COMBINING ABILITY OF EARLY AND INTERMEDIATE MAIZE (*Zea mays* L.) INBRED LINES FOR DROUGHT TOLERANCE USING LINE BY TESTER ANALYSIS

BY

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NOVEMBER, 2016

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DEPARTMENT OF CROP AND SOIL SCIENCES

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A Thesis Submitted to the Department of Crop and Soil Sciences, Faculty of Agriculture, College of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana in Partial Fulfilment of the Requirements for the Degree of

MASTER OF PHILOSOPHY IN PLANT BREEDING

BY

SANGARE ADJA ROKIATOU

(AGRONOMY Engineer)

NOVEMBER, 2016

DECLARATION

I hereby declare that, except for specific references which I have duly acknowledged, this work is the outcome of my own research and that neither a part nor whole of this document has been submitted for any other degree at any other University.

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ABSTRACT

Maize (*Zea mays* L.) is an annual plant belonging to the family (*Graminae or Poaceae).* It is a major cereal crop in West Africa, accounting for slightly over 20% of all food crops produced for domestic production in the sub-region. It is one of the most important cereals in Ghana, which is cultivated in all the agro-ecological zones. The objectives of this study were to estimate the general and specific combining ability effects of the inbred lines, determine the mode of gene action controlling grain yield and drought tolerance. A study was undertaken to assess the combining ability of 17 early and 26 intermediate maize inbred lines and one check for each genotypic group for drought tolerance using line by tester (line x tester) analyses. This trial was conducted in the screen house of the Department of Horticulture, KNUST in 2016. A randomized complete block design with three replications was used in the experiment. Some inbred lines with desirable general combining ability (GCA) effects for the studied traits were identified under drought-stress condition. For early maize genotypes inbred lines L1 followed by L4 were best general combiners for number of kernel row per ear, number of kernels per row, cob weight and grain yield under drought-stress condition. For intermediate maize genotypes under drought-stress condition, the line L4 was best general combiner for grain yield, cob weight, number of kernel rows per ear and ear diameter for their positive and significant GCA effects. These lines could be selected for their good traits to develop high yielding hybrids and for further exploitation in a breeding programme. Hybrid combination, L7 x T2 and L8 x T1 under well-watered condition and L6 x T2 under drought-stressed condition for intermediate maize genotypes were good specific combiners for grain yield while, for early maize genotypes, crosses were not significant for yield under well-watered and drought-stress conditions. The low ratio of σ^2gca/σ^2sca, in the current study showed

the preponderance of non-additive gene actions for almost all the traits for early and intermediate maize genotypes. The inbred lines L1 (S6-15-22) and L4 (CML538) for early maize maturity genotypes and L4 (CML502) for intermediate maize maturity genotypes were identified as best general combiners that can withstand drought-stress. These lines showed positive and significant GCA effects for yield and yield-related traits under drought-stress condition. The cross L6 X T2 was identified as good specific combiners that can withstand drought-stress for the positive and significant SCA effect for grain yield and yield-related traits under drought-stress condition.

Positive and significant mid-parent heterosis was observed under drought-stress condition for early and intermediate maize maturity genotypes. The crosses L2 X T1 and L3 X T2 observed high mid-parent heterosis for early and intermediate maturity genotypes, respectively. Generally, the results of the current study identified crosses with good level of heterosis, inbred lines with good GCA effects and cross combinations with desirable SCA effect for the traits studied. The results indicate the possibility of developing desirable cross combinations through crossing and or recombination of inbred lines with desirable traits of interest. Hence, the information from this study could be useful to researchers who would like to develop high yielding varieties of maize under drought-stress condition.

DEDICATION

This work is dedicated to my lovely mother, Dr. Fatimata CAMARA and to the memory of my late father, Mr. Abdoulaye SANGARE.

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LIST OF ABBREVIATIONS

AGRA:	Alliance For Green Revolution In Africa
ANOVA:	Analyses Of Variance
CRI:	Crops Research Institute
CRRA:	Centre De Recherche Rurale D'Agriculture
CYMMYT	International Maize And Wheat Improvement Center
FAO:	Food And Agricultural Organization
FAOSTAT:	Food And Agricultural Organization Statistical Data Base
GCA:	General Combining Ability

IER:	Institut D'economie Rural
IFPRI:	International Food Policy Research Institute
IITA:	International Institute Of Tropical Agriculture
IMCDA:	Improved Msc. In Cultivar Development For Africa
KNUST :	Kwame N'Krumah University Of Science And Technology
NARP:	National Agricultural Research Project
RCBD:	Randomized Complete Block Design
SCA:	Specific Combining Ability
Vs:	Versus
WAP:	Weeks After Planting
WCA:	West And Central Africa
WUE:	Water Use Efficiency

CHAPTER ONE

1.0 INTRODUCTION

Maize (*Zea mays* L.) is an annual plant belonging to the family *Graminae or Poaceae* (Sprague and Dudley, 1988). It is a major cereal crop in West Africa, accounting for slightly over 20% of all food crops produced for domestic consumption in the sub-region (IITA, 2000). It is cultivated in all the agro-ecological zones of Ghana (Fening *et al.*, 2011). Worldwide, maize is currently the third most traded cereal, after wheat and rice, with more than 160 million hectares cultivated every year (FAOSTAT, 2010). The production was estimated to be 985 million tons for the 2012/2013 season an increase of 9% from 2011/2012 (Brandt, 2013).

According to Badu-Apraku *et al.* (2011), in West and Central Africa (WCA), maize is consumed directly and serves as major staple diet for some 200 million people, providing about 15% of the total caloric intake of rural and urban consumers, while in developed countries, it is mainly used as livestock feed (DuPlessis, 2003). Industrially, maize is used to produce alcohol, starch, pulp, abrasive, and oil in the pharmaceutics and recently for fuel production (Morris, 2007; Acharya and Young, 2008).

The demand for maize in developing countries is expected to be about 504 million tons by 2020 and this is expected to exceed the demand for both wheat and rice (IFPRI, 2000). To meet this demand, there is a need for increased maize production in the developing countries while maintaining the same land resources since population growth and environmental conditions limit the opportunity for increasing maize area (Pingali and Pandey, 2001). The need to increase maize production in developing countries is challenged by a number of constraints including both abiotic and biotic stresses. Among the major abiotic stresses limiting tropical maize production are drought and low soil fertility. Drought is known to cause substantial reduction in the economic yield of crop plants, a major threat to food security, sustainability of production systems, and the well-being of people living in drought-prone areas. It adversely affects the lives of 2.6 billion people (43% of the world population) that are engaged in agriculture (Saxena *et al.,* 2002). Possibly due to climate change, drought effects on maize production are generally severe in the dry Savanna zone of West Africa (Fajemisin *et al.*, 1985). This is because rainfall in this region is irregular in terms of timing (can start early or very late in the season), quantity (some times less than 600 mm/annum) and distribution (could be poorly distributed) (Izge and Dugje, 2011). Most tropical maize is produced under rain fed conditions, and in area where drought is considered to be the most important abiotic constraint to production (CIMMYT, 1999).

Drought at any stage of crop development affects production, but grain yield losses can be greater if the drought stress occur at the most drought-sensitive stage of crop growth, such as flowering and grain filling. Drought stress can reduce yield by 50% when it occurs at flowering period, by 21% when it happens at the grain filling stage (Denmead and Shaw, 1960), and by 90% when it strikes from few days before tassels emergence to the beginning of grain filling (NeSmith and Ritchie, 1992).

Drought would intensify in the years ahead in response to climate change (Acquaah, 2012), Therefore, the survival of resource-poor, small scale maize growers in sub Saharan Africa who cultivate drought-susceptible maize varieties with little or no access to irrigation facilities has become a great challenge.

According to FAO (2006) and Derera *et al.* (2008), additional irrigation could possibly improve maize production in drought prone areas but in general, most rain fed farmers are resource poor, smallholders, and have a limited capacity to adopt high-input technologies (Bänziger and Diallo, 2001; FAO, 2006). A better approach to help these resource poor subsistence farmers is by using varieties that tolerate or escape the periodic droughts which befall the region.

One of the most important conditions for identifying high yielding hybrids is the information about parents' genetic structure and their combining ability (Ceyhan, 2003). The choice of selection and breeding method to be used for genetic improvement of crop plants therefore, will depend on the magnitude of genetic variability and the nature of gene action leading the inheritance of desirable traits (Aminu and Izge, 2013).

Line x tester analysis method (Kempthorne, 1957) is a tool widely used by plant breeders to generate reliable information on the general and specific combining ability effects and aids in selecting desirable parents and crosses. This method has been used in maize breeding by several workers and continues to be applied in quantitative genetic studies in maize (Rawlings and Thompson, 1962; Joshi *et al.*, 2002; Sharma *et al.*, 2004). The effectiveness of this method depends mainly upon the type of tester used in the evaluation. According to Hallauer (1975), a suitable tester should be simple in use, provide information that correctly classifies the relative merit of lines, and increases the genetic gain. Although, it is difficult to identify testers having all these characteristics, it can help to provide information to estimate the combining ability and also the type of gene action involved in the expression of yield and yield related traits.

Therefore, in the present study, the main objective was to undertake analysis of 17 early and 26 intermediate maize inbred lines for grain yield and drought tolerance.

The specific objectives were to:

i. assess the general and specific combining ability of the parents and hybrids for yield and drought tolerance, ii. determine the nature of gene action controlling the traits of yield and drought tolerance of the inbred lines; iii. identify parents and hybrids that can withstand drought stress, and iv. estimate heterosis for yield and drought stress.

CHAPTER TWO

2.0 LITTERATURE REVIEW

2.1 Botany and description of maize

Maize belongs to the tribe Maydeae. The genus *Zea* consists of four species of which *Zea mays* L. is economically important (Doeblay, 1990). The number of chromosomes in *Zea mays* is 2 n = 20.

Zea mays originated in Mesoamerican region, now Mexico and Central America (Watson and Dallwitz, 1992). The plant is tall, determinate, monoecious, annual plant. It produces large, narrow, opposite leaves, borne alternatively along the length of stem. This pattern of development is the same for all maize varieties, although may vary between different hybrids, location, time of planting and season. The various stages of maize growth are broadly divided into the vegetative and reproductive stage. Maize is generally protandrous, that is, the male flower matures earlier than the female flower. Generally, there are two functional florets, though; the development of the lower floret may be delayed slightly in comparison to the upper floret. Pollen grains per anther have been reported to range from 2000 to 7500 (Kiesselbach, 1949). Pollen grains are very small, hardly visible to the naked eye, light in weight, and easily carried by wind. Silks are covered with numerous hairs, (trichomes) which form an angle with the silk where pollen grains are harboured. The base of the silk is unique, as it elongates continuously until fertilization occurs. The cobs bear many rows of ovules that are always even in number. The female inflorescence or ear develops from one or more lateral branches (shanks) usually borne about half-way up the main stalk from auxiliary shoot buds. The pollen shed in maize is not a continuous process and generally begins two to three days before silk emergence and continues for five to eight days. Pollen shed stops when the tassel is too dry or wet and restarts when temperature conditions are favourable. Pollen grain remains viable for 18 to 24 h under favourable condition. Pollen longevity is favoured by high humidity and cool temperature. Under favourable conditions the interval between anthesis and silking is one to two days and increases under any stress situation. Maize is about 95% cross-pollinated and 5% self-pollinated (Poehlman, 1959).

2.2 Importance of maize

Maize is one of the oldest cultivated grains and one of the most productive crop species. It can be directly consumed as food at various developmental stages from baby corn to mature grain (McCutcheon, 2007). Maize is the major source of starch and is used as a food ingredient, either in its native form or chemically modified (White, 1994). Maize is mostly used as major food in developing countries; however it is used as a major source of carbohydrate in industry and livestock in developed countries (Paliwal, 2000). It is an important source of protein, iron, vitamin B, and minerals. In eastern Africa, maize is by far the main staple crop grown by the vast majority of rural households (Felix *et al.*, 2010). In Ghana, it is prepared and served in many local meal forms such as "Tuwo Zafi", "kenkey", "banku", "koko". The high consumption of maize throughout most of the region, reflect its role as the primary food staple (Felix *et al.*, 2010).

2.3 World maize production

Maize is grown all over the world, although there are large differences in yields. Also according to FAOSTAT (2010), maize is one of the most productive species of food plants. It is estimated that in 2012, the total world production of maize was 875,226,630 tons with the United States, China, and Brazil harvesting 31, 24, and 8% of the total production of maize, respectively (FAO, 2012). The present area planted to maize in

Ghana is about 1 million ha, with the yield and production averages of about 1.74 metric tons (MT) per ha and 1.65 MT, respectively (FAOSTAT, 2013). Maize is grown in all agro-ecological regions in Ghana; however, the Forest Savanna Transition Zone with a bimodal rainfall regime is the major agro-ecological region for maize (NARP, 1993).

2.4 Challenges of drought to maize production

The main cause of food insecurity for many households is drought. In developing countries, drought has been estimated to cause annual maize yield loss of 24 MT. The estimated losses are about 15% (about 1.2 MT) annually in Indonesia (Dahlan *et al.*, 1997); 0.7 t/ha or 68% in the commercial farming sector, and 1.69 t/ha or 37% in the large-scale commercial sector in Zimbabwe (Machida, 1997); 10-75% in Asia (Logrono and Lothrop, 1997); and 1.2 MT in Argentina (Eyherabide *et al.*, 1997). Drought is also a factor that limits maize productivity in Ghana (SARI, 1995; Obeng-Antwi *et al.*, 1999). Yield reduction in developing countries, is continually due to frequently drought and low soil fertility (mainly nitrogen efficiency), leading to decrease in grain yield in these countries, and in a bad year it can be the main constraint on yield in developed countries as well (Agrama and Moussa, 1996).

2.5 Drought stress effects on maize

Drought stress seriously delays the growth and development of maize. Specific symptoms of drought stress in plant are the change from green to green-grey and rolling of the lower leaves followed by those in the upper canopy. Leaf folding reduces the leaf area and therefore, light interception is reduced which also decreases the photosynthetic activity and growth is slowing (Edmeades *et al.*, 2000). Leaf area and photosynthesis are directly related to each other (Stoskopf, 1981). Timing for pollen shedding is affected negligibly by drought stress then; pollen shedding occurs generally at normal time even under drought stress but in severe drought situation, pollen shedding is adversely affected. On daily basis under drought stress, pollen grain productivity reduces from 3 to 8% (Rhoads and Bennett, 1990). When drought stress occurs seven to ten days prior to flowering, pollen shedding is accelerated and silking is delayed by drought prevalence and this increases the anthesis-silking interval followed by 40-50% yield losses (Nielsen, 2005a, b).

Lower the value of anthesis silking interval (ASI) the higher will be the productivity and vice versa (Bassetti and Westagat, 1993). Pollination process is affected in the following ways by drought stress; (a) silk becomes dried under dehydrated conditions and no more supportive for pollen tube development, (b) pollen shedding occurs before silking which causes increase in anthesis-silking interval (Nielson, 2002), (c) silk elongation rate is reduced (Lauer, 2012), (d) silk becomes non-receptive for pollen grain (Nielsen, 2005a, b). Therefore, the pollination process is seriously affected by drought stress in maize and reduces the yield by affecting the number of kernels per rows, harvest index, number of kernel per cob and grain yield per plant (Anjum *et al.*, 2011b).

Leaf senescence also begin at the base of the plant and spreads upward to the ear. Severe stress at flowering may lead to the complete abortion of ears and the plant (Edmeades *et al.*, 2000). Roots system also has critical importance for plant because these are one of the main detectors of drought stress. Root length, root volume, root density and number of roots are the characteristic structural traits which are disturbed under drought stress and resultantly the whole areal plant parts are disturbed (Cahn *et al.*, 1989).

2.6 Adaptation of maize to drought

2.6.1 Strategy to drought adaptation or tolerance

Drought stress effects are very uncertain and unpredictable because they impair the yield, yield potential and across the years performance. Drought stress heterogeneity in nature has variable effects in space and time. Degree and severity of stress further increase the erratic and unpredictable of stress (Gill *et al.*, 2003). Plant species differ in the stages at which they are more prone to drought stress. Some species are most vulnerable to stress damage during the early vegetative stage, while others are most susceptible during pre or post-anthesis stage, with others in between.

Effective secondary maize traits associated with drought resistance are; leaf rolling, stay green, shorter anthesis silking interval, cob barrenness (number of kernels per ear), root system, increased leaf erectness, kernel weight and low canopy temperature Bolaños and Edmeades 1996; Edmeades *et al.*, 2000. Genetic variability in secondary traits of maize yield components and physiological traits can also be exploited to accelerate the improvement in yield under drought stress. Heterosis acts as important mechanism for stress tolerance, as maize hybrids give higher yield even under drought stress relative to open pollinated varieties (OPVs) maize varieties (Blum, 1988). However, selection of genotypes with better yield under drought conditions is effective tool for combating against drought stress. Numerous general strategies may be identified by which plants adapt to drought.

2.6.2 Drought escape

A main objective of breeding is to develop cultivars that can escape drought by being early in maturity as to complete their life cycle within a given season length. In low land tropics, around

400-500 mm is the lower limit of average rainfall season for optimum maize production, in mid tropics it is 350-450 mm and in highland 300-400 mm (Bänziger *et al.*, 2000).

Matching of phenology of the crop with water availability is selection goal in breeding for earliness (Edmeades, 2013). Drought escape is described as shortening of growing season or life cycle of crop before the prevalence of drought stress. Drought escape is important against terminal drought therefore; reproductive growth stage is to be involved for escaping drought (Araus *et al*., 2002). Since days to sowing, days to flowering and days to maturity are highly genetically heritable traits and selection for earliness can easily be accomplished.

Genotype and environment interaction (G x E) is a contributing factor of crop duration and induce the plants to complete their life cycle before the beginning of drought. Development of early maturing and short duration cultivars are helpful for escaping the crop from terminal drought stress (Kumar and Abbo, 2001). Crop duration is directly linked with yield and any reduction in crop duration eventually reduces the yield (Turner *et al*., 2001). The characteristic feature of drought escape is earliness. Early maturing genotypes have lower evapo-transpiration, lower leaf area index and lower yield potential.

2.6.3 Drought tolerance

It is described as the potential of crop plants to maintain their growth and development under drought stress conditions. Yield stability is also associated with drought tolerance under drought conditions. Drought tolerance mechanism is a very complex mechanism and plants have developed numerous adaptations at physiological and molecular levels to confer drought tolerance. The characteristic feature of drought tolerance accessions is higher economic yield under drought stress conditions. Survival is essential at seedling stages whereas, later on survival without economic yield no more importance for breeders and farmers (Bänziger *et al.*, 2000). Plant phenology, plant growth and development, grain filling and translocation of photo assimilate reserves are main traits to be targeted for improvement of drought tolerance in maize (Edmeades, 2013). Osmoprotection by osmotic regulation and antioxidant scavenging defense system, plant growth regulators, stress responsive proteins, water channel proteins, transcription factors and signaling pathways actively participate in conferring drought tolerance in crop plant (Edmeades, 2013).

2.7 Inbred lines development

An inbred line is a breeding material that is homozygous and essential in hybrid production. It is developed and maintained by repetitive selfing of selected plants. In general, developing process of inbred lines from cross-pollinated species and developing pure line from self-pollinated species is not different (Acquaah, 2012).

Inbred lines are developed by selfing hybrids, pools and population. In the first days of maize breeding and still in developing countries, inbred lines were derived from relatively unimproved populations, and are still being done. However, in the recent past towards line recycling method such as backcrossing and pedigree greater efforts are observed. This is because selfing in crosses between elite inbred lines has higher probability of yielding superior new lines than selfing in more heterogeneous materials (Pandey 1998). Each cycle of selfing increases homozygosity by 50% and by the seventh generation of selfing 99% of the homozygosity is reached. Inbred lines are selected based on their performance as well as their combining ability from crosses to a tester. Pedigree selection consists of the development of new inbred lines by adding genes from other elite inbred lines

(Hallauer, 1990).Reciprocal recurrent selection using opposite populations as testers for improvement of populations to be used to develop inbred lines for production of single crosses was proposed by Comstock *et al.* (1949).

2.8 Concept of line x tester analysis and combining ability

2.8.1 Line x tester analysis

A single cross diallel can give the most complete information for hybrid performance since this method provides information of GCA and SCA (Sprague and Tatum, 1942). This mating scheme has been extensively used in breeding for the assessment of the genetic potential of parents that range from inbred lines to wide genetic base varieties (Hallauer and Miranda, 1988; Bernado, 2002). Although, it is difficult to use practically a large number of crosses generated from a few lines (Hallauer *et al.*, 1988).

Davis (1927) suggested the procedure of inbred lines x variety cross or testcross procedure, which is a type of progeny test for evaluating maize inbred lines in a hybrid breeding programme. Testers are used for identifying superior genotypes to be used in breeding programmes. The importance is to find a tester that provides the best discrimination among genotypes according to the purpose of selection (Hallauer and Miranda, 1988).

Kempthorne (1957) defined a method of statistical analysis of the line x tester for testing and estimates desirable GCA and SCA effects of inbred lines and hybrids, respectively.

This statistical analysis method is used to breed both cross and self-pollinated plants.
Matzinger (1953), for inbred line evaluation, described a desirable tester as one that combines the greatest simplicity in use with the maximum information on performance to be expected from tested lines when used in other combinations or grown in other

combination or grown in other environments. Singh and Chaudhary (1985) also stated that line x tester analysis is an appropriate and efficient method with suitable speed.

However, it was recognized that no single tester can completely fulfill these characteristics. Inbred lines, single cross hybrid or heterogeneous materials can be used as a tester. Abel and Pollak (1991) proposed at least two (and possibly more) divergent testers that contain an inherently great level of favorable alleles.

The line x tester test hosted by Davis (1927) made possible the screening of inbred lines based first on GCA with a broad base tester. This process was shown to be effective by Jenkins and Brunson (1932) and was broadly used consequently.

2.8.2 Combining ability

The concept of combining ability is important in plant and animal breeding. It was coined by Sprague and Tatum (1942) to define the terms general and specific combining ability. They defined the terms as follows: general combining ability is used to designate the average performance of a line in hybrid combination and specific combining ability is used to designate those cases in which certain combination do relatively better or worse than would be expected on the basis of the average performance of the lines involved.

GCA and SCA concepts became useful for characterization of inbred lines in crosses and often have been included in the description of an inbred line (Hallauer and Miranda, 1988). Combining ability is among the best tools in identifying the better combiners, which may be hybridized, to exploit heterosis and select better crosses for direct use or other breeding features. Twumasi *et al.* (2003) reported that the hybrids developed from heterotic pairs produced grain yield up to 28% better than the standard checks. Differences in GCA among lines are mainly due to additive genetic effects and greater order additive interactions, while the difference in SCA is primarily attributed to the non-additive dominance genetic effect (Sprague and Tatum, 1942; Falconer, 1989). Previously, numerous studies in different countries have reported significant GCA and SCA effects for grain yield and yield components in maize inbred lines.

