA}
35	Mnelkassa 7	11.007^{B}	$24^{EBDAGCF}$	1.3^{BEDC}	18.3^{EBDAC}	6.37^{BA}

36	Yellow Pop	10.347B	18^{GF}	1.0333^{ED}	18^{EBDAC}	3.9^{BA}

Appendix 1…

No	Trait	KR	PE	KW
1	Al 205 X CML 157	$33.667^{EBDHACF}$	13.8667^{A}	296^{EHGF}
2	Al 205 X CML 316	$33.667^{EBDHACF}$	12.8^{EBDACF}	$327.33^{EBDHAGCF}$
3	AL 206 X AL 99 CML 79A	35^{EBDACF}	12.8^{EBDACF}	$354^{EBDHAGCF}$
4	AL 206 X CML 316	$33^{EBIDHAGCF}$	13.2^{BDAC}	377^{BDAC}
5	AL 206 X CML 44	37^{BAC}	13.4667^{BAC}	$337.33^{EBDHAGCF}$
6	Al 99 AL 281 X CML 157	35.333^{EBDAC}	12.8^{EBDACF}	293^{HGF}
7	Al 99 AL 281 X CML 44	$31^{EIDHJGF}$	13.8667^{A}	$335.67^{EBDHAGCF}$
8	Al 99 CML 270 X Al 99 CML 79A	$33.667^{EBDHACF}$	12.1333^{EDGCF}	$334.3^{EBBDHAGCF}$
9	Al 99 CML 270 X CML 44	29.333^{IHJG}	13.0667^{EBDAC}	185.67^{I}
10	Al 99 CML 300A X AL 99 CML 79A	$31.667^{EIDHJGCF}$	13.0667^{EBDAC}	280.67^{H}
11	Al 99 CML 300A X CML 44	36.333^{BDAC}	13.2^{BDAC}	$360^{EBDAGCF}$
12	Al 99 CML 370 X AL 205	$34.667^{EBDAGCF}$	12.933^{EBDACF}	$342^{EBDHAGCF}$
13	Al 99 CML 39A X AL 99 CML 79A	37.667^{BA}	13.7333^{BA}	363^{EBDACF}
14	Al 99 CML 39A X CML 316	$31.333^{EIDHJGF}$	11.8667^{EDGF}	$325.33^{EBDHAGCF}$
15	Al 99 CML 39A X CML 44	29.667^{IHJGF}	12.533^{EBDGCF}	373.67^{BDAC}
16	Al 99 CML 79A X CML 316	30.667^{EIHJGF}	$12.53^{EBDAGCF}$	371^{EBDAC}
17	Al 99 CML 79A X CML 44	$33^{EBIDHAGCF}$	11.8667^{EDGF}	$337^{EBDHAGCF}$
18	CML 306 X CML 44	37.667^{BA}	12.2667^{EDGCF}	$339.67^{EBDHAGCF}$
19	CML 126 X CML 157	$34.333^{EBDAGCF}$	12^{EDGF}	$34767^{EBDHAGCF}$
20	CML 126 X CML 316	$32.67^{EBIDHAGCF}$	12^{EDGF}	396^{A}
21	CML 157 X AL 99A 79A	$34.667^{EBDAGCF}$	12.8^{EBDACF}	$328.33^{EBDHAGCF}$

Appendix 1…

No	Trait	KR	PE	KW
22	CML 157 X CML 316	$33.33^{EBIDHAGCF}$	12.1333^{EDGCF}	305^{EDHGCF}
23	CML 157 X CML 44	35.33^{EBDAC}	13.2^{BDAC}	$315^{EBDHGCF}$
24	CML 161 X CML 165	38^{A}	12.53^{EBDACF}	$308.33^{EBDHGCF}$
25	CML 306 X CML 157	$34^{EBDAGCF}$	13^{EBDACF}	382.33^{BA}
26	CML 306 X CML 316	28.333^{IHJ}	10.4^{H}	303.67^{EDHGF}
27	CML 316 X CML 44	27^{J}	11.2^{HG}	$333.67^{EBDHAGCF}$
28	CML 32 X AL 99 CML 79A	$32.33^{EBIDHJGCF}$	12.2667^{EDGCF}	$343^{EBDHAGCF}$
29	CML 32 X CML 44	29.333^{IHJG}	12.2667^{EDGCF}	$347.33^{EBDHAGCF}$
30	CML 44 X CML 157	28^{IJ}	13.2^{BDAC}	$306.33^{EBDHGCF}$
31	TL 99 AL 1505-35 X CML 316	30.333^{EIHJGF}	12.4^{EBDGCF}	$349^{EBDHAGCF}$
32	Birkata	30.667^{EIHJGF}	$12.533^{EBDAGCF}$	$333.33^{EBDHAGCF}$
33	Bukuri	$31.333^{EIDHJGF}$	11.6^{HGF}	381.33^{BAC}
34	Bukuri	$31.333^{EIDHJGF}$	11.6^{HGF}	$328.33^{EBDHAGCF}$
35	Mnelkassa 7	30^{EIHJGF}	11.7333^{EHGF}	$310.67^{EBDHGCF}$
36	Yellow Pop	$32.333^{EBIDHJGCF}$	12.8^{EBDACF}	285^{HG}

Appendix 1...