Mahantesh (2006) assessed the heterosis and combing ability for yield component in single cross hybrids of maize. Inbred lines for days to anthesis, days to silking, days to brown husk maturity, plant height, ear height, ear length, grain yield, number of ears per plant, ear diameter, number rows per ear, number of kernels per row and 1000 kernel weight and he reported that the mean squares due to all these traits were significantly different. He also reported that, both GCA and SCA variances were significant for all the traits expect ear diameter, number of rows per ear and number of kernels per row. Koppad (2007) analyzed the combining ability effects and variances for yield and yield components of 28 parents and 75 hybrids of maize lines along with four commercial checks. He reported high significant differences among the entries (parents, hybrids, and checks) for all studied traits. Significant GCA and SCA effects were also reported for these traits with ratio of GCA/SCA less than unity indicating the involvement of nonadditive gene effect.

Rahman *et al.* (2010) assessed 24 F2 maize inbred lines for anthesis date and silking date, anthesis-silking interval, ear and plant heights using line x tester analysis method to identify superior F2 lines for combining ability as potential source in the production of improved maize germplasm. They reported highly significant differences among the testcrosses and their combining ability effect for all studied parameters.

Shams *et al.* (2010) estimated combining ability, gene action and proportional contribution of cross component of 36 F1 crosses which have been produced by crossing 12 maize inbred lines with three testers using line x tester mating design. The observed variables were ear length, ear height, number of kernel row per ear, kernel number per row, 100 grain weight and grain yield. They reported significant differences among genotypes for all the studied traits except kernel number per row. They discovered that dominance and additive variances are important under drought stress conditions. Also, contribution of lines, tester and their interactions exhibited that female lines contributed higher compared to male lines under drought stress conditions in all the studied traits and maternal parents played the most important role under drought stress conditions.

Badu-Apraku *et al.* (2011a) reported in a combining ability of early-maturing white maize inbreds under stress and non-stress environments that mean squares of both GCA and SCA were significant for all the traits except days to silking, anthesis-silking interval and ear aspect and the importance of additive gene action for all the traits studied.

Aminu and Izge (2013) reported significant GCA mean square for lines, testers and line by tester interaction for tasselling date, silking date, anthesis-silking interval, plant height, ear height and yield in their study of gene action and heterosis for yield and yield traits in maize, under drought conditions in Northen Guinea and Sudan Savannas of

Borno State, Nigeria.

2.9 Heterosis

Allard (1960) describe heterosis as the hybrid vigor expressed in hybrids and denotes the superiority in performance of hybrid individuals compared with their parents. The term heterosis was firstly developed by Shull (1952). He described the concept as the interpretation of increased vigor, size, and fruitfulness, speed of development of resistance to disease or climate rigours of any type. Falconer and Mackey (1996) also defined heterosis as the difference between the hybrid value for one trait and the mean value of the two parents for the same traits. It is essential in maize breeding and dependent on the level of dominance and differences in gene frequency. The genetic divergence of parental crosses is important for hybrid vigor manifestation (Collins, 1910).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimentation site

The experimentation was carried out during the minor crop season of 2015 and the major season of 2016. Crossing blocks were established at the Crop Research Institute (CRI), of the Council for Scientific and Industrial Research (CSIR), Fumesua, Kumasi in the Ashanti Region of Ghana. Evaluation of crosses was done in the major season from March to June of 2016 in the screen house at the Department of Horticulture,

Faculty of Agriculture and Natural Science, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana which is geographically situated between latitudes 01^0; 36^0 and 01^0; 43^0 West of the Greenwich meridian.

3.2 Experimental materials

A total of 45 maize genotypes of two maturity groups and checks were used for the study. The two maturity groups used were early and intermediate maturing maize inbred lines. The lines were acquired from maize breeding program of CRRA/IER-Sotuba, Mali but originally introduced from CIMMYT-Cameroon, CIMMYT-Zimbabwe; and IITA-Nigeria. The list of the origin and characteristics of the inbred lines used in the study are presented in Table 3.1. For the checks, Omankwa is an early maturing, quality protein maize and open pollinated variety whilst Mamaba is a medium maturing, white quality protein hybrid maize and drought tolerant, both released by CSIR-CRI for all agroecologies in Ghana.

Early maturity lines

Eighteen (18) genotypes of maize made up of 10 crosses produced by crossing five inbred lines as female with two testers as male (TZEI-22, tester A and 9071, tester B), five female inbred lines parent, two testers, and one standard check (Omankwa) were used for early maturity lines.

Intermediate maturity lines

Twenty seven (27) genotypes of maize made up of 16 crosses produced by crossing eight inbred lines as female with two testers as male (P43SR, tester C and CML491, tester D), 8 female inbred lines, 2 testers, and one standard check (Mamaba) were used for the intermediate maturity lines.

Table 3. 1. List of maize genotypes, origins and codes

No	Origins	Maize genotypes	Codes

		Early maturity	
1	IER, Mali	S6 15-22	L1
2	IER, Mali	S6 7-14	L2
3	IER, Mali	S6 60	L3
4	CIMMYT, Zimbabwe	C M L 538	L4
5	CYMMYT, Cameroon	87036	L5
6	IITA, Nigeria	9071	T1
7	IITA, Nigeria	TZEI-22	T2
8	CRI, Ghana	Omankwa	CHECK
		Intermediate maturity	
1	CIMMYT, Zimbabwe	CML 494	L1
2	IER, Mali	S6 90-93	L2
3	IER, Mali	S6 68-73	L3
4	CIMMYT	CML502	L4
5	IER, Mali	S6 82-86	L5
6	CIMMYT	J 16-1	L6
7	IER, Mali	S6 61-67	L7
8	IER, Mali	S6 44-45	L8
9	IITA, Nigeria	P43SR	T1
10	CIMMYT, Zimbabwe	CML 491	T2
11	CRI, Ghana	Mamaba	CHECK

3.3 Design and Experimental management

The crossing block was prepared in October, 2015 for minor season. Line x tester mating design was followed for making 45 F1 progenies consisting of early and intermediate maturing. Seeds were planted in four row plots for female lines and 20 row plots for male testers of 5 m long. The spacing of 75 cm between plants and 40 cm within row were used under irrigated conditions.

To evaluate the combining ability for yield and drought tolerance, F1 seeds were evaluated along with their parents and checks in the screen house. The Randomized Complete Block Design (RCBD) with 3 replications was used. Separately, 18 treatments for the early maturing and 27 treatments for the intermediate maturing were used. Each plot consisted of three plastic pots for the early and intermediate genetic group materials. A total of 810 plastic pots were used. Respectively, 324 plastic pots for early maturity lines and 486 plastics pots for intermediate maturity lines were used. The total number of pots for early and intermadiate maturing maize genotypes was divided into two groups (well-watered and drought-stress), respectively. For each maturity group, the well-watered and drought-stress experiments were done separately in the same screen house.

3.4 Soil sampling and analyses

Soil analysis was carried out on soil sample before sterilization application. The sample was taken and stored in polythene bag for analysis. Soil chemical analysis was done following standard protocols of landen (1991) for soil pH, Jones (1991) for total nitrogen, Black (1986) for exchangeable bases and cation.

3.5 Planting

Early maturity genotypes

Three seeds of each genotype were planted per pot in 324 plastic pots containing each 18 kg of soil. They were thinned to one plant per pot when seedlings established, while 324 plants were obtained. This total number of plants obtained includes the different crosses, female inbred lines, testers and the check Omankwa. Sowing was done on March 11th, 2016.

Intermediate maturity genotypes

Three seeds of each genotype were planted per pot in 486 plastic pots containing each 18 kg of soil. They were thinned to one plant per pot when seedlings are established, while, 486 plants were obtained. This total number of plants obtained includes the different crosses, female inbred lines, testers and the check Mamaba. Sowing was done on March 11th, 2016.

3.6 Irrigation schedule

Early maturity genotypes

Water was withdrawn at six weeks after planting (6 WAP) for the early maturity genotypes. Cultural practices such as weeding were done physically during the entire growing period as required. All the 324 potted plants received one litre of water every two days. Watering at two days interval was done until the sixth week corresponding to 40 days after planting. An intermittent drought-stressed assessment was achieved by withdrawing water from one group (162 pots) after the sixth week after planting, for seven days. Rescue watering was applied once each week. The remaining 162 wellwatered potted plants received water every two days throughout the experiment and this served as the control.

Intermediate maturity maize genotypes

Water was withdrawn at seven weeks after planting (7 WAP) for the intermediate maturity genotypes. Cultural practices such as weeding were done physically during the entire growing period as required. All 486 potted plants received one litre of water every two days. Watering at two days interval was done until the seventh week after planting. An intermittent drought stressed assessment was achieved by withdrawing water from one group (243 pots) after the seventh week corresponding to 47 days after planting, for seven days. Rescue watering was applied once each week. The remaining 243 wellwatered potted plants received water throughout the experiment and this served as the control.

3.7 Fertilizer application

For early and intermediate maturity maize genotypes, 5g of NPK (15-15-15) was applied per pot two weeks after planting (2 WAP) and this was followed with top dressing with

5g of urea per pot at five weeks after planting (5 WAP). Fertilizer applications were done a day before watering so that nutrients could be available to the plant roots.

Data collected

For both early and intermediate maturity maize genotypes, data on yield and other important agronomic traits were taken on plot and individual plant basis. For data on individual plant basis, the three plants of each plot for each genotype were used.

Anthesis date (AD): Recorded as the number of days from sowing to when 50% of the plants have extruded anthers (Bänziger *et al.*, 2000).

Silking date (SD): Recorded as the number of days from sowing to when 50% of the plants in a plot show silks (Bänziger *et al.*, 2000).

Anthesis to silking interval (ASI): Recorded as the difference between anthesis date and silking date (ASI = SD – AD) (Bänziger *et al.*, 2000).

Leaf Rolling (LR): This was recorded 45 DAP based on 1-5 scale, as 1 = unrolled, turgid, 2 = leaf rim starts to roll, 3 = leaf has a shape of V, 4 = rolled leaf rim covers part of leaf blade and, 5 = leaf is rolled like an onion leaf (Bänziger *et al.*, 2000).

Plant Height (PH): Determine the average height of the three plants per plot measured from the base of the plant to the flag leaf in cm using a meter stick. The measurement was made two weeks after pollen shedding ceased (Badu-Apraku *et al.*, 2012). **Ear Height (EH):** Determine the average height of the three plants per plot measured from the base of the plant to the node bearing the upper most ear of the same plants used to measure plant height in cm using a meter stick (Badu-Apraku *et al.*, 2012). **Leaf Senescence (LS):** Scored based on 1 to 10 scale, during grain filling by estimating the percent of dead leaf area and dividing by 10 as 1= 10% dead leaf area, 2 = 20% dead leaf area, 3 = 30%

dead leaf area, 4 = 40% dead leaf area, 5 = 50% dead leaf area, 6 = 60% dead leaf area, 7 = 70% dead leaf, 8 = 80% dead leaf area, 9 = 90% dead leaf area and 10 = 100% dead leaf area (Bänziger *et al.*, 2000).

Plant aspect (PLTASP): was recorded on a scale of 1 to 5 based on overall plant type, where, 1 = excellent plant type (desirable plant and ear characteristics) and 5 = poor plant type (undesirable plant and ear characteristics) (Badu-Apraku *et al.*, 2012).

Number of Ears per Plant (NEPP): The total number of harvested ears that bear kernels in each plot divided by the stand count at harvest (Badu-Apraku *et al.*, 2012). **Ear aspect (EASP):** Data were recorded based on a scale of 1 to 5, where 1 = Good, uniform, large, and well filled ears; 3 = average and 5 = ear with poor aspect (BaduApraku *et al.*, 2012).

Ear length (EL): The average length of ears (cm) from the base to the tip of the ear using a caliper.

Ear Diameter (ED): Determine the average diameter (cm) of the harvested cobs. Measurement was done in cm using a caliper.

Number of Kernel Rows per Plant (NKRE): This was counted from the cobs harvested per plot and the average number was recorded.

Number of Kernels per Row (NKR): This was recorded by counting kernels in each row from the cobs harvested per plot and the average number was recorded.

Moisture content (MOIST): A sampled grain from the harvested ear of each genotype was taken to determine the grain moisture content with an electronic moisture tester at harvest. It was calculated at 12.5% grain moisture (Badu-Apraku *et al.* 2012). **100 Grains Weight (HGWT):** For each plot, 100 grains were taken and weighed using sensitive balance.

Yield per Plant (YPP): Yield = Grain yield x (100 – actual grain moisture %)/87.5

(Badu-Apraku *et al.* 2012).

3.8 Statistical analyses

3.8.1 Analysis of variance

For all the traits, collected data were analyzed using line x tester analysis Agricolae package version 1.2-4 procedure in R.3.2. The analyses were done according to the line x tester analysis to partition the mean square due to crosses into lines, tester and line by tester effects (Singh and Chaudary, 1979) using R computer program (Agricolae package version 1.2-4). The variance due to genotypes was partitioned into parents, crosses, parents vs. crosses, lines, testers, and lines x testers. The structure of analysis of variance is shown in Table 3.2.

3.8.2 Combining ability analysis

The linear model used was developed on the procedures established by Kempthorne (1957) as follows:

$Y_{ijk} = \mu + r_k + g_i + g_j + s_{ij} + e_{ijk}$

Where,

Y_{ijk} = Value of a character measured on cross of line i by tester j in the k^{th} replication

μ = Population mean r_k = Effect of k^{th} replication g_i = general combining ability (GCA) effects of the i^{th} line, g_j= general combining ability (GCA) effects of the j^{th} tester,

S_{ij} = specific combining ability (SCA) effects of ith line and j^{th} tester such as S_{ij} is equal to S_{ji}, e_{ijk} = experimental error for ij_k^{th}

observation i = Lines 1, 2, 3, … i, and

j = Testers 1, 2, 3, … t.

Table 3. 2. Structure of ANOVA used in line x tester analysis for combining ability

Source of variation	Degree of freedom (df)	Mean square (MS)
Replication	r-1	M_r
Treatment	t-1	M_t
Parent	p-1	M_p
Crosses	c-1	M_c
Parents v/s Crosses	1	M_p v/s M_c
Lines	f-1	M_f
Testers	m-1	M_m
Lines x Testers	(f-1) (m-1)	M_y
Error	(r-1)(t-1)	M_e

Estimation of general combining ability effects

General combining ability effects of lines (g_i) and tester (g_j) were calculated as:

a. Lines $g_i = \frac{Xi..}{tr} - \frac{X..}{ltr}$

b. Tester $gj = \frac{Xj..}{lr} - \frac{X...}{ltr}$

Where, gi = GCA effects for ith line, gj = GCA effects for jth tester

Xi… = Sum of the ith line

Xj… = Sum of the jth tester

X… = grand sum

L = lines number t =

testers number and r =

replications number

$\sum gi = \sum gi = 0$ was obtained

Estimation of specific combining ability effects It

was calculated as follows:

$S_{ij} = \frac{Xij.}{r} - \frac{Xi..}{tr} - \frac{Xj.}{lr} + \frac{X...}{ltr}$

Where, Sij = SCA effect of the ijth crosses

Xij = i x j cross sum

Calculation of standard error (S.E.) for GCA and SCA effects

1. S.E (GCA_{line}) = $(Me/rt)^{1/2}$
2. S.E (GCA_{tester}) = $(Mse/rl)^{1/2}$
3. S.E (SCA effects) = (Mse/r) ½
4. S.E (gi-gj) line = $(2Me/rt)^{1/2}$
5. S.E (gi-gj) tester = $(2Mse/rl)^{1/2}$
6. S.E (sij - skl) = $2Mse/r)^{1/2}$

Where,

Me = Mean squares error

l = lines number t =

testers number

GCA and SCA effects and their standard errors (S.E) were estimated according to Singh and Chaudhary (1985).

The significance of GCA effects of testers is tested as: $t = \frac{Gj-0}{S.E.gj}$
Since the error degrees of freedom are usually greater than 30, the value of calculated "t" is regarded as significant if it exceeds 1.96. Hence, all the GCA effects are significant at 5 % level, if they are greater than the value (S.E.gi or gj X 1.96). By similar analogy, any GCA effect larger than (S.E.gi or gj X 2.576) is regarded as significant at 1 per cent level.

3.8.3 Genetic components

$\sigma 2_{GCA}$ line = Cov. half sib (line) = [Ml-Mlxt]/(rxt)

σ^2_{GCA} tester = Cov. Hal sib (tester) = [Mt-Mlxt]/(rxl)

Covariance of half sib (average) = {[(l-1)(Ml)+(t-1)(Mt)]/(l+t-2) - Mlxt}/r(2lt-l-t)

Covariance full sib Cov.Hs-r(l+t) Cov Hs]/3xr

Where,

Ml = Lines mean squares

Mt = Tester mean squares

Mlxt = Line by tester mean squares Me

= Mean squares error r =

Replications number σ^2 $_{GCA}$ = cov half

sib = [(1+f)/4]2 x σ^2_A σ^2 $_{SCA}$ = (Mlxt -

Me)/r= [(1+f)/4]2 x σ^2_D

F = Inbreeding depression coefficient

A = Additive variance

D = Dominance variance
= [(Ml-Me)+(Mt-Me)+(Mlxt-Me)]/3xr -
[6r

The ratio between the variance of general combing ability and the variance of specific combining ability was expressed as $\sigma^2_{GCA}/\sigma^2_{SCA}$. If the ratio is more than 1 ($\sigma^2_{GCA}/\sigma^2_{SCA} > 1$), it indicates that the additive gene action is more important for the trait, and if the ratio is less than 1 ($\sigma^2_{GCA}/\sigma^2_{SCA} < 1$), it indicates that non-additive gene action is important for the trait.

3.8.4 Proportional contribution of lines, testers, and line by tester interaction to the total variation

The contribution of females (lines), males (testers) and females (lines) x males (testers) to the variation were calculated as:

1. Contribution of lines = {SS(L) x 100}/hybrids SS
2. Contribution of testers = {SS(T) x 100}/hybrids SS
3. Contribution of Lines x Testers interaction = {SS (LxT) x 100}/hybrids SS

Where,

SS (L) = lines sum of squares

SS (T) = testers sum of squares

Hybrids SS = hybrids sum of squares

3.8.5 Heterosis

High parent (HP) and mid-parent (MP) heterosis were computed according to Singh and Narayanan (1993).

$$HP = \frac{F1 - HP}{HP} \times 100$$

$$MP = \frac{F1 - MP}{MP} \times 100$$

Where,

$MP = (P_1+P_2)/2$

Standard errors calculation:

S.E. of high parent heterosis = (2 x Me x 1/r) ^{½}

S.E. of mid-parent heterosis = (1.5 x Me x 1/r)$^{1/2}$

Where Me is the mean squares error obtained from the analysis of variance. The significance was tested using P-value table for the t-test. **Estimates of heritability** h^2b = VG/VP, and

h^2n = VA/VP Where, h^2b =

Broad sense heritability; h^2n =

Narrow sense heritability;

VG = Genotypic variance;

VA = Additive variance;

VP = Phenotypic variance

CHAPTER FOUR

4.0 RESULTS

4.1 Soil analysis

The characteristics of the top soil submitted to the routine analysis are presented in

Table 4.1.

Table 4. 1. Characteristics of the top soil used for the evaluation

Sample Soil		Characteristics
P^H		5.120
Avail P mg/kg		25.689
%TOTAL N		0.073
Exch. Bases (cmol/kg)	K	0.081
	Ca	7.80
	Mg	0.96
	Na	0.37
Exch. Acidity (cmol/kg)	AI	1.67
	H	10.86
% Org. Carbon		1.177
%Org. Matter		2.029
% Sand		68.40
% Silt		19.40
% Clay		12.20
Texture Class		Sandy Loam

4.2 Analyses of Variance (ANOVA)

Analyses of variance were done separately for the early and intermediate maize genotypes.

4.2.1 Early maturity maize genotypes

The results of the analyses for early maize genotypes under well-watered and droughtstress conditions are presented in Table 4.2. Mean squares due to genotypes were highly significant (P <0.01) for anthesis date, plant height, ear height, ear aspect, ear length, ear diameter, number of kernel row per ear, number of kernel per row, cob weight and grain yield under both environmental conditions. Silking date was highly significant

(P <0.01) under well-watered condition, whereas under drought-stress it was not significant

(P >0.05). Leaf rolling, leaf senescence and plant aspect also were highly significant (P <0.01) under drought stress. However, it was not significant (P >0.05) under wellwatered condition. Anthesis-silking interval and number of ear per plant were significant (P <0.05) under well-watered and drought-stress, respectively. Mean squares due to crosses were highly significant (P < 0.01) under both conditions for grain yield. They were highly significant (P <0.01) for others trait such us ear height, plant aspect, ear diameter, number of kernel row per ear, number of kernel per row, cob weight and hundred grain yield under drought-stress, while not significant under well-watered condition. Mean squares due to lines were significant (P <0.05) for plant height, ear height, number of kernel per row and grain yield under well-watered condition. However, it was not significant under drought-stress condition. Mean squares due to lines was highly significant (P <0.01) and significant (P <0.05) under-drought stress condition for number of kernel row per cob and number of kernel per row, respectively. With respect to testers mean squares, number of kernel row per ear, number of kernel per row, cob weight and grain yield were significant (P <0.05) under drought stresscondition and not significant (P >0.05) under well-watered condition.

Table 4. 2. Mean squares for early maturity maize

Source	Df	AD		SD		ASI		LR		CHLC		PH	
		WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
Replications	2	15.37	5.25	5.47	192.24	2.73	254.43	0.01	0.20	91.23*	96.14	535.64*	291.8
Treatments	16	17.38**	37.39**	16.12**	110.18	4.37*	121.75	0.06	0.63**	100.48**	162.85*	1,865.51**	1,688.38**
Parents (P)	6	25.16**	45.54**	23.94**	159.32	8.22**	156.44	0.13*	0.92**	151.69**	332.21**	2,515.72**	2,006.03**
P vs. C	1	93.58**	166.94**	40.88**	76.62	10.76*	469.75	0.00	2.54**	203.07**	473.4*	12,101.98**	12,477.95**
Crosses (C)	9	3.72	17.57	8.16*	81.14	1.1	59.94	0.03	0.23	54.94*	15.44	294.66	277.76
Lines (L)	4	5.78	22.28	11.28	13.62	1.22	39.42	0.04	0.17	83.32	19.76	566.75*	320.68
Testers (T)	1	2.13	13.33	3.33	0.30	0.13	9.63	0.00	1.19*	1.44	13.2	124.03	683.16
LX T	4	2.05	13.92	6.25	168.88	1.22	93.05	0.02	0.05	39.93	11.67	65.22	133.5
Error	32	5.83	8.38	3.32	233.74	1.98	212.85	0.05	0.12	19.23	82.67	148.5	163.67

*: significant difference; **: highly significant difference; AD: anthesis date, SD: silking date; ASI: anthesis-silking interval; LR: leaf rolling; CHLC: chlorophyll content; PH: plant height, WW: Well-watered; DS: Drought-stress

Table 4.2. Mean squares for early maturity maize continued

Source	Df	EH		LS		PLTASP		NEPP		EA		EL	
		WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
Replications	2	31.57	87.67	1.59*	9.51**	3.35**	0.08	0.25	0.53	0.25	0.19	10.88*	0.09
Treatments	16	712.11**	1029.07**	0.31	2.24**	0.23	0.7**	0.23	1.09*	4.48**	1.09**	12.32**	12.88**
Parents	6	1238.92**	1464.21**	0.05	4.1**	0.3	0.63**	0.3	0.96	1.77**	1.86**	3.75	4.44**
P vs. C	1	2969.75**	4782.89**	0.15	9.02**	0.01	0.7*	1.08	2.48*	54.18**	0.99*	120.37**	0.21
Crosses	9	110.06	321.89**	0.5	0.25	0.21	0.74**	0.09	1.02*	0.77*	0.59*	6.02*	19.92**
Lines	4	207.01*	339.15	0.4	0.19	0.3	1	0.12	1.63	0.91	0.51	11.41*	24.88
Testers	1	101.97	768.31	1.2	0.02	0	0.53	0.13	1.2	0.84	0.02	3.84	27.38
L X T	4	15.12	193.02	0.43	0.36	0.17	0.53*	0.05	0.37	0.61	0.82*	1.17	13.09**
Error	32	73.09	87.09	0.31	0.82	0.37	0.16	0.3	0.48	0.26	0.23	2.29	1.17

*: significant difference; **: highly significant difference; Df: degree of freedom; EH: ear height; LS: leaf senescence; PLTASP: plant aspect; NEPP: number of ear per plant; EA: ear aspect; EL: ear length, WW: Well-watered; DS: Drought-stress

Table 4.2. Mean squares for early maturity maize continued

Source	Df	ED		NKRE		NKR		COBWT		GYPP	
		WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
Replications	2	5.13	15.97	1.34	6.03	31.01	19.05	2961.44	757.03	137.26	19.05
Treatments	16	54.65**	35.75**	8.72**	33.48**	218.97**	98.55**	30310.99**	1924.57**	1615.79**	95.48**
Parents	6	52.33**	20.54	9.74**	23.715**	117.1**	76.52**	4651.54**	1060.15*	214.95**	46.51
P vs. C	1	513.67**	0.28	71.57**	11.92	2512.11**	70.94*	431126.05**	849.50	22197.88**	45.59
Crosses	9	5.19	49.84**	1.06	42.39**	32.09	116.31**	2882.28	2620.30**	262.8**	133.67**
Lines	4	3.31	67.69	1.64	63.90*	65.61*	174.60**	3998.66	3042.26	521.57*	107.53
Testers	1	8.49	108.57	0.44	91.91*	0.18	300.71**	5797.41	7957.99*	109.33	632.59*
L X T	4	6.25	17.3	0.64	8.49	6.54	11.92	1037.12	863.92	42.39	35.09
Error	32	7.55	14.53	1.84	3.59	14.92	11.56	1341.83	359.04	64.05	20.23

*: significant difference; **: highly significant difference; Df: degree of freedom; ED: ear diameter; NKRE: number of kernel row per ear; NKR: number of kernel per row; COBWT: cob weight; PLTASP: plant aspect; GYPP: grain yield per plant, WW: Well-watered; DS: Drought-stress.

4.2.2 Intermediate maturity maize genotypes

The analysis results for the studied traits under well-watered and drought stress environmental condition is presented in Table 4.3. Under both environmental conditions, the mean squares due to genotypes were highly significant (P<0.01) for anthesis date, leaf rolling, chlorophyll content, ear height, ear aspect, ear length, ear diameter, number of kernel row per ear, number of kernel per row, cob weight and grain yield. The mean squares were not significant (P > 0.05) for anthesis silking date, leaf senescence and plant aspect. Silking date was highly significant (P<0.01) under well-watered condition and not significant (P >0.05) under drought-stress condition. Plant height and number of ear per plant were highly significant (P<0.01) under drought-stress condition and not significant (P >0.05) under well-watered condition. Mean squares due to crosses under both environmental conditions were highly significant (P <0.01) for anthesis date, ear length, number of kernel row per ear, number of kernel per ear, cob weight and grain yield. Also, number of ear per plant, ear aspect, and ear diameter were highly significant (P < 0.01) under drought stress and leaf rolling under well-watered condition. Line mean squares were significant (P <0.05) for anthesis date, ear aspect, number of kernel per row under well-watered condition and plant height and ear height under drought-stress condition. For tester mean squares due to leaf rolling and ear length were highly significant (P <0.01) under both environmental conditions. Anthesis date, anthesis silking interval, number of kernel row per ear and number of kernel per row were significant (P <0.05) under well-watered condition, however, not significant (P > 0.05) under drought stress.

Table 4. 3. Mean squares for intermediate maturity of maize

Source	Df	AD		SD		ASI		LR		CHLC		PH	
		WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
Replications	2	1.08	1.89	4.47	113.28	4.71	76.71	0.07	0.89**	155.19**	203.03**	3294.8	967.31*
Treatments	25	11.95**	8.65**	9.63**	66.22	3.14	67.52	0.08**	0.95**	121.47**	60.32**	1700.68	657.07**
Parents	9	11.69**	11.62**	10.89**	132.46**	3.57	130.58**	0.07	1.26**	118.54**	80.53**	3649.78*	641.39*
P vs. C	1	81.42**	19.87**	52.31**	164.77	3.21	296.00**	0.08	9.84**	301.87**	25.89	800.63	5234.00**
Crosses	15	7.47**	6.12**	6.02*	19.91	2.87	14.45	0.09**	0.17	111.21**	50.49*	591.22	361.34
Lines	7	11.67**	9.71	7.00	17.55	1.48	9.24	0.05	0.15	166.22	96.41**	526.88	656.26*
Testers	1	21.33**	2.52	0.08	2.52	18.75*	0.02	0.81**	0.99**	171.54	0.08	325.57	28.57
L X T	7	1.29	3.05	5.89	24.76	1.99	21.74	0.04	0.07	47.58	11.76	693.52	113.97
Error	50	2.72	1.50	2.74	43.08	2.17	45.15	0.04	0.18	28.57	22.68	1511.76	267.52

*: significant difference; **: highly significant difference; Df: degree of freedom; AD: anthesis date, SD: silking date; ASI: anthesis-silking interval; LR: leaf rolling; CHLC: chlorophyll content; PH: plant height, WW: Well-watered; DS: Droughtstress.

Table 4.3. Mean squares for intermediate maturity maize continued

Source	Df	EH		LS		PLTASP		NEPP		EA		EL	
		WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
Replications	2	506.90**	765.47**	-	46.14**	5.28**	1.50*	0.17	0.50	0.08	3.57**	3.13	10.76**
Treatments	25	405.23**	278.67**	-	4.44	0.40	0.72	0.27	0.99**	1.83**	1.68**	24.47**	22.43**
Parents	9	416.20**	378.86**	-	4.12	0.48	0.39	0.37	0.48	1.51**	1.53**	10.10**	8.53**
P vs. C	1	2962.27**	2563.67**	-	10.06	2.71*	1.95*	2.26**	4.46**	26.98**	1.54	348.00**	103.02**
Crosses	15	228.18*	66.22	-	4.25	0.20	0.84	0.07	1.06**	0.34	1.78**	11.52**	25.39**
Lines	7	175.59	123.31**	-	2.76	0.05	0.85	0.10	1.18	0.57*	2.85	2.32	4.40
Testers	1	486.48	23.39	-	0.03	0.33	2.08	0.08	0.75	0.15	0.14	139.09**	243.77**
L X T	7	243.88*	15.26	-	6.34	0.33	0.66	0.04	0.99*	0.14	0.93*	2.49	15.18**
Error	50	95.33	83.46	-	5.55	0.40	0.46	0.25	0.35	0.20	0.40	2.12	2.10

*: significant difference; **: highly significant difference; Df: degree of freedom; EH: ear height; LS: leaf senescence; PLTASP: plant aspect; NEPP: number of ear per plant; EA: ear aspect; EL: ear length; WW: Well-watered; DS: Droughtstress.

Table 4.3. Mean squares for intermediate maturity maize continued

Source	Df	ED	NKRE	NKR	COBWT	GYPP

		WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
Replications	2	246.58**	157.39**	1.50	18.31**	28.18*	82.90*	5022.98	13732.96**	37.11	233.37**
Treatments	25	52.66**	33.48**	5.64**	8.67**	145.40**	62.46**	22685.17**	3437.71**	725.23**	91.18**
Parents	9	43.77	15.93	7.09**	6.79*	105.23**	74.76**	4952.99*	1147.28	132.22	65.60
P vs. C	1	195.01**	1.77	29.66**	2.23	1608.88**	94.97*	425426.51**	13651.89**	11501.47**	135.40
Crosses	15	48.51*	46.12**	3.17**	10.24**	71.94**	52.91**	6475.05**	4131.02**	362.62**	103.58**
Lines	7	63.4	56.42	2.13	13.08	86.18**	67.12	2485.81	5378.17	216.75	124.08
Testers	1	53.87	4.30	19.80**	0.84	399.69**	70.50	20093.77	3538.05	1588.92	57.60
L x T	7	32.85	41.79**	1.84	8.73*	10.88	36.20	8518.76**	2968.58*	333.30**	89.65*
Error	50	25.39	13.82	1.34	3.21	9.04	21.77	2028.42	1102.73	68.27	39.43

*: significant difference; **: highly significant difference; Df: degree of freedom; ED: ear diameter; NKRE: number of kernel row per ear; NKR: number of kernel per row; COBWT: cob weight; PLTASP: plant aspect; GYPP: grain yield per plant; WW: Well-watered; DS: Drought-stress.

4.3 Estimates of general combining ability effects

General combining ability effects were estimate for early and intermediate maize maturity genotypes.

4.3.1 Early maturity maize genotypes

Estimates of GCA effects of five early maize inbred lines and two testers studied in line by tester analysis under well-watered and drought-stress conditions are presented in Table 4.4. Grain yield exhibited significant positive and negative ($P < 0.05$) GCA effect under both conditions. The inbred line L1 (S6-15-22) showed maximum GCA effect of 4.28g/plant followed by 3.93g/plant under drought-stress condition. The inbred line L5 (87036) showed the lowest GCA effect of -16.25g/plant and -5.95g/plant under wellwatered and drought-stress conditions, respectively.

For anthesis date, L5 (87036) manifested a positive and significant GCA effect of 3.2 days under drought-stress. However, it was not-significant ($P > 0.05$) under wellwatered condition. L5 (87036) showed positive and significant GCA effect of 2.37 days for silking date under well-watered condition, however, it was not significant ($P > 0.05$) under drought-stress. L5 (87036) was the poorest general combiner for plant height with a positive and significant GCA effect of 16.76 cm under well watered condition, while L3 (S6-60) was good combiner under drought-stress condition with a negative and significant GCA effect of -12.45 cm.

With respect to ear height, L5 (87036) was poorest general combiner under both environmental conditions for their positive and significant GCA effect of 10.35cm and 11.17 cm, respectively. L3 (S6-60) (-9.33 cm) was good general combiner for the negative and significant GCA effect.

For plant aspect, L5 (87036) (0.67) was poor general combiner and showed positive and significant GCA effect under drought-stress condition, while plant aspect was notsignificant under well-watered condition. The inbred line L5 (87036), was notsignificant under well-watered condition for number of ear per plant, it presented a negative and significant GCA effect of -0.77 under drought-stress condition. Positive and negative GCA effect was observed for ear aspect under well-watered and droughtstress conditions, respectively (Table 4.4). L5 (87036), showed positive and significant GCA effect of 0.69 under well-watered condition and L4 (CML538) exhibited negative and significant GCA effect of -0.43 under drought-stress condition.

For ear length, the inbred line L1 (S6-15-22) showed positive and significant GCA effect 1.35 and 2.14 under well-watered and drought-stress conditions respectively. L4 (CML538) showed a negative and significant GCA effect under well watered condition, while L5 (87036) showed negative and significant GCA effect of -1.64 and -3.38 under well watered and drought-stress conditions, respectively.

Ll (S6-15-22) and L4 (CML538) showed positive and significant GCA effect for number of kernel row per ear, number of kernel per row and cob weight under drought stress. L4 (CML538) also showed positive and significant GCA effect for ear diameter under drought-stress. L5 (87036) showed negative and significant GCA effect for ear diameter, number of kernel row per ear, while not significant under well-watered condition. It also showed negative and significant GCA effect of number of kernel per

row and cob weight under well-watered and drought-stress condition.

Table 4. 4. Estimates of general combing ability effects for early maturity maize lines

Line entries	AD		SD		ASI		LR		CHLC		PH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1 (S6-15-22)	-0.37	-0.47	-0.47	1.70	0.07	2.17	0.00	0.00	2.33	1.53	-3.69	-0.73
L2 (S6-7-14)	-0.87	-1.63	-1.13	-0.63	-0.43	1.00	-0.02	-0.22	3.71	-1.99	-4.52	4.77
L3 (S6-60)	0.13	-1.30	-0.13	-1.47	-0.27	-0.17	0.12	-0.03	1.31	1.21	-0.64	-12.45*
L4 (CML538)	-0.53	0.20	-0.63	1.53	-0.10	1.33	-0.11	0.25	-1.70	1.22	-7.91	3.97
L5 (87036)	1.63	3.20*	2.37*	-1.13	0.73	-4.33	0.01	0.00	-5.64*	-1.98	16.76*	4.44
S.E.(gca for line)	0.99	1.18	0.74	6.24	0.57	5.96	0.09	0.14	1.79	3.71	4.98	5.22
S.E.(gi - gj)line	1.39	1.67	1.05	8.83	0.81	8.42	0.13	0.20	2.53	5.25	7.04	7.39
Male (Tester) entries												
T1 (9071)	-0.27	0.67	-0.33	0.10	-0.07	-0.57	0.01	0.20	0.22	0.66	2.03	4.77
T2 (TZEI-22)	0.27	-0.67	0.33	-0.10	0.07	0.57	-0.01	-0.20	-0.22	-0.66	-2.03	-4.77
S.E. (gca for tester)	0.62	0.75	0.47	3.95	0.36	3.77	0.06	0.09	1.13	2.35	3.15	3.30

maize

S.E.(gi -gj)tester	0.88	1.06	0.67	5.58	0.51	5.33	0.08	0.13	1.60	3.32	4.45	4.67

*: significant difference; **: highly significant difference; SE:standard error; AD: anthesis date, SD: silking date; ASI: anthesissilking interval; LR: leaf rolling; CHLC: chlorophyll content; PH: plant height, WW: Well-watered; DS: Drought-stress.

Table 4.4. Estimates of general combing ability effects for early maturity maize lines continued

Line entries	EH		LS		PLTASP		NEPP		EA		EL	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1 (S6-15-22)	-3.99	-1.66	-0.11	0.09	0.23	-0.33	-0.20	0.57	-0.20	-0.01	1.35*	2.14**
L2 (S6-7-14)	-3.16	-2.50	-0.06	0.26	-0.10	0.00	0.13	-0.10	-0.09	0.32	0.70	0.15
L3 (S6-60)	-1.66	-9.33*	-0.06	-0.02	0.23	0.00	-0.03	-0.10	-0.26	-0.10	0.91	0.46
L4 (CML538)	-1.55	2.31	0.44	-0.13	-0.27	-0.33	-0.03	0.40	-0.14	-0.43*	-1.33*	0.63
L5 (87036)	10.35*	11.17*	-0.22	-0.19	-0.10	0.67*	0.13	-0.77*	0.69*	0.21	-1.64*	-3.38**
S.E.(gca for line)	3.49	3.81	0.23	0.37	0.25	0.16	0.22	0.28	0.21	0.20	0.62	0.44
S.E.(gi - gj)line	4.94	5.39	0.32	0.52	0.35	0.23	0.31	0.40	0.29	0.28	0.87	0.62
Male (Tester) entries												
T1 (9071)	1.84	5.06	-0.20	0.02	0.00	-0.13	0.07	0.20	0.17	-0.03	0.36	0.96
T2 (TZEI-22)	-1.84	-5.06	0.20	-0.02	0.00	0.13	-0.07	-0.20	-0.17	0.03	-0.36	-0.96

maize

S.E. (gca for tester)	2.21	2.41	0.14	0.23	0.16	0.10	0.14	0.18	0.13	0.12	0.39	0.28
S.E.(gi -gj)tester	3.12	3.41	0.20	0.33	0.22	0.15	0.20	0.25	0.19	0.17	0.55	0.39

*: significant difference; **: highly significant difference; SE: standard error; EH: ear height; LS: leaf senescence; PLTASP: plant aspect; NEPP: number of ear per plant; EA: ear aspect; EL: ear length; WW: Well-watered; DS: Drought-stress.

Table 4.4. Estimates of general combing ability effects for early maturity lines continued

Line entries	ED		NKRE		NKR		COBWT		GYPP	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1 (S6-15-22)	-0.69	0.97	0.36	1.94*	2.26	4.94*	-7.72	20.95*	1.85	4.28*
L2 (S6-7-14)	0.14	-1.22	-0.70	0.83	1.92	-0.06	7.28	-7.38	2.10	-1.02
L3 (S6-60)	-0.27	1.20	0.41	0.97	0.81	0.03	13.06	-4.78	5.91	-1.24
L4 (CML538)	1.22	4.04*	0.36	2.02*	0.81	3.86*	27.63	22.75*	6.39	3.93*
L5 (87036)	-0.39	-5.00*	-0.42	-5.76**	-5.80*	-8.78**	-40.24*	-31.54**	-16.25**	-5.95*
S.E.(gca for line)	1.12	1.56	0.55	0.77	1.58	1.39	14.95	7.74	3.27	1.84
S.E.(gi - gj)line	1.59	2.20	0.78	1.09	2.23	1.96	21.15	10.94	4.62	2.60

maize

Male (Tester) entries										
T1 (9071)	-0.53	1.90	0.12	1.75	-0.08	3.17	-13.90	16.29	-1.91	4.59**
T2 (TZEI-22)	0.53	-1.90	-0.12	-1.75	0.08	-3.17	13.90	-16.29	1.91	-4.59**
S.E. (gca for tester)	0.71	0.98	0.35	0.49	1.00	0.88	9.46	4.89	2.07	1.16
S.E.(gi -gj)tester	1.00	1.39	0.50	0.69	1.41	1.24	13.38	6.92	2.92	1.64

*: significant difference; **: highly significant difference; SE: standard error ; ED: ear diameter; NKRE: number of kernel row per ear; NKR: number of kernel per row; COBWT: cob weight; PLTASP: plant aspect; GYPP: grain yield per plant; WW: Wellwatered; DS: Drought-stress.

4.3.2 Intermediate maturity maize genotypes

Estimates of GCA effects of the eight intermediate maize inbred lines and two testers studied in line x tester over well-watered and drought-stress conditions for the traits studied are presented in Table 4.5. The inbred lines L4 (CML502) showed the highest GCA effect of 8.35g/plant, whereas L8 (S6-44-45) exhibited the lowest GCA effect of 6.49g/plant under drought-stress condition. Under well watered condition L6 (J16-1) followed by L3 (S6-68.93) exhibited the maximum GCA effect of 7.88g/plant and 6.67g/plant, respectively whereas L8 (S6-44-45) and L1 (CML494) showed the lowest GCA effect of -7.91g/plant and -7.67g/plant, respectively.

For anthesis and silking date, both positive and negative significant GCA effects were observed under the two environmental conditions. Under well-watered condition, L1 (CML494), L8 (S6-44-45) showed positive and significant GCA effects whereas L4 (CML502) and L6 (J16-1) showed negative and significant GCA effects. L4 (-1.33) and L6 (-2.33) were good combiners, while L1 (1.50) and L8 (1.33) were poor combiners. Under drought-stress L3 (S6-68-73) and L6 (J16-1) showed negative and significant GCA effects. L8 (S6-44-45) showed positive and significant GCA effects. L3 and L6 with GCA values of -1.23 were good combiners and L8 (2.60) was poor combiner. L4 (CML502) with GCA of -1.58 was good general combiner and L1 (CML494) with GCA of 1.42 was poor general combiner for silking date under well-watered condition.Leaf rolling showed positive and significant GCA effects for L8 (0.19) under well watered condition. However, under drought-stress condition leaf rolling showed non-significant GCA effect (Table 4.5). With respect to plant height, L8 (S6-44-45) showed high negative and significant GCA effect (-7.54) and was good general combiner under drought stress condition. Plant height showed non- significant GCA effect under wellwatered condition (Table 4.5). For ear height, the estimate of GCA effects showed that L6 (J16-1) (-10.09) under well-watered condition and L8 (S6-44-45) (-7.36) under drought stress have negative and significant GCA effects.

The inbred line L8, under drought stress showed positive and significant GCA effect for plant aspect (0.79) and was poor general combiner. The best general combiner was L4 (0.54) with negative and significant GCA effect. Plant aspect was non-significant under well-watered condition. For number of ear per plant under drought-stress, L4 (054) was showed positive and significant GCA effects, however L8 (-0.96) was poor general combiner with a negative and significant GCA effects. The inbred line L8, under wellwatered and drought stress showed positive and significant GCA effect for ear aspect (0.68, 1.58) and were poor general combiner. The best general combiner was L4 (-0.53) with negative and significant GCA effect.

Inbred line L3 (S6-68-73), manifested a poor general combiner with negative and significant GCA effect of -1.76 cm for ear length under drought-stress condition and the tester 1 (P43SR) was good combiner with positive and significant GCA effects, whereas non-significant under well-watered condition. Under drought-stress, L4 (CML502) showed, positive and significant GCA effects for ear diameter, number of kernel row per ear and cob weight. L8 (S6-44-45) showed negative and significant GCA effects for ear diameter, number of kernel row per ear, number of kernel per row and cob weight (Table 4.5).