No	Trait	AY	GY	AB	HI
1	Al 205 X CML 157	2.7333^{EBDGCF}	7173^{EBDAC}	14702^{FBDEC}	0.61333^{A}
2	Al 205 X CML 316	2.1^{EHGF}	6204^{EDF}	11416^{FGDE}	0.59667^{BA}
3	AL 206 X AL 99 CML 79A	2.8667^{EBDAGCF}	7432^{EBDAC}	15455^{BDEC}	0.59^{BAC}
4	AL 206 X CML 316	3.7667^{BA}	9770^{BA}	18907^{BA}	0.58^{BDAC}
5	AL 206 X CML 44	3.2667^{BDAC}	8467^{BDAC}	14973^{BDEC}	0.57333^{EBDAC}
6	Al 99 AL 281 X CML 157	2.7333^{EBDGCF}	7078^{EBDC}	12191^{FGDEC}	0.57^{EBDAC}
7	Al 99 AL 281 X CML 44	3.1667^{EBDAC}	8456^{BDAC}	15588^{BDAC}	0.57^{EBDAC}
8	Al 99 CML 270 X Al 99 CML 79A	2.8^{EBDGCF}	7314^{EBDAC}	13855^{FBDEC}	0.57^{EBDAC}
9	Al 99 CML 270 X CML 44	1.4I^{H}	3709^{F}	7009^{G}	0.56667^{EBDAC}
10	Al 99 CML 300A X AL 99 CML 79A	1.9667^{IHGF}	5427^{EDF}	10831^{FGDE}	0.56333^{EBDAC}
11	Al 99 CML 300A X CML 44	2.6667^{EBDGCF}	6888^{EBDFC}	13744^{FBDEC}	0.56^{EBDAC}
12	Al 99 CML 370 X AL 205	3.9667^{A}	8236^{BDAC}	15086^{BDEC}	0.55667^{EBDAC}
13	Al 99 CML 39A X AL 99 CML 79A	3.1333^{EBDAC}	10347^{A}	21375^{A}	0.55667^{EBDAC}
14	Al 99 CML 39A X CML 316	2.4^{EDHGF}	6199^{EDF}	12430^{FGDEC}	0.55333^{EBDAC}
15	Al 99 CML 39A X CML 44	2.5333^{EDGF}	6657^{EBDFC}	11979^{FGDE}	0.54667^{EBDAC}
16	Al 99 CML 79A X CML 316	2.2667^{EDHGF}	5972^{EDF}	11421^{FGDE}	0.54333^{EBDAC}
17	Al 99 CML 79A X CML 44	2.5667^{EDGF}	6660^{EBDFC}	12886^{FDEC}	0.54^{EBDAC}
18	CML 306 X CML 44	2.8333^{EBDGCF}	7315^{EBDAC}	15098^{BDEC}	0.53667^{EBDAC}
19	CML 126 X CML 157	3.2333^{BDAC}	8433^{BDAC}	15596^{BDAC}	0.53333^{EBDAC}
20	CML 126 X CML 316	3.7^{BAC}	9594^{BAC}	18035^{BAC}	0.53333^{EBDAC}
21	CML 157 X AL 99A 79A	2.8^{EBDGCF}	7273^{EBDAC}	12786^{FGDEC}	0.53^{EBDAC}
22	CML 157 X CML 316	2.6^{EDGCF}	6735^{EBDFC}	12129^{FGDE}	0.52333^{EBDAC}
23	CML 157 X CML 44	2.4^{EDHGF}	6270^{EDF}	11079^{FGDE}	0.51667^{EBDC}

Appendix 1…

No	Trait	AY	GY	AB	HI
24	CML 161 X CML 165	2.5667^{EDGF}	6652^{EBDFC}	12872^{FGDEC}	0.51667^{EBDC}
25	CML 306 X CML 157	2.9667^{EBDACF}	7698^{EBDAC}	14387^{FBDEC}	0.51333^{EBDC}
26	CML 306 X CML 316	0.8667^{I}	5512^{EDF}	8886^{FG}	0.51333^{EBDC}
27	CML 316 X CML 44	2.7^{EBDGCF}	6963^{EBDC}	11428^{FGDE}	0.51333^{EBDC}
28	CML 32 X AL 99 CML 79A	3.2^{EBDAC}	8470^{BDAC}	14805^{BDEC}	0.50667^{EBDC}
29	CML 32 X CML 44	2.6667^{EBDGCF}	7001^{EBDC}	12356^{FGDEC}	0.5^{EDC}
30	CML 44 X CML 157	2.8333^{EBDGCF}	7434^{EBDAC}	12451^{FGDEC}	$0.5E^{DC}$
31	TL 99 AL 1505-35 X CML 316	3^{EBDACF}	7802^{EBDAC}	14886^{DBEC}	0.49333^{ED}
32	Birkata	2.7667^{EBDGCF}	7208^{EBDAC}	13250^{FBDEC}	0.49^{ED}
33	Bukuri	2.5^{EDHGF}	6480^{EDFC}	13050^{FBDEC}	0.49^{ED}
34	Bukuri	2.9333^{EBDACF}	7639^{EDAC}	12709^{FGDEC}	0.48333^{E}
35	Mnelkassa 7	2.2333^{EDHGF}	5805^{EDF}	117744^{FGDE}	0.48333^{E}
36	Yellow Pop	1.7667^{IHG}	4717^{EF}	9620^{FGE}	0.48^{E}