Table 4. 5. Estimates of general combining ability effects for intermediate maturity maize lines

Line (Female)	AD		SD		ASI		LR		CHLC		PH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1 (CML494)	1.50*	0.27	1.42*	0.15	-0.08	-0.10	-0.02	-0.24	1.07	-0.03	-2.12	-1.33
L2 (S6-90-93)	1.00	0.77	0.92	1.15	-0.08	0.40	0.03	0.06	-2.76	0.78	13.85	9.70
L3 (S6-68-73)	-1.00	-1.23*	-0.75	-1.35	0.25	-0.10	-0.02	0.03	-1.73	0.83	3.71	4.01
L4 (CML502)	-1.33*	-0.90	-1.58*	-2.69	-0.25	-1.77	-0.05	0.20	1.55	3.80*	-0.56	10.62
L5 (S6-82-86)	0.50	-0.06	0.25	-0.19	-0.25	-0.10	-0.02	0.06	-5.61*	-3.36	8.72	-3.22
L6 (J16-1)	-2.33	-1.23*	-1.25	-1.19	1.08	0.06	0.03	0.17	10.69**	5.35*	-5.23	6.84
L7 (S6-61-67)	0.33	-0.23	0.25	2.31	-0.08	2.56	-0.13	-0.11	2.19	0.18	-1.06	-5.27
L8 (S6-44-45)	1.33*	2.60**	0.75	1.81	-0.58	-0.94	0.19*	-0.18	-5.41*	-7.54**	-17.31	-21.35**
S.E.(gca for line)	0.67	0.50	0.68	2.68	0.60	2.74	0.08	0.17	2.18	1.94	15.87	6.68
S.E.(gi - gj)line	0.95	0.71	0.96	3.79	0.85	3.88	0.11	0.24	3.09	2.75	22.45	9.44
Tester (Male)												
T1 (P43SR)	-0.67	-0.23	0.04	-0.23	0.63	-0.02	0.13	0.14	-1.89	0.04	2.60	-0.77
T2 (CML491)	0.67	0.23	-0.04	0.23	-0.63	0.02	-0.13	-0.14	1.89	-0.04	-2.60	0.77
S.E. (gca for tester)	0.34	0.25	0.34	1.34	0.30	1.37	0.04	0.09	1.09	0.97	7.94	3.34
S.E.(gi -gj)tester	0.48	0.35	0.48	1.90	0.43	1.94	0.06	0.12	1.54	1.38	11.22	4.72

*: significant difference; **: highly significant difference; SE:standard error; AD: anthesis date, SD: silking date; ASI: anthesis-silking interval; LR: leaf rolling; CHLC: chlorophyll content; PH: plant height; WW: Well-watered; DS: Droughtstress.

Table 4.5. Estimates of general combining ability effects for intermediate maturity maize lines continued

Line (Female)	EH		LS		PLTASP		NEPP		EA		EL	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1 (CML494)	4.35	-0.80	-	1.07	0.08	-0.04	-0.08	0.04	-0.10	0.27	-0.11	0.93
L2 (S6-90-93)	4.16	5.22	-	-0.57	-0.08	0.13	0.08	0.04	-0.15	-0.48	-0.67	0.19
L3 (S6-68-73)	1.46	1.03	-	-0.10	0.08	-0.21	-0.08	0.04	-0.21	-0.17	-0.49	-1.76*
L4 (CML502)	2.96	3.92	-	-0.10	0.08	-0.54*	0.08	0.54*	0.18	-0.53*	-0.78	-0.18
L5 (S6-82-86)	1.13	-6.08	-	0.68	-0.08	-0.04	0.08	0.04	-0.15	-0.42	0.82	0.45
L6 (J16-1)	-10.09*	2.31	-	-0.38	0.08	-0.04	0.08	0.38	-0.26	-0.20	0.40	-0.62
L7 (S6-61-67)	2.85	1.75	-	-0.99	-0.08	-0.04	0.08	-0.13	0.01	-0.05	0.75	0.40
L8 (S6-44-45)	-6.82	-7.36*	-	0.40	-0.08	0.79*	-0.25	-0.96**	0.68**	1.58**	0.08	0.59
S.E.(gca for line)	3.99	3.73	-	0.96	0.26	0.28	0.20	0.24	0.18	0.26	0.59	0.59
S.E.(gi - gj)line	5.64	5.27	-	1.36	0.37	0.39	0.29	0.34	0.26	0.37	0.84	0.84
Tester (Male)												
T1 (P43SR)	3.18	-0.70	-	0.03	-0.08	-0.21	0.04	0.13	-0.06	-0.05	1.70	2.25*
T2 (CML491)	-3.18	0.70	-	-0.03	0.08	0.21	-0.04	-0.13	0.06	0.05	-1.70	-2.25*
S.E. (gca for tester)	1.99	1.87	-	0.48	0.13	0.14	0.10	0.12	0.09	0.13	0.30	0.30
S.E.(gi -gj)tester	2.82	2.64	-	0.68	0.18	0.20	0.14	0.17	0.13	0.18	0.42	0.42

*: significant difference; **: highly significant difference; SE: standard error; EH: ear height; LS: leaf senescence; PLTASP: plant aspect; NEPP: number of ear per plant; EA: ear aspect; EL: ear length; WW: Well-watered; DS: Drought-stress.

Table 4.5. Estimates of general combining ability effects for intermediate maturity maize lines continued

Line (Female)	ED		NKRE		NKR		COBWT		GYPP	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1 (CML494)	2.54	-0.73	1.09*	-0.60	-0.66	-0.88	-21.22	-1.05	-7.67*	-1.86
L2 (S6-90-93)	-6.26*	-0.54	-0.07	-0.22	-0.72	1.01	2.58	7.17	-1.92	-0.13
L3 (S6-68-73)	2.65	2.14	-0.19	1.49*	0.48	-0.63	16.88	8.80	6.67*	4.05
L4 (CML502)	3.76	6.20**	0.48	1.71*	-1.44	1.59	-12.15	54.89**	-2.10	8.35**
L5 (S6-82-86)	0.90	0.00	-0.74	0.60	5.17**	4.54*	14.18	-7.93	1.10	-2.92
L6 (J16-1)	-0.43	-0.64	0.26	0.82	2.67*	-0.13	23.90	-0.86	7.88*	0.92
L7 (S6-61-67)	-2.35	-2.56	-0.57	-1.03	2.17	1.59	9.67	-5.96	3.95	-1.92
L8 (S6-44-45)	-0.80	-3.88*	-0.27	-2.76**	-7.66**	-7.10**	-33.84	-55.07**	-7.91*	-6.49*
S.E.(gca for line)	2.06	1.52	0.47	0.73	1.23	1.91	18.39	13.56	3.37	2.56
S.E.(gi - gj)line	2.91	2.15	0.67	1.03	1.74	2.69	26.00	19.17	4.77	3.63
Tester (Male)										
T1 (P43SR)	-1.06	-0.30	-0.64	-0.13	2.89	1.21	20.46	8.59	5.75	1.10
T2 (CML491)	1.06	0.30	0.64	0.13	-2.89	-1.21	-20.46	-8.59	-5.75	-1.10
S.E. (gca for tester)	1.03	0.76	0.24	0.37	0.61	0.95	9.19	6.78	1.69	1.28

S.E.(gi -gj) tester	1.45	1.07	0.33	0.52	0.87	1.35	13.00	9.59	2.39	1.81

*: significant difference; **: highly significant difference; SE:standard error ; ED: ear diameter; NKRE: number of kernel row per ear; NKR: number of kernel per row; COBWT: cob weight; PLTASP: plant aspect; GYPP: grain yield per plant; WW: Well-watered; DS: Drought-stress.

4.4 Specific combining ability effects

Specific combining ability effects were estimates for early and intermediate maize maturity genotypes.

4.4.1 Early maturity maize genotypes

The estimates of SCA effects of the 10 crosses under well-watered and drought-stress condition are presented in Table 4.6. Non-significant SCA effects were observed among crosses evaluated for some characters such as grain yield, anthesis and silking date, anthesis and silking interval, leaf rolling, chlorophyll content, plant height, ear height, leaf senescence, number of ear per plant, ear diameter, number of kernel row per ear, number of kernel per row and cob weight.

With respect to plant aspect, L2 X T2 showed positive and significant SCA effect while L2 X T1 showed negative and significant SCA effect under drought-stress condition. For ear aspect, L5 X T1 and L2 X T2 showed positive and significant SCA effects under well-watered and drought-stress conditions, respectively. L5 X T2 and L2 X T1 presented negative and significant SCA effect under well-watered and drought-stress conditions, respectively.

The crosses L1 X T2, L3 X T2 and L5 X T1 showed positive and significant SCA effect for ear length while L1 X T1, L3 X T1 and L5 X T2 showed negative and significant SCA effects under drought-stress condition.

Table 4. 6. Estimates of specific combining ability effects for early maturity maize crosses

Crosses entries	AD		SD		ASI		LR		CHLC		PH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1 X T1	0.10	-0.33	0.00	-0.43	-0.27	-0.10	-0.04	-0.14	-3.27	-0.71	3.69	0.23
L1 X T2	-0.10	0.33	0.00	0.43	0.27	0.10	0.04	0.14	3.27	0.71	-3.69	-0.23
L2 X T1	-0.40	-1.17	-0.67	-2.10	-0.10	-0.93	0.05	-0.03	2.00	-0.05	-1.70	3.95
L2 X T2	0.40	1.17	0.67	2.10	0.10	0.93	-0.05	0.03	-2.00	0.05	1.70	-3.95
L3 X T1	0.27	-0.50	0.33	-0.60	0.07	-0.10	-0.04	0.05	-2.25	-1.87	0.85	3.40
L3 X T2	-0.27	0.50	-0.33	0.60	-0.07	0.10	0.04	-0.05	2.25	1.87	-0.85	-3.40
L4 X T1	-0.73	-0.67	-1.17	-5.60	-0.43	-4.93	-0.04	0.05	1.16	1.72	-4.76	-7.86
L4 X T2	0.73	0.67	1.17	5.60	0.43	4.93	0.04	-0.05	-1.16	-1.72	4.76	7.86
L5 X T1	0.77	2.67	1.50	8.73	0.73	6.07	0.07	0.08	2.35	0.91	1.91	0.28
L5 X T2	-0.77	-2.67	-1.50	-8.73	-0.73	-6.07	-0.07	-0.08	-2.35	-0.91	-1.91	-0.28
S.E.(sca effect)	1.39	1.67	1.05	8.83	0.81	8.42	0.13	0.20	2.53	5.25	7.04	7.39
S.E.(sij - skl)tester	1.97	2.36	1.49	12.48	1.15	11.91	0.18	0.29	3.58	7.42	9.95	10.45

*: significant difference; **: highly significant difference; SE:standard error; AD: anthesis date, SD: silking date; ASI: anthesissilking interval; LR: leaf rolling; CHLC: chlorophyll content; PH: plant height; WW: Well-watered; DS: Drought-stress.

Table 4.6. Estimates of specific combining ability effects for early maturity maize crosses continued

Crosses entries	EH		LS		PLTASP		NEPP		EA		EL	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1 X T1	0.77	-2.56	0.09	-0.25	-0.17	0.13	-0.07	0.30	-0.11	0.22	-0.08	-1.21
L1 X T2	-0.77	2.56	-0.09	0.25	0.17	-0.13	0.07	-0.30	0.11	-0.22	0.08	1.21*
L2 X T1	-2.07	1.88	0.03	-0.19	-0.17	-0.53*	-0.07	-0.03	-0.22	-0.61*	0.38	-0.14
L2 X T2	2.07	-1.88	-0.03	0.19	0.17	0.53*	0.07	0.03	0.22	0.61*	-0.38	0.14
L3 X T1	0.10	3.66	0.14	0.09	0.17	0.13	0.10	-0.37	-0.17	0.19	0.36	-1.30*
L3 X T2	-0.10	-3.66	-0.14	-0.09	-0.17	-0.13	-0.10	0.37	0.17	-0.19	-0.36	1.30*
L4 X T1	2.10	-8.59	-0.47	-0.02	0.00	0.13	0.10	0.13	-0.06	-0.08	-0.70	0.31
L4 X T2	-2.10	8.59	0.47	0.02	0.00	-0.13	-0.10	-0.13	0.06	0.08	0.70	-0.31
L5 X T1	-0.90	5.61	0.20	0.37	0.17	0.13	-0.07	-0.03	0.56*	0.28	0.04	2.34**
L5 X T2	0.90	-5.61	-0.20	-0.37	-0.17	-0.13	0.07	0.03	-0.56*	-0.28	-0.04	-2.34**
S.E.(sca effect)	4.94	5.39	0.32	0.52	0.35	0.23	0.31	0.40	0.29	0.28	0.87	0.62
S.E.(sij - skl)tester	6.98	7.62	0.46	0.74	0.50	0.33	0.44	0.56	0.41	0.39	1.24	0.88

*: significant difference; **: highly significant difference; SE: standard error; EH: ear height; LS: leaf senescence; PLTASP: plant aspect; NEPP: number of ear per plant; EA: ear aspect; EL: ear length; WW: Well-watered; DS: Drought-stress.

Table 4.6. Estimates of specific combining ability effects for early maturity maize crosses continued

Crosses entries	ED		NKRE		NKR		COBWT		GYPP	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1 X T1	0.66	0.62	0.38	0.59	0.08	0.17	-6.80	9.37	-1.10	4.56
L1 X T2	-0.66	-0.62	-0.38	-0.59	-0.08	-0.17	6.80	-9.37	1.10	-4.56
L2 X T1	1.00	2.57	-0.34	0.58	1.41	1.89	-0.01	8.16	-3.67	0.45
L2 X T2	-1.00	-2.57	0.34	-0.58	-1.41	-1.89	0.01	-8.16	3.67	-0.45
L3 X T1	-1.58	-1.94	-0.35	-1.45	0.08	-2.03	-0.04	-18.74	0.55	-12.20
L3 X T2	1.58	1.94	0.35	1.45	-0.08	2.03	0.04	18.74	-0.55	12.20
L4 X T1	0.30	-0.61	0.16	-1.06	-0.03	-0.36	21.06	6.51	12.71	2.84
L4 X T2	-0.30	0.61	-0.16	1.06	0.03	0.36	-21.06	-6.51	-12.71	-2.84
L5 X T1	-0.39	-0.65	0.16	1.33	-1.54	0.33	-14.21	-5.30	-8.49	4.35
L5 X T2	0.39	0.65	-0.16	-1.33	1.54	-0.33	14.21	5.30	8.49	-4.35
S.E.(sca effect)	1.59	2.20	0.78	1.09	2.23	1.96	21.15	10.94	13.94	7.96
S.E.(sij - skl)tester	2.24	3.11	1.11	1.55	3.15	2.78	29.91	15.47	19.71	11.25

*: significant difference; **: highly significant difference; SE: standard error ; ED: ear diameter; NKRE: number of kernel row per ear; NKR: number of kernel per row; COBWT: cob weight; PLTASP: plant aspect; GYPP: grain yield per plant; WW: Wellwatered; DS: Drought-stress.

4.4.2 Intermediate maturity maize genotypes

The estimates of SCA effects of the 16 crosses under well-watered and drought-stress conditions are presented in table. The crosses evaluated in the current study showed considerable variation in SCA effects for different traits. Grain yield manifested both positive and negative significant SCA effects among the crosses under both environmental conditions.

Under well-watered condition L7 xT2 and L8 X T1 have positive and significant SCA effects for grain yield per plant. The crosses L7 xT2 (13.57g/plant) and L8 X T1 (10.47g/plant) were good specific combiners while, L7 X T1 (-13.57g/plant) and L8 X T2 (-10.47g/plant) were poor specific combiners. Under drought-stress L6 X T2 (6.36g/plant) showed positive and significant SCA effects and was good specific combiner whereas L6 X T1 (-6.36g/plant) was poor specific combiner with negative and significant SCA effects.

For anthesis date, crosses were not significant under well-watered condition. Under drought-stress only the cross L8 X T1 (-1.6 days) showed negative and significant SCA effect for earliness and drought escape, however L8 X T2 (1.6 days) showed positive and significant SCA effect. Non-significant SCA effects were observed among the crosses studied for silking date, anthesis silking interval, leaf rolling, plant height, ear height, leaf senescence, plant aspect, ear length and number of kernel per row under both well-watered and drought-stress conditions.

For number of ear per plant, crosses L8 X T2 and L8 X T1 were good and poor specific combiners respectively under drought-stress condition, while not-significant under wellwatered condition. With a positive and significant SCA effect for ear aspect, the inbred

line L6 X T1 was poorest specific combiner while L6 X T2 was good specific combiner with a negative and significant SCA effect.

Under drought-stress condition L6 X T2 was good specific combiner with positive and significant SCA effect for ear diameter, number of kernel row per ear and cob weight, whereas L6xT1 was poor specific combiner, for the same traits. Cob weight was found also significant under well-watered condition. L7 X T2 and L8 X T1 showed good specific combiners for cob weight; however L7 X T1 and L8 X T2 were poor specific combiners for this trait under well-watered condition.

Table 4. 7. Estimates of specific combining ability effects for intermediate maturity maize crosses

Crosses entries	AD		SD		ASI		LR		CHLC		PH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1 X T1	0.00	0.40	0.46	-1.77	-0.13	-2.15	-0.05	0.05	2.29	0.79	-17.44	-3.95
L1 X T2	0.00	-0.40	-0.46	1.77	0.13	2.15	0.05	-0.05	-2.29	-0.79	17.44	3.95
L2 X T1	-0.50	-0.44	-0.71	-1.10	-0.13	-0.65	0.12	-0.03	3.935	-1.18	-3.63	-3.43
L2 X T2	0.50	0.44	0.71	1.10	0.13	0.65	-0.12	0.03	-3.935	1.18	3.63	3.43
L3 X T1	-0.17	0.23	0.29	-1.60	0.54	-1.81	0.07	0.05	-2.673	0.50	4.62	-1.40
L3 X T2	0.17	-0.23	-0.29	1.60	-0.54	1.81	-0.07	-0.05	2.673	-0.50	-4.61	1.40
L4 X T1	-0.50	0.23	-1.54	-1.60	-0.96	-1.81	-0.08	-0.23	-0.93	-2.07	1.01	-0.79
L4 X T2	0.50	-0.23	1.54	1.60	0.96	1.81	0.08	0.23	0.93	2.07	-1.01	0.79
L5 X T1	0.00	0.40	-0.38	2.23	-0.29	1.85	0.01	-0.03	2.10	1.58	7.28	2.60
L5 X T2	0.00	-0.40	0.38	-2.23	0.29	-1.85	-0.01	0.03	-2.10	-1.58	-7.28	-2.60
L6 X T1	0.50	0.56	0.79	3.56	0.38	3.02	0.06	0.03	1.56	-1.14	-10.55	-4.89
L6 X T2	-0.50	-0.56	-0.79	-3.56	-0.38	-3.02	-0.06	-0.03	-1.56	1.14	10.55	4.89
L7 X T1	0.83	0.23	1.63	1.06	0.88	0.85	-0.05	0.02	-3.45	1.81	1.28	4.88
L7 X T2	-0.83	-0.23	-1.63	-1.06	-0.88	-0.85	0.05	-0.02	3.45	-1.81	-1.28	-4.88
L8 X T1	-0.17	-1.60*	-0.54	-0.77	-0.29	0.69	-0.09	0.15	-2.84	-0.30	17.42	6.97
L8 X T2	0.17	1.60*	0.54	0.77	0.29	-0.69	0.09	-0.15	2.84	0.30	-17.42	-6.97
S.E.(sca effect)	0.95	0.71	0.96	3.79	0.85	3.88	0.11	0.24	3.09	2.75	22.45	9.44
S.E.(sij - skl)tester	1.35	1.00	1.35	5.36	1.203	5.49	0.15	0.34	4.37	3.89	31.75	13.36

maize

*: significant difference; **: highly significant difference; SE:standard error; AD: anthesis date, SD: silking date; ASI: anthesis-silking interval; LR: leaf rolling; CHLC: chlorophyll content; PH: plant height; WW: Well-watered; DS: Droughtstress.

Table 4.7. Estimates of specific combining ability effects for intermediate maturity maize crosses continued

Crosses entries	EH		LS		PLTASP		NEPP		EA		EL	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1 X T1	-9.19	-0.91	-	-0.41	-0.25	-0.29	0.13	0.04	0.00	-0.36	-0.68	0.30
L1 X T2	9.19	0.91	-	0.41	0.25	0.29	-0.13	-0.04	0.00	0.36	0.68	-0.30
L2 X T1	-2.32	2.23	-	1.56	-0.08	0.21	-0.04	-0.29	-0.06	0.00	0.83	-1.40
L2 X T2	2.32	-2.23	-	-1.56	0.08	-0.21	0.04	0.29	0.06	0.00	-0.83	1.40
L3 X T1	2.93	2.37	-	1.09	0.08	0.21	0.13	0.38	0.11	-0.25	-0.02	-0.45
L3 X T2	-2.93	-2.37	-	-1.09	-0.08	-0.21	-0.13	-0.38	-0.11	0.25	0.02	0.45
L4 X T1	5.87	-0.19	-	-1.14	0.08	0.21	-0.04	-0.13	-0.28	-0.11	0.44	-0.64
L4 X T2	-5.87	0.19	-	1.14	-0.08	-0.21	0.04	0.13	0.28	0.11	-0.44	0.64
L5 X T1	6.04	-1.52	-	-0.14	0.25	0.04	-0.04	0.38	0.06	0.22	-0.33	-1.27
L5 X T2	-6.04	1.52	-	0.14	-0.25	-0.04	0.04	-0.38	-0.06	-0.22	0.33	1.27
L6 X T1	-7.74	-0.47	-	0.81	0.08	0.38	-0.04	-0.29	0.06	0.78*	-0.74	-0.98
L6 X T2	7.74	0.47	-	-0.81	-0.08	-0.38	0.04	0.29	-0.06	-0.78*	0.74	0.98
L7 X T1	-2.57	-1.91	-	-0.69	0.25	-0.63	-0.04	0.54	0.22	0.18	-0.37	1.06
L7 X T2	2.57	1.91	-	0.69	-0.25	0.63	0.04	-0.54	-0.22	-0.18	0.37	-1.06
L8 X T1	6.98	0.42	-	-1.08	-0.42	-0.13	-0.04	-0.63*	-0.11	-0.45	0.88	3.37
L8 X T2	-6.98	-0.42	-	1.08	0.42	0.13	0.04	0.63*	0.11	0.45	-0.88	-3.37
S.E.(sca effect)	5.64	5.27	-	1.36	0.366	0.39	0.29	0.34	0.26	0.37	0.84	0.84
S.E.(sij - skl) tester	7.97	7.46	-	1.923	0.512	0.55	0.41	0.49	0.36	0.52	1.188	1.18

*: significant difference; **: highly significant difference; SE: standard error; EH: ear height; LS: leaf senescence; PLTASP: plant aspect; NEPP: number of ear per plant; EA: ear aspect; EL: ear length; WW: Well-watered; DS: Drought-stress.

Table 4.7. Estimates of specific combining ability effects for intermediate maturity crosses continued

maize

Entries	ED		NKRE		NKR		COBWT		GYPP)	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1 X T1	0.61	2.97	0.59	1.55	-1.39	2.82	11.44	12.16	3.66	-0.69
L1 X T2	-0.61	-2.97	-0.59	-1.55	1.39	-2.82	-11.44	-12.16	-3.66	0.69
L2 X T1	3.15	0.80	0.09	0.67	-1.44	-0.69	-24.41	-27.07	0.15	-2.68
L2 X T2	-3.15	-0.80	-0.09	-0.67	1.44	0.69	24.41	27.07	-0.15	2.68
L3 X T1	0.17	0.38	0.31	-0.54	1.59	1.35	16.12	23.60	3.02	6.22
L3 X T2	-0.17	-0.38	-0.31	0.54	-1.59	-1.35	-16.12	-23.60	-3.02	-6.22
L4 X T1	-2.16	-1.87	-0.58	0.13	1.39	1.12	34.47	-5.96	4.05	0.08
L4 X T2	2.16	1.87	0.58	-0.13	-1.39	-1.12	-34.47	5.96	-4.05	-0.08
L5 X T1	-1.46	-2.19	-0.14	-1.09	-0.66	-2.16	4.08	6.21	-0.28	-0.97
L5 X T2	1.46	2.19	0.14	1.09	0.66	2.16	-4.08	-6.21	0.28	0.97
L6 X T1	1.57	-4.56*	-0.69	-1.98*	0.50	-3.71	-27.76	-34.38*	-7.49	-6.36*
L6 X T2	-1.57	4.56*	0.69	1.98*	-0.50	3.71	27.76	34.38*	7.49	6.36*
L7 X T1	-3.85	2.04	-0.41	-0.13	-1.33	-1.77	-65.63*	27.66	-13.57**	4.11
L7 X T2	3.85	-2.04	0.41	0.13	1.33	1.77	65.63*	-27.66	13.57**	-4.11
L8 X T1	1.97	2.42	0.84	1.38	1.34	3.04	51.68*	-2.22	10.47*	0.30
L8 X T2	-1.97	-2.42	-0.84	-1.38	-1.34	-3.04	-51.68*	2.22	-10.47*	-0.30
S.E.(sca effect)	2.91	2.15	0.67	1.03	1.74	2.69	26.00	19.17	4.77	3.63
S.E.(sij -) skl tester	4.11	3.04	0.95	1.46	2.45	3.81	36.77	27.11	6.75	5.13

*: significant difference; **: highly significant difference; SE: standard error; ED: ear diameter; NKRE: number of kernel row per ear; NKR: number of kernel per row; COBWT: cob weight; PLTASP: plant aspect; GYPP: grain yield per plant; WW: Well-watered; DS: Drought-stress.

4.5 Estimates of genetic component and proportional contribution to the total variances

Genetic component and proportional contribution to the total variances were estimated for early and intermediate maturity maize genotypes.

4.5.1 Early maturity maize genotypes

The estimates of genetic components of variance, heritability and the proportional contribution of lines, testers and line and tester interaction to the total variances are presented in Table 4.8. The variance due to general combining ability was larger than de variance of specific combining ability for silking date, anthesis silking interval, leaf rolling, plant height, leaf senescence, number of ear per plant under drought-stress condition indicating the preponderance of additive gene action than non-additive gene action in the inheritance of these traits.

General combining ability variance was larger than the specific combining ability variance for anthesis date, anthesis silking interval, leaf rolling, plant height, ear height, plant aspect, number of ear per plant, ear length, ear diameter, number of kernel row per ear, number of kernel per row, cob weight and grain yield under well-watered condition, indicating the preponderance of additive gene action over the non-additive gene action in the inheritance of these traits. Under well-watered condition, the variance due to general combining ability was lower than the variance of specific combing ability for silking date, leaf senescence, ear aspect, indicating the preponderance of non-additive gene action than the additive gene action in the inheritance for these traits.

The variance of general combining ability was lower than the variance of specific combing ability for anthesis date, ear height, plant aspect, ear aspect, ear length, ear diameter, number of kernel row per ear, number of kernel per row, cob weight and grain yield, indicating the preponderance of non-additive gene action than additive gene action in the inheritance of these traits. The ratios of general combining ability/specific combining ability effects were lower than unity for all the traits studied, indicating a preponderance of non-additive gene action than additive gene action in the inheritance of these traits.

The results of the proportional contribution of lines to the total variation were higher than the testers for all traits under both well-watered and drought-stress conditions. The highest contribution to the total variation among the lines was given by number of kernel per row followed by plant height, ear length and ear height under well-watered condition. Under drought-stress condition, the highest contribution to the total variance among the lines was given by number of ear per plant followed by ear diameter, and plant aspect. The lowest contribution to the total variations among lines was given by ear diameter under well-watered condition and by silking date under drought-stress condition.

The highest contributions of the lines and tester interaction (L X T) were given by ear diameter and silking date under well-watered and drought-stress conditions, respectively. The results of the interaction between lines and testers (L X T) were lower for ear height and number of kernel per row under well-watered and drought-stress condition Table 4.8. The highest contributions by lines, testers and line by tester interaction (L X T) to the total variation was given by line for anthesis date, silking date, leaf rolling, plant height, ear height, plant aspect, number of ear per plant, ear aspect, ear length, number of kernel row per ear, number of kernel per row, cob weight and grain yield, by their interaction for leaf senescence and ear diameter under well-watered condition. Under drought-stress condition, the highest contribution was given by lines for anthesis date, plant height, ear height, plant aspect, number of ear per plant, ear length, ear diameter, number of kernel row per ear and umber of kernel per row, by the testers for leaf rolling, cob weight and grain yield and by their interaction for silking date, anthesis-silking interval and leaf senescence (Table 4.8).

Table 4. 8 Estimates of genetic component and proportional contribution of lines, testers and line x tester to the total variances for early maize genotypes

Source	AD		SD		ASI		LR		CHLC		PH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
δ gca	0.04	0.08	0.04	-2.02	0.00	-0.76	0.00	0.00	0.35	0.09	5.29	3.33
δ sca	-1.26	1.85	0.98	-21.62	-0.25	-39.93	-0.01	-0.03	6.90	-23.67	-27.76	-10.06
VA	0.15	0.34	0.18	-8.10	-0.01	-3.06	0.00	0.01	1.39	0.35	21.18	13.32
VD	-1.26	1.85	0.98	-21.62	-0.25	-39.93	-0.01	-0.03	6.90	-23.67	-27.76	-10.06
δ gca/sca	-0.03	0.05	0.05	0.09	0.01	0.02	-0.02	-0.13	0.05	0.00	-0.19	-0.33
h^2n	0.03	0.03	0.04	-0.04	-0.01	-0.02	0.02	0.12	0.05	0.01	0.15	0.08
h^2b	-0.23	0.21	0.26	-0.15	-0.15	-0.25	-0.24	-0.11	0.30	-0.39	-0.05	0.02
Proportional contribution of lines, testers and their interactions to total variance												
Lines	69.12	56.37	61.43	7.46	49.32	29.22	67.61	27.29	67.41	56.90	85.49	51.31
Testers	6.37	8.43	4.54	0.04	1.35	1.79	1.61	61.88	0.29	9.50	4.68	27.33
Lines x Testers	24.50	35.20	34.03	92.50	49.32	68.99	30.78	10.83	32.30	33.60	9.84	21.36

δ gca: variance of GCA; δ sca : variance of SCA; VA: additive variance; VD: dominance variance; h^2n : narrow sense heritability; h^2b : broad sense heritability; AD: anthesis date, SD: silking date; ASI: anthesis-silking interval; LR: leaf rolling; CHLC: chlorophyll content; PH: plant height; WW: Well-watered; DS: Drought-stress.

Table 4.8. Estimates of genetic component and proportional contribution of lines, testers and line x tester to the total variances for early maize genotypes continued

Source	EH		LS		PLTASP		NEPP		EA		EL	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
δ gca	2.19	2.97	0.00	0.00	0.00	0.00	0.00	0.02	0.00	-0.01	0.11	0.16
δ sca	-19.32	35.31	0.04	-0.15	-0.07	0.12	-0.08	-0.04	0.12	0.20	-0.38	3.97
VA	8.76	11.90	0.01	-0.01	0.00	0.02	0.00	0.06	0.01	-0.02	0.45	0.63
VD	-19.32	35.31	0.04	-0.15	-0.07	0.12	-0.08	-0.04	0.12	0.20	-0.38	3.97
δ gca/sca	-0.11	0.08	0.04	0.02	-0.01	0.04	-0.01	-0.41	0.03	-0.03	-0.30	0.04
h^2n	0.14	0.09	0.02	-0.02	0.01	0.06	0.02	0.12	0.04	-0.05	0.19	0.11
h^2b	-0.17	0.35	0.13	-0.25	-0.21	0.47	-0.36	0.05	0.34	0.43	0.03	0.80
Proportional contribution of lines, testers and their interactions to total variance												
Lines	83.60	46.83	35.22	34.34	64.29	60.00	58.33	71.01	52.82	38.31	84.29	55.51
Testers	10.30	26.52	26.64	0.74	0.00	8.00	16.67	13.04	12.09	0.43	7.09	15.27
Lines x Testers	6.11	26.65	38.13	64.93	35.71	32.00	25.00	15.94	35.09	61.26	8.62	29.21

δ gca: variance of GCA; δ sca : variance of SCA; VA: additive variance; VD: dominance variance; h^2n : narrow sense heritability; h^2b : broad sense heritability; EH: ear height; LS: leaf senescence; PLTASP: plant aspect; NEPP: number of ear per plant; EA: ear aspect; EL: ear length; WW: Well-watered; DS: Drought-stress.

Table 4.8. Estimates of genetic component and proportional contribution of lines, testers and line x tester to the total variances for early maize genotypes continued

Source	ED		NKRE		NKR		COBWT		GYPP)	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
δ gca	-0.02	0.75	0.01	0.17	0.59	1.08	42.58	22.82	45.61	9.24
δ sca	-0.43	0.92	-0.40	1.02	-2.79	1.12	-101.57	233.99	-70.12	48.12
VA	-0.10	3.00	0.04	0.68	2.36	4.30	170.32	91.28	182.45	36.95
VD	-0.43	0.92	-0.40	1.02	-2.79	1.12	-101.57	233.99	-70.12	48.12
δ gca/sca	0.06	0.81	-0.02	0.17	-0.21	0.96	-0.42	0.10	-0.65	0.19
h^2n	-0.01	0.16	0.03	0.12	0.16	0.24	0.12	0.13	0.26	0.13
h^2b	-0.08	0.21	-0.24	0.31	-0.03	0.31	0.05	0.46	0.16	0.30
Proportional contribution of lines, testers and their interactions to total variance										
Lines	28.32	60.36	68.59	43.13	90.87	49.50	61.66	39.11	88.82	21.62
Testers	18.17	24.20	4.62	39.82	0.06	41.89	22.35	42.40	4.13	62.07
Lines x Testers	53.51	15.43	26.79	17.05	9.06	8.61	15.99	18.49	7.05	16.31

δ gca: variance of GCA; δ sca : variance of SCA; VA: additive variance; VD: dominance variance; h^2n : narrow sense heritability; h^2b : broad sense heritability; ED: ear diameter; NKRE: number of kernel row per ear; NKR: number of kernel per row; COBWT: cob weight; PLTASP: plant aspect; GYPP: grain yield per plant; WW: Well-watered; DS: Drought-stress.

4.5.2 Intermediate maturity maize genotypes

Estimates of genetic components of variance and heritability for the traits under drought-stress and well-watered condition are presented in Table 4.9. Under wellwatered condition the variance due to general combining ability was lower than the variance of specific combining ability (SCA) for silking date, ear height, ear diameter, number of kernel row per ear, cob weight and grain yield, suggesting the preponderance of non-additive gene action controlling these characters (Table 4.9).

The variance of GCA was larger than the variance of SCA for anthesis date, anthesis silking interval, plant height, number of ear per plant, ear aspect, ear length, number of kernel per row, indicating that the additive gene action played the major role than the non-additive gene action in the inheritance of these traits. Under drought-stress condition the variances due to general combining ability were lower than the variances of specific combining ability for anthesis date, leaf senescence, plant aspect, number of ear per plant, ear aspect, ear length, ear diameter, number of kernel row per ear, number of kernel per ear, cob weight and grain yield. The variances of general combining ability were higher than the specific combining ability for silking date, anthesis silking interval, leaf rolling, plant height and ear height.

Under well-watered condition, the ratios GCA/SCA were less than unity for all the traits except for leaf rolling, ear length and number of kernel per row and under drought-stress it was less than unity for all the traits (Table 4.9). This revealed the preponderance of non-additive gene action than additive gene action in the inheritance of all the traits studied.

The results of the proportional contribution of lines to the total variation were higher than the testers in most of the traits under well-watered and drought-stress condition (Table 4.9). The highest contribution to the total variations among the lines was given by ear aspect followed by plant aspect and anthesis date under well-watered condition. Under drought-stress the highest contribution to the total variations among lines was given by chlorophyll content, followed by ear height and plant height. The lowest contribution to the total variations among the lines was given by plant aspect under wellwatered condition and ear length under drought-stress condition.

The highest contributions of the lines and tester interaction (LXT) were given by plant aspect and anthesis silking interval under well-watered and drought-stress conditions respectively. The results of the interaction between lines and testers were lower for number of kernel per row and ear height under well-watered and drought-stress conditions (Table 4.9).

The highest proportional contribution by lines, testers and line by tester interaction to the variation was given by lines for anthesis date, silking date, number of ear per plant, ear aspect, ear diameter and number of kernel per row, by testers for leaf rolling, ear length, number of kernel row per ear and yield, and by their interaction for plant height, plant aspect, cob weight and grain yield under well-watered condition. Under droughtstress condition, the highest contribution was given by lines for anthesis date, leaf rolling, plant height, ear height, plant aspect, number of ear per plant, ear aspect, ear diameter, number of kernel row per ear, number of kernel per row, cob weight and grain yield and by the testers for ear length and by their interaction for anthesis-silking interval and leaf senescence (Table 4.9).

Table 4. 9. Estimates of genetic component and proportional contribution of lines, testers and line x tester to the total variances for intermediate maturity maize genotypes

Source	AD		SD		ASI		LR		CHLC		PH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
δ gca	0.09	0.04	0.00	-0.07	0.01	-0.10	0.00	0.00	0.90	0.55	-1.45	3.51
δ sca	-0.48	0.52	1.05	-6.11	-0.06	-7.80	0.00	-0.04	6.33	-3.64	-272.75	-51.19
δ^2 A	0.35	0.18	0.01	-0.28	0.05	-0.41	0.00	0.01	3.62	2.20	-5.81	14.06
δ^2D	-0.48	0.52	1.05	-6.11	-0.06	-7.80	0.00	-0.04	6.33	-3.64	-272.75	-51.19
h^2n	0.14	0.08	0.00	-0.01	0.02	-0.01	0.09	0.04	0.09	0.10	-0.01	0.06
h^2b	-0.05	0.32	0.28	-0.17	-0.01	-0.22	0.08	-0.20	0.26	-0.07	-0.23	-0.16
δ gca/sca	-0.18	0.09	0.00	0.01	-0.20	0.01	-3.51	-0.04	0.14	-0.15	0.01	-0.07
Proportional contribution of lines, testers and their interactions to total variance												
Lines	72.92	74.04	54.24	41.12	24.03	29.82	25.05	42.02	69.75	89.12	41.59	84.75
Testers	19.05	2.75	0.09	0.84	43.61	0.01	57.54	38.77	10.28	0.01	3.67	0.53
Lines x Testers	8.04	23.21	45.66	58.03	32.36	70.17	17.41	19.22	19.97	10.87	54.74	14.72

δ gca: variance of GCA; δ sca : variance of SCA; VA: additive variance; VD: dominance variance; h^2n : narrow sense heritability; h^2b : broad sense heritability; AD: anthesis date, SD: silking date; ASI: anthesis-silking interval; LR: leaf rolling; CHLC: chlorophyll content; PH: plant height; WW: Well-watered; DS: Drought-stress.

Table 4.9. Estimates of genetic component and proportional contribution of lines, testers and line x tester to the total variances for intermediate maturity maize genotypes continued

Source	EH		LS		PLTASP		NEPP		EA		EL	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
δ gca	-0.22	0.72	-	-0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.13	0.15
δ sca	49.52	-22.73	-	0.26	-0.02	0.07	-0.07	0.21	-0.02	0.18	0.12	4.36
δ^2 A	-0.89	2.90	-	-0.12	-0.01	0.01	0.00	0.00	0.01	0.05	0.51	0.58
δ^2D	49.52	-22.73	-	0.26	-0.02	0.07	-0.07	0.21	-0.02	0.18	0.12	4.36
h^2n	-0.01	0.05	-	-0.02	-0.02	0.02	0.01	0.01	0.06	0.08	0.19	0.08
h^2b	0.34	-0.31	-	0.03	-0.08	0.14	-0.39	0.38	-0.04	0.36	0.23	0.70
δ gca/sca	-0.01	-0.03	-	-0.11	0.08	0.04	-0.01	0.01	-0.15	0.07	1.04	0.03
Proportional contribution of lines, testers and their interactions to total variance												
Lines	35.91	86.89	-	30.35	11.11	47.02	66.67	51.83	78.17	74.97	9.39	8.09
Testers	14.21	2.36	-	0.05	11.11	16.56	8.33	4.71	2.95	0.53	80.53	64.00
Lines x Testers	49.88	10.75	-	69.60	77.78	36.42	25.00	43.46	18.88	24.51	10.08	27.91

δ gca: variance of GCA; δ sca : variance of SCA; VA: additive variance; VD: dominance variance; h^2n : narrow sense heritability; h^2b : broad sense heritability; EH: ear height; LS: leaf senescence; PLTASP: plant aspect; NEPP: number of ear per plant; EA: ear aspect; EL: ear length; WW: Well-watered; DS: Drought-stress.

Table 4.9. Estimates of genetic component and proportional contribution of lines, testers and line x tester to the total variances for intermediate maturity maize genotypes continued

Source	ED		NKRE		NKR		COBWT		GYPP	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
δ gca	0.22	0.06	0.02	0.02	0.87	0.24	-29.03	16.51	0.42	0.20
δ sca	2.49	9.33	0.17	1.84	0.62	4.81	2163.45	621.95	88.34	16.74
δ^2 A	0.89	0.25	0.08	0.09	3.47	0.95	-116.12	66.05	1.67	0.79
δ^2D	2.49	9.33	0.17	1.84	0.62	4.81	2163.45	621.95	88.34	16.74
h^2n	0.03	0.01	0.05	0.02	0.26	0.03	-0.03	0.01	0.01	0.01
h^2b	0.12	0.41	0.15	0.38	0.31	0.21	0.50	0.57	0.57	0.31
δ gca/sca	0.09	0.01	0.11	0.01	1.41	0.05	-0.01	0.03	0.00	0.01
Proportional contribution of lines, testers and their interactions to total variance										
Lines	60.99	57.09	31.28	59.64	55.90	59.19	17.92	60.76	27.89	55.90
Testers	7.40	0.62	41.60	0.54	37.04	8.88	20.69	5.71	29.21	3.71
Lines x Testers	31.61	42.29	27.12	39.82	7.06	31.93	61.40	33.54	42.89	40.39

δ gca: variance of GCA; δ sca : variance of SCA; VA: additive variance; VD: dominance variance; h^2n : narrow sense heritability; h^2b : broad sense heritability; ED: ear diameter; NKRE: number of kernel row per ear; NKR: number of kernel per row; COBWT: cob weight; PLTASP: plant aspect; GYPP: grain yield per plant; WW: Well-watered; DS: Drought-stress.

4.6 Mean performances of genotypes and heterosis

Mean performances of genotypes used and mid-parent heterosis for the crosses were estimated for early and intermediate maturity maize genotypes.

4.6.1 Early maturity maize genotypes

The mean performances of the genotypes (10 crosses and 1 check) are given in Table 4.10. A number of crosses out yielded the check Omankwa. High yielding crosses were L4 x T1 with (6.99g/plant) and (20.77g/plant) under well-watered condition and drought-stress condition, respectively. On the other hand, lower yielding crosses was L5 X T1 and L5 X T2 with (5.73g/plat) under well-watered and L5 X T2 (0.00g/plant) under drought-stress condition. The overall mean grain yield for all the genotypes evaluated was 6.26g/plant and 10.83g/plant under well-watered and drought-stress conditions, respectively. The maximum mean performance of anthesis date and silking date were recorded by L5 X T1 (48.33 days) and (52.67 days), respectively under wellwatered condition. Under drought-stress condition, the maximum mean number for anthesis date (53.33 days), silking date (59.67 days) were recorded by the cross L5 X T1. The lowest performances for number of days to anthesis were observed for the crosses L2 X T1 (44.67days), L4 X T1 (44.67 days) under well-watered-condition and for L2 x T1 (44.67days), under drought-stress condition. The lowest silking dates were observed for L2 X T1 and L4 X T1 (47 days) under well watered condition and L5 X T2 (42 days) under drought-stress conditions. The check Omankwa recorded 46.67 days and 48.39 days for anthesis date under well-watered and drought-stress conditions, respectively. For silking date Omankwa recorded 50.33 days and 51.33 days under wellwatered and drought-stress conditions, respectively. Furthermore, anthesis-silking interval, leaf rolling, plant height, leaf senescence, plant aspect, number of kernel row per ear, and cod weight were in the range of 4.33 days (L5 x T1) to 2.33 days (L2 x T1 and L4 x T1); 1.39 (L3 x T1 and L5 x T1) to 1.17 (L4 x T1); 199.78 cm (L5 x T1) to 168.44cm (L4 x T1); 2.33 (L4 x T2) to 1 (L1 x T1, L2 x T1, L4 x T1, L5 x T1 and L4 x T2); 3 (L1 x T2 and L3 x T1) to 2.33 (L2x T1, L4 x T1, L4 x T2, L5 x T2); 13.44 (L1 x T1) to 11.67 (L2 x T1) 304.32 g (L2 x T2) to 214.78 g (L5 x T1) under well-watered condition. The same traits under drought-stressed were in the range of 12 (L4 x T2) to 4.67 (L5 x T2); 4.44 (L5 x T1) to 3.78 (L2 x T2); 179.78 cm ((L2 x T1) to 145.67 cm (L3 x T2); 9 (L2 x T2) to 8 (L5 x T2); 5 (L5 x T1, L5 x T2 and L2 x T2) to 3.67 (L2 x T1); 13.11 (L1 x T1) to 6.17 (L5 x T1); 89.14 g (L1 x T1) to 10.7 (L2x T2).

The estimates of heterosis for yield and yield related traits under both well-watered and drought-stressed conditions are presented in Table 4.10.

Under well-watered condition, the highest value of mid-parent heterosis for grain yield per plant was recorded by L2 X T1 (37.25g/plant) and the lowest mid-parent heterosis was recorded by L5 X T2 (-15.42g/plant). Under drought-stress condition the highest vas recorded by L1 X T1 (165.74) and the lowest value by L5 X T2 (-100g/plant).

For days to anthesis, all the traits exhibited negative and significant mid-parent heterosis except L4 x T2, L5 x T1 under well-watered and drought-stressed conditions and L5 x T2 in well-watered condition. Under well-watered and drought stress conditions, heterosis were ranged from -10.62 (L3 x T1) to -1.64 (L4 x T2) and from -10.36 (L2 x T1) to -2.76 (L4 x T2), respectively. For silking date, most of the traits showed negative and significant mid-parent heterosis except L2x T2, L4 x T2, L5 x T1 and L5 x T2 and were ranged from -7.83 (L3 x T1) to 2.91 (L4 x T2) under well-watered condition.

Under drought-stressed condition, positive and significant heterosis were observed from L5 x T1 and L5 x T2 and were ranged from -0.94 (L1 x T1) to 33.08 (L4 x T2).

Under well-watered condition, L2 x T1 and L5 x T2 showed negative and significant mid-parent heterosis for anthesis-silking date, while L1 x T1, L2 x T2, L3 x T1, L3 x T2, L4 x T1, L4 x T2 and L5x T1 showed positive and significant mid-parent heterosis. Under drought-stress condition all the crosses showed negative and significant midparent heterosis except, L1 x T1, L2 x T1, L3 x T1. Leaf rolling under well-watered condition showed negative and significant mid-parent heteosis for L1 x T1, L1 x T2, L4 x T1, L4 x T2, while L2 x T2, L3 x T1, L3 x T2, L5 x T1 and L5 x T2 showed positive and significant mid-parent heterosis. Under drought-stress condition all the traits showed positive and significant mid-parent heterosis. For plant height Positive and significant mid-parent heterosis was observed for L1x T1, L1 x T2, L2 x T1, L2 x T2 and L4 x T2 under both environmental conditions and L5 x T1 under well-watered condition.

For leaf senescence, negative and significant mid-parent heterosis was observed for L1x T1, L3x T1, L4 x T1, L5 x T1 and L5 x T2, while L1 x T2, L2 x T2, L3 x T2 and L4 x T2 showed positive and significant mid-parent heterosis under well-watered condition. Under drought-stressed condition all the crosses showed positive and significant midparent heterosis except L1x T1 and L4 x T1. All the crosses under well-watered condition manifested a positive and significant mid-parent heterosis number of kernel row per ear and cod weight. For the same trait under drought-stressed condition, except the crosses L2 X T2 and L4 X T2, all the other crosses showed positive and significant mid-parent heterosis.

Table 4. 10. Table of mean and mid-parent heterosis for early maize genotypes

Genotypes	AD				SD				ASI			
	Mean		MPH		Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1	47.00	47.00			50.67	55.00			3.67	8.00		
L2	50.00	48.33			49.00	50.33			-1.00	2.00		
L3	54.00	58.00			56.00	59.33			2.00	1.33		
L4	45.33	46.67			47.67	49.00			2.33	2.33		
L5	50.00	52.00			53.33	40.33			3.33	-11.67		
T1	49.67	51.33			50.33	52.67			0.67	1.33		
T2	46.50	50.00			49.50	39.67			3.00	-10.33		
L1XT1	45.67	46.67	-5.51**	-5.07*	48.33	53.33	-4.30**	-0.94	2.67	6.67	23.04**	42.98**
L1XT2	45.33	46.00	-3.04	-5.15*	48.67	54.00	-2.83*	14.08	3.33	8.00	-0.15	-786.70**
L2XT1	44.67	44.67	-10.36**	-10.36**	47.00	49.33	-5.37**	-4.21	2.33	4.67	-1512.12**	180.48**
L2XT2	46.67	45.67	-3.27*	-7.11**	49.33	53.33	0.16	18.51	2.67	7.67	167.00**	-284.15**
L3XT1	46.33	45.67	-10.62**	-16.45**	49.00	50.00	-7.83**	-10.71	2.67	4.33	100.00**	225.56**
L3XT2	46.33	45.33	-7.80**	-16.06**	49.00	51.00	-7.11**	3.03	2.67	5.67	6.80**	-226.00**
L4XT1	44.67	47.00	-5.96**	-4.08*	47.00	48.00	-4.08**	-5.58	2.33	1.00	55.33**	-45.36**
L4XT2	46.67	47.00	1.64	-2.76	50.00	59.00	2.91*	33.08**	3.33	12.00	24.95**	-400.00**
L5XT1	48.33	53.33	-3.02	3.22	52.67	59.67	1.62	28.32*	4.33	6.33	116.50**	-222.44**
L5XT2	47.33	46.67	-1.91	-8.49**	50.33	42.00	-2.11	5.00	3.00	-4.67	-5.21**	-57.55**
Omankwa	46.67	49.67			50.33	51.33			3.67	1.67		
Grand mean	47.29	48.39			49.90	50.96			2.61	2.57		
LSD (5%)	3.87	4.95			3.05	24.89			2.36	23.99		

-parent

CV (%)	2.00	1.00			0.90	5.80			18.50	133.10		
SE±	1.90	2.44	1.71	2.05	1.50	12.25	1.29	10.81	1.16	11.80	0.99	10.32

*: significant difference; **: highly significant difference; LSD: least significant difference; CV: coefficient of variation; SE: standard error; AD: anthesis date; SD: silking date; ASI: anthesis-silking interval; WW: Well-watered; DS: Drought-stress.

Table 4.10. Table of mean and mid heterosis for early maize genotypes continued

Genotypes	LR				CHLC				PH			
	Mean		MPH		Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1	1.61	3.44			40.79	32.43			113.56	95.00		
L2	1.22	3.39			50.11	42.15			110.67	103.61		
L3	1.00	3.50			30.89	42.90			172.67	143.56		
L4	1.39	4.06			33.83	22.99			134.11	138.00		
L5	1.17	4.61			39.70	24.28			185.56	165.56		
T1	1.44	4.06			32.17	19.50			158.78	154.22		
T2	1.17	2.94			30.74	17.24			159.11	141.56		
L1XT1	1.28	4.22	-16.07**	12.53**	40.22	24.08	10.25**	-7.26	181.11	170.56	33.00**	36.88**
L1XT2	1.33	4.11	-4.32**	28.84**	46.32	24.18	29.51**	-2.64	169.67	160.56	24.45**	35.75**
L2XT1	1.33	4.11	0.00	10.34**	46.87	21.22	13.93**	-31.16**	174.89	179.78	29.81**	39.46**
L2XT2	1.22	3.78	2.09**	19.43**	42.43	19.99	4.96	-32.68**	174.22	162.33	29.16**	32.42**
L3XT1	1.39	4.39	13.93**	16.14**	40.22	22.60	27.56**	-27.56**	181.33	162.00	9.42	8.81
L3XT2	1.44	3.89	32.72**	20.81**	44.28	25.01	43.70**	-16.83*	175.56	145.67	5.83	2.18
L4XT1	1.17	4.33	-17.31**	6.65**	40.62	26.20	23.09**	23.32**	168.44	167.17	15.02	14.41

-parent

L4XT2	1.22	4.17	-4.69**	19.14**	37.86	21.43	17.27**	6.54	173.89	173.33	18.61*	24.00*
L5XT1	1.39	4.44	6.51**	2.42**	37.88	22.19	5.41	1.37	199.78	175.78	16.04*	9.94
L5XT2	1.22	3.89	4.27**	3.05**	32.73	19.04	-7.07*	-8.29	191.89	165.67	11.35	7.89
Omankwa	1.06	3.94			37.19	27.37			191.11	162.78		
Grand mean	1.28	3.96			39.16	25.27			167.57	153.73		
LSD (5%)	0.35	0.64			7.25	15.48			19.81	21.30		
CV (%)	2.10	2.80			5.80	6.60			3.10	2.30		
SE±	0.17	0.32	0.16	0.24	3.57	7.62	3.10	6.43	9.75	10.48	8.62	9.05

*: significant difference; **: highly significant difference; LSD: least significant difference; CV: coefficient of variation; SE: standard error; LR: leaf rolling; CHLC: chlorophyll content; PH: plant height; WW: Well-watered; DS: Drought-stress.

Table 4.10. Table of mean and mid heterosis for early maize genotypes continued

Genotypes	EH				LS				PLTASP			
	Mean		MPH		Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1	43.33	31.33			1.11	8.78			3.00	4.33		
L2	46.44	54.61			1.00	7.50			2.33	5.00		
L3	90.67	89.22			1.33	5.44			2.33	4.67		
L4	65.67	68.00			1.11	8.11			2.33	4.00		
L5	93.33	96.33			1.22	7.78			2.33	5.00		
T1	83.78	80.78			1.00	9.00			3.00	4.00		
T2	76.78	66.11			1.00	7.44			2.67	5.00		
L1XT1	85.56	90.00	34.62**	60.56**	1.00	8.44	-5.21**	-5.06**	2.67	4.00	-11.00**	-3.96**

-parent

L1XT2	80.33	85.00	33.76**	74.47**	1.22	8.89	15.64**	9.62**	3.00	4.00	5.82**	-14.26**
L2XT1	83.56	93.61	28.34**	38.28**	1.00	8.67	0.00	5.09**	2.33	3.67	-12.57**	-18.44**
L2XT2	84.00	79.72	36.34**	32.07**	1.33	9.00	33.00**	20.48**	2.67	5.00	6.80**	0.00
L3XT1	87.22	88.56	-0.01	4.19	1.11	8.67	-4.72**	20.08**	3.00	4.33	12.57**	-0.12
L3XT2	83.33	71.11	-0.47	-8.44	1.22	8.44	4.72**	31.06**	2.67	4.33	6.80**	-10.44**
L4XT1	89.33	87.94	19.54**	18.21*	1.00	8.44	-5.21**	-1.34*	2.33	4.00	-12.57**	0.00
L4XT2	81.44	95.00	14.34*	41.67**	2.33	8.44	120.85**	8.55**	2.33	4.00	-6.80**	-11.11**
L5XT1	98.22	111.00	10.91	25.35**	1.00	8.78	-9.91**	4.65**	2.67	5.00	0.19	11.11**
L5XT2	96.33	89.67	13.26*	10.40	1.00	8.00	-9.91**	5.12**	2.33	5.00	-6.80**	0.00
Omankwa	103.67	91.44			1.00	8.78			2.00	3.67		
Grand mean	81.83	81.64			1.17	8.26			2.56	4.39		
LSD (5%)	13.80	15.96			0.91	1.51			1.01	0.69		
CV (%)	1.50	2.70			24.70	9.50			18.60	1.30		
SE±	6.79	7.85	6.05	6.60	0.45	0.74	0.39	0.64	0.50	0.34	0.43	0.28

*: significant difference; **: highly significant difference; LSD: least significant difference; CV: coefficient of variation; SE: standard error; EH: ear height; LS: leaf senescence; PLTASP: plant aspect; WW: Well-watered; DS: Drought-stress.

Table 4.10. Table of mean and mid heterosis for early maize genotypes continued

Genotypes	NEPP				EA				EL			
	Mean		MPH		Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1	2.67	2.33			3.56	4.00			13.28	11.61		
L2	3.00	2.33			3.11	5.00			12.67	9.67		
L3	3.00	2.67			4.33	4.67			12.78	10.33		
L4	3.00	2.50			3.11	3.33			10.07	8.42		

-parent

L5	3.00	2.00			4.11	5.00			11.17	8.00		
T1	3.33	3.33			3.22	5.00			11.72	9.72		
T2	2.33	1.50			2.00	3.25			11.33	9.00		
L1XT1	3.00	3.00			1.11	4.22			16.61	11.56		
			0.00	6.01**			-67.26**	-6.22**			32.88**	8.39**
L1XT2	3.00	2.00	20.00**	4.44**	1.00	3.83	-64.03**	5.66**	16.06	12.06	30.52**	17.03**
L2XT1	3.33	2.00	5.21**	-29.33**	1.11	3.72	-64.93**	-25.60**	16.42	10.64	34.65**	9.75**
L2XT2	3.33	1.67	24.95**	-12.79**	1.22	5.00	-52.25**	21.21**	14.94	9.00	24.50**	-3.59**
L3XT1	3.33	1.67	5.21**	-44.33**	1.00	4.11	-73.51**	-14.99**	16.61	9.78	35.59**	-2.44**
L3XT2	3.00	2.00	12.57**	-4.08**	1.00	3.78	-68.40**	-4.55**	15.17	10.47	25.84**	8.33**
L4XT1	3.33	2.67	5.21**	-8.40**	1.22	3.50	-61.45**	-15.97**	13.31	11.56	22.17**	27.45**
L4XT2	3.00	2.00	12.57**	0.00	1.00	3.72	-60.86**	13.07**	14.00	9.03	30.84**	3.67**
L5XT1	3.33	1.33	5.21**	-50.09**	2.67	4.50	-27.15**	-10.00**	13.73	9.58	19.97**	8.13**
L5XT2	3.33	1.00	24.95**	-42.86**	1.22	4.00	-60.07**	-3.03**	12.94	3.00	15.02**	-64.71**
Omankwa	2.67	2.33			1.94	3.00			12.50	11.39		
Grand mean	3.06	2.13			2.11	4.09			13.63	9.71		
LSD (5%)	0.92	1.13			0.84	0.85			2.54	1.90		
CV (%)	3.10	9.20			7.00	3.60			5.80	1.80		
SE±	0.45	0.55			0.41	0.42			1.25	0.94		
			0.39	0.49			0.36	0.34			1.07	0.76

*: significant difference; **: highly significant difference; LSD: least significant difference; CV: coefficient of variation; SE: standard error; NEPP: number of ear per plant; EA: ear aspect; EL: ear length; WW: Well-watered; DS: Drought-stress.

Table 4.10. Table of mean and mid heterosis for early maize genotypes continued

Genotypes	ED		NKRE		NKR	
L1	Mean	MPH	Mean	MPH	Mean	MPH

				-parent								
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
	28.41	23.69			10.33	9.83			13.28	11.94		
L2	28.48	24.62			10.56	8.67			16.89	12.50		
L3	30.28	26.33			7.39	4.72			6.56	4.22		
L4	32.85	27.16			9.67	9.67			19.67	12.50		
L5	34.55	20.30			8.78	3.00			9.22	1.50		
T1	30.86	24.48			11.78	9.11			17.11	11.00		
T2	40.27	28.23			12.78	10.00			24.89	15.50		
L1XT1	38.13	28.32	28.67**	17.58**	13.44	13.11	21.57**	38.44**	31.89	20.56	109.87**	79.25**
L1XT2	37.87	23.27	10.28**	-10.36**	12.44	8.44	7.66**	-14.88**	31.89	13.89	67.09**	1.24
L2XT1	39.29	28.08	32.42**	14.38**	11.67	12.00	4.48**	34.98**	32.89	17.28	93.47**	47.06**
L2XT2	38.36	19.13	11.59**	-27.61**	12.11	7.33	3.77**	-21.48**	30.22	7.17	44.66**	-48.79**
L3XT1	36.32	25.99	18.81**	2.30	12.78	10.11	33.33**	46.20**	30.44	13.44	157.20**	76.61**
L3XT2	40.53	26.06	14.90**	-4.47	13.22	9.50	31.09**	29.08**	30.44	11.17	93.58**	13.29**
L4XT1	39.67	30.15	24.53**	16.77**	13.22	11.56	23.26**	23.11**	30.33	18.94	64.93**	61.19**
L4XT2	40.14	27.57	9.79**	-0.45	12.67	10.17	12.87**	3.41*	30.56	13.33	37.16**	-4.79*
L5XT1	37.38	21.08	14.29**	-5.85*	12.44	6.17	21.01**	1.90	22.22	7.00	68.78**	12.00**
L5XT2	39.22	18.57	4.84*	-23.47**	11.89	9.06	10.30**	39.38**	25.44	12.16	49.16**	43.06**
Omankwa	38.56	30.88			12.11	10.61			25.56	14.83		
Grand mean	36.18	25.22			11.63	9.06			23.86	12.16		
LSD (5%)	4.53	6.21			2.30	3.18			6.71	5.78		
CV (%)	1.70	4.20			2.00	6.80			4.70	10.70		
SE±	2.23	3.06	1.94	2.70	1.13	1.56	0.96	1.34	3.30	2.84	2.73	2.40

-parent

*: significant difference; **: highly significant difference; LSD: least significant difference; CV: coefficient of variation; SE: standard error; ED: ear diameter; NKRE: number of kernel row per ear; NKR: number of kernel per row;

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Table 4.10. Table of mean and mid heterosis for early maize genotypes continued

Genotypes	PDWT				GYPP			
	Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS
L1	61.85	39.96			5.30	8.18		
L2	95.41	28.85			4.81	7.27		
L3	66.23	26.13			5.74	7.08		
L4	82.14	68.48			7.87	17.09		
L5	80.68	7.12			7.08	11.88		
T1	110.61	41.06			4.97	8.34		
T2	177.31	28.05			6.47	5.49		
L1XT1	254.72	89.14	195.40**	120.04**	6.50	21.95	26.64**	165.74**
L1XT2	296.11	37.82	147.63**	11.22	6.10	9.11	3.69	33.28**
L2XT1	276.5	59.59	168.42**	70.48**	6.71	15.53	37.25**	98.98**
L2XT2	304.32	10.7	123.17**	-62.39**	6.30	4.94	11.76*	-22.57**
L3XT1	282.25	35.29	219.22**	5.05	6.15	10.36	14.8*	34.37**
L3XT2	310.13	40.2	154.69**	48.39**	6.62	9.67	8.5	53.86**
L4XT1	317.92	88.07	229.88**	60.80**	6.99	20.77	8.92	63.35**
L4XT2	303.61	42.48	134.04**	-11.99	6.59	9.59	-8.12	-24.58**
L5XT1	214.78	21.98	124.56**	-8.76	5.73	10.61	-4.81	4.95
L5XT2	271.01	43.69	110.09**	148.45**	5.73	0.00	-15.42*	-100.00**
Omankwa	211.24	77.8			7.05	17.03		
Grand mean	206.49	43.69			6.26	10.83		
LSD (5%)	60.81	33.44			1.04	7.98		

CV (%)	5.9	- 19.1			5.40	13.10		
SE±	29.92	16.42	25.9	13.4	0.36	2.78	5.66	3.18

*: significant difference; **: highly significant difference; LSD: least significant difference; CV: coefficient of variation; SE: standard error; COBWGT: cob weight; GYPP: grain yield per plant; WW: Well-watered; DS: Drought-stress.

4.6.2 Intermediate maturity maize genotypes

The mean performances of the genotypes (16 crosses and 1 check) are given in Table. A total of crosses out yielded the check Omankwa. High yielding crosses were L3 x T1 (60.37g/plant) and (25.57g/plant) under well-watered and drought-stress conditions respectively. On the other hand, lower yielding crosses were L8 x T2 with (20.78g/plant) and (6.33g/plant) under well-watered and drought-stress conditions, respectively. The overall mean grain yield for all the genotypes evaluated was 35.41g/plant and 13.56g/plant for well-watered and drought-stress conditions, respectively. The maximum mean performance of anthesis date (54.67 days) and silking (55.67 days) were recorded by L1 X T2; L8 X T2 and L7 X T2 under well-watered condition. Under drought-stress condition, the maximum mean number for anthesis date

(58 days) and silking date (60.67 days) were recorded by the crosses L8 X T2 and L7 X T1. The lowest performances for number of days to anthesis were observed for the crosses L4 x T1 and L6 X T1 (50 days), under well-watered-condition and for L6 X T2 (52 days), under drought-stress condition. The lowest silking dates were observed for L4 X T1 (50.67 days) under well watered condition and for L4 X T1 and L6 X T2 (50 days), under drought-stress conditions. The check Mamaba performed 52.67 days and

58 days for anthesis date under well-watered and drought-stress conditions respectively. For silking date Mamaba performed 55.33 days and 54.33 days under well-watered and drought-stress conditions, respectively. Furthermore, anthesis-silking interval, leaf rolling, plant height, leaf senescence, plant aspect number of kernel row per ear, and cod weight were in the range of 3.33 days (L6 x T1) to -0.33 days (L7 x T2); 1.44 (L6 x T1 and L8 x T1) to 1.00 (L2 x T2, L3 x T2 and L7 x T2); 225.28 cm (L2 x T2) to 173.06 cm

(L8 x T2); 1 (for all the crosses); 3.33 (L1 x T2 and L8 x T2) to 2.67 (L1 x T1, L2 x T1, L5 x T2, L7 x T2); 15 (L4 x T2) to 11.78 (L5 x T1); 319.86g (L7 x T2) to 159.05g (L8 x T2) under well-watered condition.

The same traits under drought-stressed were in the range of 12 (L4 x T2) to -4.67 (L5 x T2); 4.44 (L5 x T1) to 3.78 (L2 x T2); 179.78 cm (L2 x T1) to 145.67 cm (L3 x T2); 9 (L2 x T2) to 8 (L5 x T2); 5 (L5 x T1, L5 x T2 and L2 x T2) to 3.67 (L2 x T1); 13.11 (L1 x T1) to 6.17 (L5 x T1); 129.92 g (L4 x T1) to 10.96 g (L8 x T2).

The estimates of heterosis were computed for yield and yield related traits under both well-watered and drought-stressed conditions.

All the crosses recorded positive and significant mid-parent heterosis for grain yield per plant under well-watered condition. The highest values were recorded by L8 X T1 (276.25g/plant) and L3 X T2 (253.23g/plant) and the lowest value was recorded by L8 X T2 (69.77g/plant). Under drought-stress condition, the highest value was recorded by L3 X T2 (49.66g/plant) and the lowest was recorded by L7 X T2 (-67.81g/plant)

For anthesis date, all the traits exhibited negative and significant mid-parent heterosis except L1 x T1, L2 x T1, L7 x T1, L8 x T1 and L8 x T2 under well-watered condition. The crosses L3 x T1, L3 x T2, L4 x T2, L5 x T2, L6 x T2 and L7 x T2 showed negative and significant mid-parent heterosis, while L1 x T1, L2 x T1, L4 x T1 and L8 x T1 showed positive and significant mid-parent heterosis drought-stressed conditions. Under well-watered condition, heterosis were ranged from 1.92 (L7 x T1) to -8.49 (L6 x T2) and from -4.52 (L1 x T1) to -6.58 (L6 x T2) under drought-stress condition.

For silking date, many traits showed negative and significant mid-parent heterosis except L7 x T1, and were ranged from 3.41 (L7 x T1) to -8.66 (L3 x T2) under wellwatered condition. Under drought-stressed condition, negative and significant heterosis were observed from L6 x T2 and were ranged from 26.80 (L8 x T1) to -0.63 (L4 x T1).

For anthesis-silking interval Under well-watered condition, L1 x T1, L1 x T2, L2 x T2, L3 x T2, L4 x T1, L7 x T2, L8 x T1, L8 x T2 showed negative and significant midparent heterosis, L3 x T1, L4 x T2, L5 x T1, L5 x T2, L6 x T1, L7 x T1 showed positive and significant mid-parent heterosis. Under drought stressed condition, L1 x T1, L3 x T1, L4 x T1, L6 x T1, L8x T1, L8 x T2 showed negative and significant mid-parent heterosis, while the other crosses showed positive and significant mid-parent heterosis.

Leaf rolling under well-watered condition showed negative and significant mid-parent heterosis for L2 x T2, L3 x T2, L4 x T1, L6 x T2, , L7 x T1, L7 x T2 while except L1 x T1 that was not significant, the other crosses showed positive and significant mid-parent heterosis. The crosses were ranged from 17.19 (L2 x T1) to -12.36 (L7 x T1). Under drought-stress condition all the traits showed positive and significant mid-parent heterosis. Crosses were ranged from 71.15 (L4 x T2) to 2.83 (L1 x T1).

Plant height showed non-significant mid-parent heterosis under well-watered condition and were ranged from 28.01 (L5 x T1) to -22.83 (L8 x T2). Except 24 x T2 and L6 x T2 who showed positive and significant mid-parent heterosis under drought-stressed condition, the other crosses showed non-significant mid-parent heterosis. The crosses were ranged from 22.75 (L6 x T2) to 3.05 (L1 x T1).

For leaf senescence, non-significant mid-parent heterosis was observed in well-watered condition. Under drought-stressed condition negative and significant mid-parent heterosis was observed for almost all the traits except for L3 x T1 and L8x T2 that showed positive and significant mid-parent heterosis and L1 x T2, L2 x T2 and L4 x 2 that showed non-significant mid-parent heterosis. The crosses were ranged from 17.10 (L8 x T2) to -28.88 (L6 x T2).

For plant aspect trait negative and significant mid-parent heterosis were observed for most of the crosses under well-watered condition except L1 x T2 that showed positive and significant mid-parent heterosis and L6 x T1, and L7 x T1 who were not significant. The crosses were ranged from 11.00 (L1 x T2) to -19.82 (L5 x T2). Under droughtstressed condition, most of the crosses showed negative and significant mid-parent heterosis except L1 x T2, L7 x T2 and L8 x T2 who showed positive and significant mid-parent heterosis, and L8 x T1 that was not significant. The crosses were ranged from 16.75 (L7 x T2) to -21.77 (L7 x T1).

Most of the crosses under well-watered condition manifested a positive and significant mid-parent heterosis for number of kernel row per ear and cod weight except the cross L7 x T1 for number of kernel row per ear.

The crosses L1 x T2, L6 x T1, L7 x T1, L7 x T2, and L8 x T2 showed negative and significant mid-parent heterosis, while the other crosses showed positive and significant mid-parent heterosis except L1 x T1 and L5 x T1 who were not significant for number of kernel row per ear. The cross L8 x T2 showed negative and significant mid-parent heterosis cob weight, whereas the other crosses showed positive and significant midparent heterosis except the non-significant crosses L1 x T2, L2 x T1, L5 x T1, L5 x T2, L6 x T1, L7 x T2 and L8 x T2.

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Table 4. 11. Table of mean and mid parent heterosis for intermediate maize genotypes

Genotypes	AD				SD				ASI			
	Mean		MPH		Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1	56.33	53.00			57.33	55.33			1.00	2.33		
L2	55.67	55.00			56.00	57.33			0.33	2.33		
L3	56.67	56.67			57.33	59.00			0.67	2.33		
L4	52.33	53.00			52.00	53.67			-0.33	0.67		
L5	56.00	56.67			55.00	55.00			-1.00	-1.67		
L6	53.67	56.00			54.67	58.00			1.00	2.00		
L7	53.00	55.33			53.67	58.33			0.67	3.00		
L8	55.00	54.33			56.33	39.00			1.33	-15.33		
T1	51.00	50.33			54.00	53.00			3.00	2.67		
T2	56.33	55.33			58.00	59.33			1.67	4.00		
L1XT1	53.33	54.00	-0.62	4.52**	55.00	55.67	-1.19	2.78	1.67	1.67	-16.50**	-33.20**
L1XT2	54.67	53.67	-2.95*	-0.91	55.33	59.67	-4.05**	4.08	0.67	6.00	-49.81**	89.57**
L2XT1	52.33	53.67	-1.88	1.91*	54.00	57.33	-1.82	3.92	1.67	3.67	0.30	46.80**
L2XT2	54.67	55.00	-2.38*	-0.30	55.33	60.00	-2.93*	2.86	0.67	5.00	-33.00**	57.98**
L3XT1	50.67	52.33	-5.88**	-2.19*	53.33	54.33	-4.19**	-2.98	2.67	2.00	45.50**	-20.00**
L3XT2	52.33	52.33	-7.38**	-6.55**	52.67	58.00	-8.66**	-1.97	0.33	5.67	-71.79**	79.15**
L4XT1	50.00	52.67	-3.22**	1.95*	50.67	53.00	-4.40**	-0.63	0.67	0.33	-49.81**	-80.24**
L4XT2	52.33	52.67	-3.68**	-2.76**	53.67	56.67	-2.42*	0.30	1.33	4.00	98.51**	71.31**
L5XT1	52.33	53.67	-2.19*	0.32	53.67	59.33	-1.52	9.87*	1.33	5.67	33.00**	1034.00**
L5XT2	53.67	53.33	-4.44**	-4.77**	54.33	55.33	-3.84**	-3.21	0.67	2.00	100.00**	71.67**
L6xT1	50.00	52.67	-4.46**	-0.93	53.33	59.67	-1.85	7.51	3.33	7.00	66.50**	199.79**
L6xT2	50.33	52.00	-8.49**	-6.58**	51.67	53.00	-8.28**	-9.66*	1.33	1.00	-0.37	-66.67**
L7XT1	53.00	53.33	1.92	0.95	55.67	60.67	3.41**	8.99*	2.67	7.33	45.50**	158.55**
L7XT2	52.67	53.33	-3.65**	-3.61**	52.33	59.00	-6.28**	0.29	-0.33	5.67	-128.21**	62.00**

-parent heterosis for intermediate maize genotypes continued

L8XT1	53.00	54.33	0.00	3.82**	54.00	58.33	-2.11*	26.80**	1.00	3.67	-53.81**	-157.98**
L8XT2	54.67	58.00	-1.79	5.78**	55.00	60.33	-3.79**	22.71**	0.33	2.33	-78.00**	-141.13**

Table 4.11. Table of mean and mid parent heterosis for intermediate maize genotypes continued

Genotypes	AD				SD				ASI			
	Mean		MPH		Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
Mamaba	52.67	51.33			55.33	54.33			2.67	3.00		
Grand Mean	53.28	53.85			54.43	56.40			1.15	2.53		
LSD (5%)	2.72	2.12			2.75	11.62			2.47	11.83		
CV (%)	3.10	2.40			3.10	12.60			131.30	285.60		
SE±	1.36	1.06			1.37	5.79			1.23	5.90		
			1.17	0.87			1.17	4.64			3.29	4.75

*: significant difference; **: highly significant difference; LSD: least significant difference; CV: coefficient of variation; SE: standard error; AD: anthesis date; SD: silking date; ASI: anthesis-silking interval; WW: Well-watered; DS: Drought-stress.

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Table 4.11. Table of mean and mid

Genotypes	LR				CHLC				PH			
	Mean		MPH		Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1	1.06	4.00			45.73	32.91			225.00	200.22		
L2	1.06	3.89			31.10	25.56			201.44	188.44		
L3	1.06	3.78			36.80	32.24			203.44	190.00		
L4	1.11	3.00			33.20	28.29			191.00	191.00		
L5	1.06	3.56			24.18	21.69			182.78	183.67		
L6	1.22	3.58			40.67	40.37			201.50	181.17		
L7	1.17	3.06			39.56	33.06			209.44	173.72		
L8	1.28	2.50			32.99	30.32			160.28	156.00		
T1	1.50	3.78			34.19	29.90			175.00	168.33		
T2	1.00	2.06			42.48	35.37			288.22	158.44		
L1XT1	1.28	4.00	0.00	2.83**	41.60	30.59	4.10	-2.60	193.44	189.89	-3.28	3.05
L1XT2	1.11	3.61	7.77**	19.14**	40.80	28.93	-7.49*	-15.26**	223.11	199.33	-13.05	11.15
L2XT1	1.50	4.22	17.19**	10.04**	39.42	29.42	20.75**	6.09*	223.22	201.44	18.60	12.92
L2XT2	1.00	4.00	-2.91**	34.45**	35.33	31.70	-3.97	4.05	225.28	209.83	-7.99	20.98*
L3XT1	1.39	4.28	8.59**	13.23**	33.84	31.16	-4.66	0.29	221.33	197.78	16.97	10.39
L3XT2	1.00	3.89	-2.91**	33.22**	42.97	30.07	8.40*	-11.05**	206.89	202.11	-15.84	16.01
L4XT1	1.22	4.17	-6.51**	23.01**	38.87	31.56	15.36**	8.47*	213.44	205.00	16.63	14.10
L4XT2	1.11	4.33	5.21**	71.15**	44.50	35.61	17.60**	11.88**	206.22	208.11	-13.94	19.11
L5XT1	1.33	4.22	3.91**	14.99**	34.73	28.05	19.00**	8.74*	229.00	194.56	28.01	10.55
L5XT2	1.06	4.00	2.91**	42.35**	34.31	24.80	2.94	-13.07**	209.22	190.89	-11.16	11.60
L6xT1	1.44	4.39	5.88**	19.29**	50.49	34.04	34.89**	-3.12	197.22	197.11	4.76	12.80

-parent heterosis for intermediate maize genotypes continued

L6xT2	1.06	4.06	-4.50**	43.97**	51.16	36.23	23.05**	-4.33	213.11	208.44	-12.97	22.75*
L7XT1	1.17	4.11	-12.36**	20.18**	36.99	31.82	0.31	1.08	213.22	194.78	10.92	13.89
L7XT2	1.00	3.78	-7.83**	47.66**	47.67	28.11	16.21**	-17.84**	205.44	186.56	-17.44	12.33
L8XT1	1.44	4.17	3.60**	32.80**	30.00	21.99	-10.69**	-26.97**	213.11	180.78	27.12	11.48
L8XT2	1.36	3.58	19.30**	57.02**	39.45	22.51	4.54	-31.47**	173.06	168.39	-22.83	7.10

Table 4.11 -

. Table of mean and mid parent heterosis for intermediate maize genotypes continued

Genotypes	LR				CHLC				PH			
	Mean		MPH		Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
Mamaba	1.11	4.00			36.06	31.30			204.11	187.56		
Grand Mean	1.19	3.78			38.48	30.28			207.72	189.39		
LSD (5%)	0.31	0.73			9.61	9.08			64.03	27.90		
CV (%)	15.90	11.80			15.30	18.30			18.80	9.00		
SE±	0.15	0.36			4.79	4.53			31.94	13.92		
			0.14	0.30			3.78	3.37			27.49	11.57

*: significant difference; **: highly significant difference; LSD: least significant difference; CV: coefficient of variation; SE: standard error; LR: leaf rolling; CHLC: chlorophyll content; PH: plant height; WW: Well-watered; DS: Drought-stress.

Table 4.11. Table of mean and mid-parent heterosis for intermediate maize genotypes continued

Genotypes	EH				LS				PLTASP			
	Mean		MPH		Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1	114.67	106.22			1.00	9.56			2.67	3.67		
L2	103.17	106.72			1.00	8.56			3.67	4.33		
L3	108.33	106.11			1.00	6.89			3.67	4.67		
L4	91.67	90.56			1.00	8.56			3.33	4.00		
L5	100.50	94.78			1.00	9.78			3.33	4.33		
L6	101.00	81.78			1.00	9.33			3.00	4.33		
L7	119.78	99.44			1.00	6.72			3.00	3.67		
L8	89.28	84.67			1.00	6.78			4.00	4.67		
T1	86.78	86.11			1.00	9.00			3.00	4.00		
T2	85.78	75.44			1.00	8.78			3.33	4.33		
L1XT1	111.11	102.56	10.31	6.65	1.00	8.33	0.00	-10.24**	2.67	3.33	-5.82**	-13.17**
L1XT2	123.11	105.78	22.83**	16.46*	1.00	9.11	0.00	-0.65	3.33	4.33	11.00**	8.25**
L2XT1	117.78	111.72	24.01**	15.87*	1.00	8.67	0.00	-1.25	2.67	4.00	-19.94**	-3.96**
L2XT2	116.06	108.66	22.85**	19.30**	1.00	5.50	0.00	-36.56**	3.00	4.00	-14.29**	-7.62**
L3XT1	120.33	107.67	23.35**	12.03*	1.00	8.67	0.00	9.13**	3.00	3.67	-10.04**	-15.34**
L3XT2	108.11	104.33	11.39	14.93*	1.00	6.44	0.00	-17.80**	3.00	3.67	-14.29**	-18.44**
L4XT1	124.78	108.00	39.85**	22.26**	1.00	6.44	0.00	-26.65**	3.00	3.33	-5.21**	-16.75**
L4XT2	106.67	109.78	20.23**	32.27**	1.00	8.67	0.00	0.00	3.00	3.33	-9.91**	-20.05**
L5XT1	123.11	96.67	31.47**	6.88	1.00	8.22	0.00	-12.46**	3.00	3.67	-5.21**	-11.88**
L5XT2	104.67	101.11	12.38*	18.80**	1.00	8.44	0.00	-9.05**	2.67	4.00	-19.82**	-7.62**
L6xT1	98.11	106.11	4.49	26.40**	1.00	8.11	0.00	-11.51**	3.00	4.00	0.00	-3.96**
L6xT2	107.22	108.44	14.81*	37.95**	1.00	6.44	0.00	-28.88**	3.00	3.67	-5.21**	-15.24**
L7XT1	116.22	104.11	12.53*	12.22*	1.00	6.00	0.00	-23.66**	3.00	3.00	0.00	-21.77**

Table 4.11. Table of mean and mid-parent heterosis for intermediate maize genotypes continued

Genotypes	EH				LS				PLTASP			
	Mean		MPH		Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L7XT2	115.00	109.33	11.89	25.03**	1.00	7.33	0.00	-5.42**	2.67	4.67	-15.64**	16.75**
L8XT1	116.11	97.33	31.90**	13.98*	1.00	7.00	0.00	-11.28**	2.33	4.33	-33.43**	-0.12
L8XT2	95.78	97.89	9.43	22.28**	1.00	9.11	0.00	17.10**	3.33	5.00	-9.14**	11.11**
Mamaba	98.89	91.22			1.00	10.00			2.67	3.67		
Grand Mean	107.56	100.09			1.00	8.02			3.05	3.99		
LSD (5%)	17.33	17.31			*	4.28			1.25	1.15		
CV (%)	9.80	10.60			0.00	32.60			25.00	17.60		
SE±	8.65	8.63			0.00	2.14			0.62	0.57		
			6.90	6.46			0.45	1.67			0.45	0.48

*: significant difference; **: highly significant difference; LSD: least significant difference; CV: coefficient of variation; SE: standard error; EH: ear height; LS: leaf senescence; PLTASP: plant aspect; WW: Well-watered; DS: Drought-stress.

-parent heterosis for intermediate maize genotypes continued

Table 4.11. Table of mean and mid-parent heterosis for intermediate maize genotypes continued

Genotypes	NEPP				EA				EL			
	Mean		MPH		Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1	2.67	2.00			1.61	2.67			14.14	13.36		
L2	2.00	2.00			2.33	2.78			10.27	9.03		
L3	2.67	2.00			2.78	3.50			7.61	8.72		
L4	2.67	2.33			2.00	3.11			10.50	10.72		
L5	2.33	2.33			1.67	2.83			10.89	9.28		
L6	2.67	1.67			2.33	2.83			12.89	11.42		
L7	3.00	2.00			3.33	2.67			11.50	9.58		
L8	2.00	1.00			3.89	5.00			9.44	9.50		
T1	2.67	2.00			2.33	3.06			11.25	10.50		
T2	3.00	2.33			2.44	3.67			9.50	7.17		
L1XT1	3.00	2.67	12.36**	33.50**	1.11	2.78	-43.65**	-2.97**	16.06	15.78	24.30**	32.27**
L1XT2	2.67	2.33	-5.82**	7.62**	1.22	3.61	-39.75**	13.88**	14.00	10.67	-9.73**	3.95**
L2XT1	3.00	2.33	28.48**	16.50**	1.00	2.39	-57.08**	-18.15**	17.00	13.33	23.88**	36.51**
L2XT2	3.00	2.67	20.00**	23.33**	1.22	2.50	-48.85**	-22.48**	11.94	11.62	17.55**	43.46**
L3XT1	3.00	3.00	12.36**	50.00**	1.11	2.44	-56.56**	-25.61**	16.33	12.33	30.75**	28.30**
L3XT2	2.67	2.00	-5.82**	-7.62**	1.00	3.06	-61.69**	-14.64**	12.97	8.72	1.93**	9.75**
L4XT1	3.00	3.00	12.36**	38.57**	1.11	2.22	-48.73**	-28.04**	16.50	13.72	26.16**	29.31**
L4XT2	3.00	3.00	5.82**	28.76**	1.78	2.56	-19.82**	-24.48**	12.22	10.00	0.00	11.79**
L5XT1	3.00	3.00	20.00**	38.57**	1.11	2.67	-44.50**	-9.34**	17.33	13.72	23.94**	38.73**
L5XT2	3.00	2.00	12.57**	-14.16**	1.11	2.33	-45.99**	-28.31**	14.59	11.75	15.25**	42.86**
L6xT1	3.00	2.67	12.36**	45.50**	1.00	3.44	-57.08**	16.81**	16.50	12.94	7.21**	18.07**
L6xT2	3.00	3.00	5.82**	50.00**	1.00	2.00	-58.07**	-38.46**	14.58	10.39	-7.19**	11.78**
L7XT1	3.00	3.00	5.82**	50.00**	1.44	3.00	-49.12**	4.71**	17.22	16.00	40.66**	59.36**
L7XT2	3.00	1.67	0.00	-22.86**	1.11	3.00	-61.53**	-5.36**	14.56	8.67	-17.43**	3.52**

Table 4.11. Table of mean and mid-parent heterosis for intermediate maize genotypes continued

parent heterosis for intermediate maize genotypes continued

Genotypes	NEPP				EA				EL			
	Mean		MPH		Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L8XT1	2.67	1.00	14.35**	-33.33**	1.78	4.00	-42.77**	-0.74	17.81	18.50	78.83**	85.00**
L8XT2	2.67	2.00	6.80**	20.12**	2.11	5.00	-33.33**	15.34**	12.64	7.25	-23.44**	-13.02**
Mamaba	3.00	2.67			1.56	2.33			14.44	10.72		
Grand Mean	2.79	2.28			1.72	3.02			13.51	11.31		
LSD (5%)	0.79	0.98			0.72	1.19			2.39	2.59		
CV (%)	17.40	26.20			25.40	24.00			10.80	14.00		
SE±	0.40	0.49			0.36	0.59			1.19	1.29		
			0.35	0.42			0.32	0.45			1.03	1.02

*: significant difference; **: highly significant difference; LSD: least significant difference; CV: coefficient of variation; SE: standard error; NEPP: number of ear per plant; EA: ear aspect; EL: ear length; WW: Well-watered; DS: Drought-stress.

Table 4.11. Table of mean and mid-

	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
L1	40.27	33.88			14.00	12.28			25.89	17.78		
L2	33.04	27.94			12.33	9.28			22.11	12.61		
L3	36.33	29.86			11.56	10.17			13.83	14.00		
L4	31.48	31.28			13.56	12.11			19.39	17.22		
L5	32.20	26.87			10.00	9.72			26.56	18.06		
L6	34.84	28.38			12.56	10.83			25.61	17.83		
L7	40.09	30.03			12.11	10.33			20.67	12.83		
L8	42.48	28.20			9.11	7.00			7.44	2.00		
T1	37.04	30.22			11.72	10.50			22.28	14.28		
T2	39.72	25.93			13.33	9.44			18.94	9.22		
L1XT1	42.09	30.89	8.89*	-3.62	14.33	11.33	11.43**	-0.53	30.44	19.00	26.39**	18.53**
L1XT2	42.98	25.54	7.46*	-14.60**	14.44	8.50	5.67**	-21.73**	27.44	10.94	22.42**	-18.96**
L2XT1	35.83	28.92	2.25	-0.55	12.67	10.83	5.36**	9.50**	30.33	17.39	36.65**	29.34**
L2XT2	31.64	27.91	-13.03**	3.62	13.78	9.75	7.40**	4.17**	27.44	16.33	33.69**	49.61**
L3XT1	41.76	31.18	13.83**	3.79	12.78	11.33	9.79**	9.63**	34.56	17.78	91.42**	25.74**
L3XT2	43.54	31.01	14.50**	11.17**	13.44	12.67	8.00**	29.22**	25.61	12.67	56.30**	9.13**
L4XT1	40.54	32.98	18.33**	7.25**	12.56	12.22	-0.63	8.09**	32.44	19.78	55.70**	25.59**
L4XT2	46.98	37.32	31.97**	30.47**	15.00	12.22	11.57**	13.41**	23.89	15.11	24.65**	14.30**
L5XT1	38.38	26.46	10.86**	-7.30**	11.78	9.89	8.47**	-2.18	37.00	19.44	51.52**	20.22**
L5XT2	43.42	31.44	20.75**	19.09**	13.33	12.33	14.27**	28.71**	32.56	21.33	43.12**	56.38**
L6xT1	40.08	23.45	11.52**	-19.97**	12.22	9.22	0.66	-13.55**	35.67	13.22	48.97**	-17.66**
L6xT2	39.06	33.17	4.77	22.15**	14.89	13.44	15.03**	32.61**	28.89	18.22	29.70**	34.71**
L7XT1	32.73	28.13	-15.13**	-6.62*	11.67	9.22	-2.06*	-11.47**	33.33	16.89	55.20**	24.60**
L7XT2	42.56	23.47	6.65*	-16.12**	13.78	8.67	8.33**	-12.29**	30.22	14.33	52.59**	29.98**
L8XT1	40.11	27.20	0.88	-6.88*	13.22	9.00	26.93**	2.86*	26.17	13.00	76.11**	59.71**

Table 4.11. Table of mean and mid-parent heterosis for intermediate maize genotypes continued

Genotypes	ED				NKRE				NKR			
	Mean		MPH		Mean		MPH		Mean		MPH	
L8XT2	38.29	22.95	-6.84*	-15.20**	12.83	6.50	14.35**	-20.92**	17.72	4.50	34.34**	-19.79**

Table 4.11. Table of mean and mid-parent heterosis for intermediate maize genotypes continued

Genotypes	ED				NKRE				NKR			
	Mean		MPH		Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS	WW	DS
Mamaba	39.40	444.34			13.56	12.28			28.11	19.28		
Grand Mean	38.77	44.41			12.84	10.41			26.09	15.00		
LSD (5%)	9.36	225.55			1.87	3.35			5.08	8.43		
CV (%)	14.70	310.30			8.90	19.70			11.90	34.30		
SE±	4.67	112.50			0.93	1.67			2.53	4.21		
			3.56	2.63			0.82	1.27			2.13	3.30

*: significant difference; **: highly significant difference; LSD: least significant difference; CV: coefficient of variation; SE: standard error; ED: ear diameter; NKRE: number of kernel row per ear; NKR: number of kernel per row; WW: Well-watered; DS: Drought-stress.

Table 4.11. Table of mean and mid-parent heterosis for intermediate maize genotypes continued

Genotypes	PDWT				GYPP			
	Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS
L1	189.66	69.29			27.73	11.48		
L2	77.68	25.84			15.49	6.02		
L3	76.84	35.28			12.89	6.87		
L4	129.60	65.71			24.47	14.08		
L5	99.44	55.43			21.79	14.2		
L6	130.55	57.80			25.1	13.01		
L7	146.79	43.03			26.33	9.06		
L8	46.77	11.73			7.01	19.33		
T1	124.22	60.97			21.28	12.5		
T2	110.69	27.01			17.47	6.77		
L1XT1	275.70	92.10	275.67**	41.41*	46.67	12.15	90.45**	-50.42**
L1XT2	211.90	50.61	241.10**	5.11	27.83	12.59	23.14**	-44.29**
L2XT1	263.66	61.09	361.18**	40.74	48.9	12.5	165.98**	-32.01**
L2XT2	271.55	98.06	388.32**	271.09**	37.09	17.2	125.06**	4.37**
L3XT1	318.49	113.38	416.81**	135.59**	60.35	25.57	253.23**	49.66**
L3XT2	245.33	49.02	361.64**	57.39*	42.81	10.95	182.02**	-27.87**
L4XT1	307.81	129.92	342.54**	105.12**	52.61	23.73	129.99**	3.74**
L4XT2	197.95	124.66	264.76**	168.90**	33.02	21.38	57.46**	1.96
L5XT1	303.75	79.27	371.62**	36.20	51.49	11.42	139.10**	-46.97**
L5XT2	254.66	49.69	342.38**	20.55	40.55	11.16	106.57**	-43.15**
L6xT1	281.63	45.75	321.09**	-22.96	51.06	9.87	120.18**	-57.44**
L6xT2	296.22	97.34	345.58**	129.55**	54.53	20.4	156.19**	-4.16**
L7XT1	229.53	102.69	269.39**	97.48**	41.05	17.49	72.44**	-26.53**

-parent heterosis for intermediate maize genotypes continued

L7XT2	319.86	23.22	348.45**	-33.70	56.68	7.05	158.81**	-67.81**
L8XT1	303.32	23.70	454.78**	-34.80	53.22	9.11	276.25**	-35.60**
L8XT2	159.05	10.96	302.02**	-43.42*	20.78	6.33	69.77**	-48.28**

Table 4.11. Table of mean and mid

Genotypes	CBWT				GYPP			
	Mean		MPH		Mean		MPH	
	WW	DS	WW	DS	WW	DS	WW	DS
Mamaba	252.71	122.96			37.95	23.97		
Mean	208.35	63.95			35.41	13.56		
LSD (5%)	75.95	68.53			13.41	11.49		
CV (%)	22.30	65.50			23.10	51.70		
SE±	37.88	34.18			4.731	4.05		
			31.85	23.48			1.54	1.42

*: significant difference; **: highly significant difference; LDS: least significant difference; CV: coefficient of variation; SE: standard error; COBWGT: cob weight; GYPP: grain yield per plant; WW: Well-watered; DS: Drought-stress.

Table 4.11. Table of mean and mid-parent heterosis for intermediate maize genotypes continued

CHAPTER FIVE

5.0 DISCUSSION

5.1 Analyses of variance for early and intermediate maturity maize genotypes

The analysis of variance revealed significant genotypes effect for many characters under-well watered and drought-stress conditions for early and intermediate maize genotypes. This provides evidence of the presence of sufficient genetic variability among lines, testers, and crosses and allows further assessment of general combining ability analyses. It also indicates that the two environmental conditions of the two genetic groups were not similar in many ways and that is why the genotypes did not perform in the same way in the environments.

In line with the current findings, significant mean square due to genotypes for grain yield and yield related traits in maize were also reported by previous investigators (Aly and Amer, 2008; Akbar et al., 2009; Rahman et al., 2010; Shams et al., 2010; Umar et al., 2014).

Mean squares due to lines and crosses for many characters under both environmental conditions, for the early and intermediate maturity maize genotypes were highly significant for many traits, indicating that the crosses were different from each other. Therefore; it is possible to select the most desirable crosses. For that reason, suitable hybrids could be developed for that specific environment.

The non-significant different testers mean squares observed for most of the traits suggest that the testers used for the current study had comparable potential for the studied traits. This finding agrees with the results of Legesse *et al.* (2009); Bayisa *et al.* (2008); Shushay *et al*. (2013); Aminu and Izge (2013); Aminu *et al.* (2014) who found significant difference mean squares due to GCA of lines. Mosa (2010) reported highly significant mean square due to top crosses entries, Wali *et al.* (2010) found high level of significant GCA mean squares due to lines for all the traits they studied. Except Shushay *et al.* (2013) who reported non-significant difference for most of the traits studied, most of these investigators reported significant difference in testers.

5.2 General combining ability effect for early and intermediate maturity maize genotypes

Variation among genotypes is the main tool for the breeder to be able to fully exploit the diversity in the population to select parents and crosses. In such programmes knowledge of combing ability of parents becomes necessary. The current results of grain yield indicates the existence of good and poor general combiners among the inbred lines studied, for early and intermediate maize genotypes, respectively.

The expression of positive and significant GCA effect for a genotype indicates a sign of good general combiner, while the contrary express poor general combiner. In this study, parent lines identified as good general combiners could be exploited for the traits of interest to improve maize yield under drought-stress condition, as these parents have potential to transfer desirable traits to their offspring. These results support reports of legesse *et al.* (2009); Mosa (2010); Makumbi *et al.* (2011); Shushay *et al.* (2013); Aminu and Izge (2013), Aminu *and al.* (2014) who also reported both positive and negative significant GCA effect in maize. However, the finding of this study contrast results of Bayisa *et al.* (2008) who found non-significant GCA effects for grain yield in line x tester analysis. This could be due to differences in the maturity group of maize used and the environments under which evaluations were carried out.

For anthesis and silking date, positive and negative significant GCA effects were observed under the two environmental conditions for both early and intermediate genotypes. Positive and significant GCA effect showed poor general combiner while negative and significant GCA effect showed good general combiner. In this study the negative GCA effects for anthesis and silking date, implies that the inbred lines are desirable under drought environment as it indicates the tendency of earliness. These parents could have genes that confer earliness and could escape drought. Therefore, there is possibility of making effective selection for these traits, which could lead to considerable genetic improvement for earliness. These findings are in agreement with that of many researchers (Legesse *et al.*, 2009; Mosa, 2010; Aly *et al.*, 2011; Badu-Apraku *et al.*, 2011; Shushay *et al.*, 2013)

Leaf rolling showed positive and significant GCA effects for only L8 (0.19) under well watered condition among intermediate maturity maize lines. The negative GCA effects for Leaf rolling is a sign of good general combiner, indicating that selection could be done for unrolled leaves, while, positive GCA effects showed poor general combiner. It is one of the important secondary traits for selecting drought tolerant genotypes. It is drought avoidance mechanism to prevent water deficit during drought stress (Bänziger *et al.*, 2000).

With respect to plant height, good and poor general combiner were observed for early and intermediate genotypes under well-watered and drought-stressed condition. L3 and L8 under drought-stress condition for early and intermediate genetic groups showed negative and significant GCA effect, they have a tendency in reducing offspring’s height. For maize, shorter plant is required for lodging resistance. That is desirable under drought and windy environment. Similar result were reported by Izge *et al.* (2007); Aminu and Izge (2013) and Aminu *et al.* (2014).

L5 had negative, significant GCA effect for number of ear per plant and was poor general combiner under drought-stressed condition for early lines and for intermediate lines under drought-stress, L4 was good combiner with positive, significant GCA effects for the same trait, however L8 showed negative and significant GCA effects and was poor combiner. The positive and significant GCA effects for this trait indicate that it is a reliable and important secondary trait for selecting drought tolerant genotypes to increase yield. This finding is similar with that of Badu-Apraku *et al*. (2011), Shushay *et al.* (2013) who reported number of ear per plant to be a major component to the increase grain yield associated with recurrent selection programs under drought-stress. A negative and significant GCA effect for this trait shows the non proliferacy of a genotype which is undesirable.

For early lines, positive and negative significant GCA effects were exhibited for ear aspect and ear length under drought-stress and well-watered conditions, respectively. Also positive and negative significant GCA effects were observed for ear diameter, number of kernel row per ear, number of kernel per row and cob weight under wellwatered and drought-stress conditions.

For intermediate inbred line, under drought-stress condition, positive and negative significant GCA effects were exhibited for ear aspect, positive and significant GCA effects for ear diameter, number of kernel row per ear and cob weight.

For ear aspect, a negative and significant GCA effect is a sign of good general combiner, while positive and significant GCA effects showed poorest GCA effects. The positive and significant GCA effects for the other traits indicate good general combination for these traits as they are important yield component that contributes to increase yield. Therefore parents with positive GCA effects for these traits could be desirable parents for drought tolerant hybrid development. Such lines contribute suitable alleles in the procedure of synthesis of new varieties. The present results is in conformity with the finding of Asif *et al.* (2007); Habtamu and Hadji (2010); Shushay *et al.* (2013), Aminu *et al.* (2014); Aly *et al.* (2011); Aly (2013); Mosa and Aly (2012); Chandel *et al.* (2014) who reported positive and significant GCA effects for these traits on maize.

5.3 Estimates of specific combining ability for early and intermediate maturity maize genotypes

The crosses evaluated in the current study showed considerable variation in SCA effects for different traits. Poor and good specific combiners have been observed from early and intermediate crosses for many traits under well-watered and drought-stress conditions. Grain yield manifested both positive and negative significant SCA effects among the crosses under both environmental conditions.

For intermediate genotypes under well-watered condition L7 x T2 and L8 x T1 have positive and significant SCA effects for grain yield. L7 x T2 and L8 x T1 were good specific combiners for grain yield while; L7 x T1 and L8 x T2 were poor specific combiners. Under drought-stress L6 x T2 showed positive and significant SCA effects. Crosses with positive and significant SCA effects are desirable and could be used for their good specific combiners in maize improvement program. The findings of this study is in agreement with the finding of Bello and Olaoye (2009); Shams *et al.* (2010);

Aminu and Izge (2013); Shushay *et al.* (2013); Aminu *et al.* (2014); who reported significant level of SCA effects in most of the crosses they studied for grain yield in maize.

On the contrary, Ahmad and Saleem (2003) and Mawere (2007) reported nonsignificant specific combining ability effects in their study.

The crosses showed non-significant SCA effect for Anthesis and silking date and anthesis-silking interval, leaf rolling, chlorophyll content for early genotypes under well-watered and drought-stress condition. For intermediate crosses, non-significance SCA effects were observed for silking date, anthesis-silking interval, leaf rolling and chlorophyll content. With respect to date to anthesis, intermediate crosses were not significant under wellwatered condition. Under drought-stress condition only the cross L8 X T1 showed negative and significant SCA effect for earliness and drought escape, whereas L 8x T2 was the latest for its positive and significant specific combining ability effects. Most of the crosses manifested non-significant difference for anthesis date. Similar finding were reported by Teshale (2001), Shushay and al. (2013) who reported non-significant SCA effects for all crosses. Bayisa (2004) and Gudata (2007) also found significant estimates of SCA effects for few crosses. On the contrary to this result, substantial significant difference of SCA effets for most of the crosses evaluated in their respective studies were reported by Alamine *et al.* (2003); Uddin *et al.* (2006) and Koppad (2007).

Non-significant SCA effects were observed among the crosses studied for plant and ear height under both well-watered and drought-stress conditions for early and intermediate crosses. This finding is in agreement with that of Mosa (2010), who also reported nonsignificant SCA effect for these traits in top-cross of maize inbred lines. On the contrary

Chandel and Mankotia (2014); Umar *et al.* (2014) found few significant SCA effect and Aminu *et al.* (2014); Aminu and Izge (2013); Shushay *et al.* (2013), found positive and negative significant SCA effects in diallel and line x tester study of maize.

Number of ear per plant showed non-significant SCA effect under both environmental conditions for early crosses. For intermediate crosses, the trait was not significant under well-watered condition. Under drought-stressed condition the crosses L8xT2 and L8xT1 were good and poor specific combiners for their positive and negative significant SCA effect, respectively. Aminu and Izge (2013); shushay *et al.* (2013) found few desirable cross combination with increased number of ear per plant in their study on line x tester analysis in maize. However, Abdel *et al.* (2009) reported considerable significant SCA effects for the diallel crosses used in their study.

For ear aspect, L5 x T2, L2 x T1 and L5 x T1, L2 x T2 showed good and poor specific combiner for their negative and significant SCA effect under well-watered condition for early crosses. For intermediate crosses, L6 x T2 and L6 x T1 were good and poor specific combiners, respectively.

For intermediate crosses under drought-stress condition, L6 X T2 was good specific combiner with positive and significant SCA effect for ear diameter, number of kernel row per ear and cob weight, whereas, L6 X T1 was poor specific combiner, for the same traits. Cob weight was found also significant under well-watered condition. L7 X T2 and L8 X T1 were good combiners; however L7 X T1 and L8 X T2 were poor specific combiners for this trait. Positive SCA effects are desirable for these traits, as they can contribute to grain yield in maize. Similar results have been previously reported by
Shushay *et al.* (2013); Chandel et Mankotia (2014) and Aly (2013).

This study revealed crosses with significant and highly desirable SCA effects for different traits such as anthesis date, ear hight, number of ear per plant, ear aspect, ear diameter, number of kernel row per ear, cob weight and grain yield. Other researchers also obtained crosses which manifested desirable SCA effects for different traits using different genotypes (Majid *et al.*, (2010); Aminu and Izge (2013); Aminu *et al.*, (2014) and Chandel and Mankotia (2014)). Good specific combining ability might involve two parents with good general combining ability, but, this is not a rule for all crosses. Sometimes two poor combiners may result to good specific combination. Crosses evaluated in this study were found with significant and desirable SCA effects for yield and yield related traits. Some of these crosses were from either one of the parents with high GCA effect or from low x low general combiners. It therefore suggest the parents with either low or high GCA would have a higher chance of finding excellent complementary with other parents. Similar results have been reported by other workers such as Aminu and Izge (2013); Shushay *et al.* (2013); Aminu *et al.* (2014). In some of the crosses observed, it appears that high SCA effect of any cross combination does not necessarily depend on GCA effects of the parents involved and this was similar to the finding of Sharma and Mani (1988) and Umar *et al*. 2014. The superior cross combination involving low x low GCA parents could results from over dominance or epistasis gene action Hallauer and Miranda (1988) and Majid *et al.* (2010). Such type of gene action may be exploited in cross pollinated crop such as maize.

5.4 Estimates of genetic component and contributions to the total variances for early and intermediate maturity maize genotypes

The present study showed that for early and intermediate genotypes, all the ratios GCA/SCA were less than the unity for all traits under both well-watered and droughtstress conditions. This revealed the preponderance of non-additive gene effect over additive gene effect. This suggests that these yield and yield related traits were governed predominantly by non-additive genes.

Such type of gene action clearly indicated that selection of superior plant in terms of grain yield, plant height and duration of vegetative growth period must be postponed to later generation, where these traits could be improved by making selections among the recombinants within the segregating population. Selection efficiency is attributed to the magnitude of heritability. Results in the current study showed that narrow sense heritability estimates were mostly lower than the broad sense heritability. This finding is in conformity with that found by Aminu *et al.* (2014); Aminu and Izge (2013) in line x tester analysis on maize, Umar *et al.* (2014); and Fellahi (2013) in line x tester analysis for grain yield and yield related traits in bread wheat. However the results contradicts the report of Legesse *et al.* (2009); Makumbi *et al.* (2011); Sharma *et al.* (2004) who found a preponderance of additive gene action controlling most of the traits they studied in line x tester analysis on maize.

In the current study contribution of lines to the total variance were high in most of the traits, followed by that of the line x tester interaction. Therefore, the lines used in this study were more diverse for most of the traits than the testers indicating higher estimates of variance due to general combing ablility. Uddin *et al.* (2008) and Aminu *et al.* (2014) found similar estimates in maize.

5.5 Mean performances and heterosis for early and intermediate maturity maize genotypes

Some of the crosses exhibited better mean values than the check, showing the probability of obtaining good hybrid (s), with numerous suitable traits.

High heterosis value for grain yield is desirable as it indicates increased yield over the checks. In agreement with the current finding, the expression of grain yield heterosis in maize has been reported by numerous investigators; shushay *et al.* (2009); Aminu *et al.* (2013); Aminu and Izge (2013); Aminu *et al.* (2014), Umar *et al.* (2014).

Negative and significant heterosis is actually desirable for days to anthesis, days to silking and anthesis-silking interval as it implies that these crosses may mature earlier and can escape end of season drought. Similar results were reported by Shushay *et al.* (2013); Aminu and Izge (2013); Aminu *et al.* (2014); Umar *et al.* (2014); Apraku *et al.* (2011), in their combining ability study in maize.

In Maize shorter plants are preferred over taller types, and consequently negative and significant heterosis is considered desirable for plant height for the development of shorter hybrids that could resist lodging particularly in windy environments. Positive and significant heterosis for number of kernel row per ear, and cob weight, is desired as they are the most yield component that directly contributes to increase grain yield. These findings, agree with results of Uddin *et al.* (2008); Shushay *et al.* (2009); Amiruzzaman *et al.* (2010) who also reported positive and significant heterosis for these traits in maize.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The current study was conducted with the objectives to estimate the general and specific combing ability effects in maize inbred lines for grain yield and yield related traits, evaluate the crosses performances and estimates mid-parent heterosis of the crosses for early and intermediate maize genotypes. From the results of the study, the following conclusion could be made:

Some inbred lines with desirable general combining ability effects (GCA) for the studied traits were identified under drought-stress condition for early and intermediate maturity genotypes. For the early maturity maize genotypes, the inbred lines L1 (S6-1522) followed by L4 (CML538) were best general combiners. These inbred lines exhibited positive and significant GCA effects for number of kernel row per ear, number of kernel per row, cob weight and grain yield. For intermediate maturity genotypes, line L4 was best general combiner for grain yield, cob weight, number of kernel row per ear and ear diameter for their positive and significant GCA effects. Therefore, these lines could be selected for their good traits to develop high yielding hybrids and for further exploitation in the breeding programme.

Estimates of specific combining ability (SCA) indicated that some cross combination had significant SCA effects for grain yield, for intermediate genotypes and not for early genotypes. The results of this study suggest that cob weight, number of kernel row per ear and ear diameter were the most reliable traits for selection for improved grain yield under drought-stress condition. It also suggests that the traits for selecting drought tolerance in early germplasm could be different from those used for selecting intermediate maturity maize germplasm. A possible explanation for the differences in the traits identified for selecting for drought tolerant in different maturity group could be the differences in the mechanism of tolerance to drought stress. Probably, the drought adaptive traits responsible for drought tolerance and the environment in the early germplasm used in the current study are different from those of the intermediate maturity group.

It was found that crosses between two lines with good general combining effects did not necessarily result into best combination for early and intermediate genotypes. For instance, low x low resulted in high specific cross combination for some crosses (L7 x T2 and L8 x T1) under well-watered condition and (L6 x T2) under drought-stressed condition, while high x low resulted in low performing combinations for other crosses (L3 x T1, L3 x T2, L6 x T1 and L6 x T2) under well-watered condition and (L4 x T1 and L4 x T2) under drought-stressed condition for intermediate genotypes. For early genotypes high x low resulted in low performing combination for (L1 x T1, L1 x T2, L3 x T1 and L3 x T2) under drought-stressed condition.

The low ratio of σ^2gca/σ^2sca, in the study showed the preponderance of non-additive gene actions for almost all the traits for early and intermediate maize genotypes. General combining ability (GCA) and specific combining ability (SCA) are important in breeding study, because, GCA effects are attributed to the preponderance of additive gene effects, while SCA indicates preponderance of genes with non-additive gene effects. Though, both GCA and SCA effects are dependent on germplasm set, evaluation method and specific environment, therefore they cannot be generally applied. The preponderance of non-additive gene actions indicates that selection of superior plants should be postponed to later generations.

The inbred lines L1 (S6-15-22) and L4 (CML538) for early maturity genotypes and L4 (CML502) for intermediate maturity maize genotypes were identified as best general combiners that can withstand drought-stress. These lines showed positive and significant GCA effects for yield and yield related traits under drought-stress condition. The cross L6 X T2 was identified as good specific combiners that can withstand drought-stress for the positive and significant SCA effect for grain yield and yield related traits under drought-stress condition.

Positive and significant mid-parent heterosis was observed under drought-stress condition for early and intermediate maturity maize genotypes. The crosses L2 X T1 and L3 X T2 observed high mid-parent heterosis for early and intermediate maturity maize genotypes, respectively.

In conclusion, the results of the present study identified crosses with high level of heterosis, inbred lines with good GCA effects and cross combinations with desirable cross SCA effect for the traits studied. The results indicate the possibility of developing desirable cross combinations through crossing and or recombination of inbred lines with desirable traits of interest. Therefore, the information obtained from the study could be beneficial for scientists who desire to develop high yielding drought tolerant varieties of maize.

6.2 RECOMMENDATION

- The inbred lines L1 (S6-15-22) and L4 (CML538) with good grain yield under drought-stress for the early maturity maize genotypes, should be further evaluated and selected for farmers
- The line L4(CML502) with good grain yield under drought-stress for the intermediate maturity maize genotypes, should be further evaluated and selected for farmers

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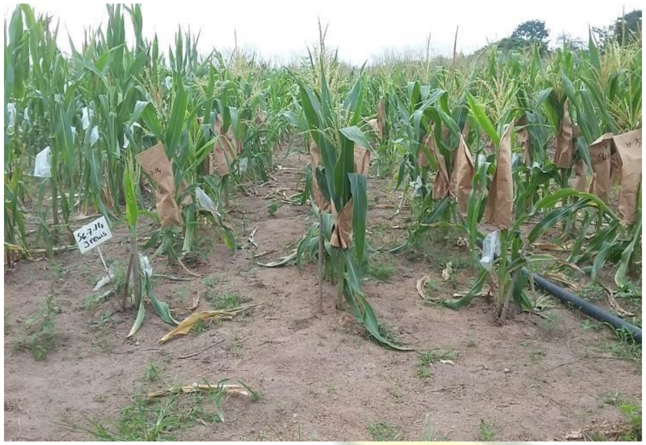
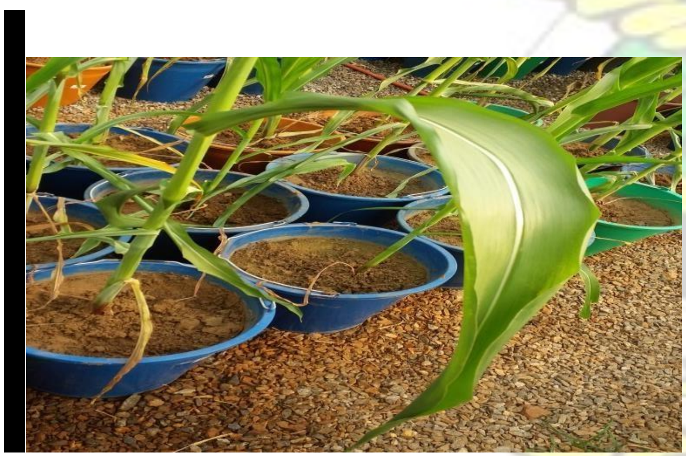
ANNEXE



CROSSING BLOCK

LEAF ROLLING SCORE 1



LEAF ROLLING SCORE 2

LEAF ROLLING SCORE 3

LEAF ROLLING SCORE 4

LEAF ROLLING SCORE 5

DROUGHT-STRESS EXPERIMENT WELL-WATERED EXPERIMENT