Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.5, No.15, 2015

Combining Ability and Gene Action Estimation in Elite Maize (Zea mays L.) Inbred Lines at Bako, Ethiopia.

Hailegebrial Kinfe[1]*, Getachew Alemayehu[2], Legesse Wolde[3], Yemane Tsehaye[4]
1*.Shire-Maitsebri Agricultural Research Center, Shire, Ethiopia
2. Department of Plant Breeding and Genetics, Bahir Dar University, Bahirdar, Ethiopia
3. Ethiopian Institute of Agricultural Research, Addis Abeba, Ethiopia
4. Department of Plant Breeding and Genetics, Mekelle University, Mekelle, Ethiopia

Abstruct

Maize (Zea mays L.) is an important food crop in Ethiopia, but its productivity in farmers' field through out the country is generally low due to limitation of high yielding improved maize hybrid varieties. Knowledge of combining ability and gene action is essential to identify good combiner inbred lines and high yielding potential hybrids to replace the local open-pollinated varieties. The objectives were to evaluate combining ability of the elite maize inbred lines with respect to yield and yield related traits and used t-test for significance level. Fourteen inbred lines were factorially mated as female (8 inbred lines) and as male parents (six inbred lines) to develop 48 single cross hybrids in the year 2013. The hybrids along with standard checks were evaluated at Bako National Maize Research Center during the year of 2014, 5 x 10 alpha lattice design with two replications. Data were recorded for grain yield and other related traits and subjected for analysis of variance using SAS soft ware. Line × tester analysis was used to estimate the general and specific combining ability effects for yield and yield related traits. Analysis of variance revealed significant variation at ($p \leq 0.05$) for most of studied traits except number of ears per plant and number of kernels per row. Regarding Combining ability analysis, mean squares due to lines, testers and line x testers were significant for most of the traits. More over, variances due to GCA were higher in magnitude than SCA for the yield and yield related traits, indicating the importance of additive gene action in controlling the expression of traits. Among lines and testers L2, L4, L6, T2 and T3 showed good general GCA for most of the characters studied. Among the crosses L6 x T2 (13.2 t ha^{-1}), L4 x T2 (12.5 tha^{-1}) and L3 x T3 (10.9 t ha^{-1}) performed better for grain yield as compared to BH-546 (9.94 t ha^{-1} and BH-547 (10.4 t ha^{-1}) for most traits studied. It can be concluded that the parental lines which manifested good general combining ability can be desirable parents for hybrids, since they may contribute favorable alleles in the synthesis of new varieties. Besides the hybrids that gave good yield can be potential varieties for commercial production. However, further evaluation of these breeding materials at more locations and year, is advisable to confirm the promising results observed in the present study.

Keywords: Combining Ability, Lines, Maize, Tester

CHAPTER 1. INTRODUCTION

Maize (*Zea mays L.*, 2n=20) is an important cereal crop belonging to the tribe *Maydeae*, of the grass family, *Poaceae*, Genus *Zea*, Species *mays* (Piperno and Flannery, 2001). Even its origin is still controversial, but the most common opinion is towards Mexico as its center of origin. Globally, maize ranked third in terms of acreage after wheat and rice (FAO, 2011).

In Ethiopia, report of FAO (2010) showed agriculture contributes about 43% of its gross domestic product (GDP), 50% of its exports and 85% of its population is directly or indirectly dependent on agriculture. The sub humid agro ecology of mid-altitude ranging from 1500 m to 2000 m above sea level is considered to be the major maize growing zone in Ethiopia (Legesse Wolde *et al.*, 2012). The major maize growing regions of the country including the present study site, Bako, receives a fairly reliable average annual rainfall ranging from (1000–1500mm). However, productivity of maize in the country has remained low, with the estimated national average yield of 2.90 ton ha^{-1} compared to the world average yield of 5.1 ton ha^{-1} (FAO, 2012). With this, Report of Mosisa Worku *et al.*(2011) during review of 3rd maize national workshop stated low maize productivity in Ethiopia is associated with several constraints that hinder its production and productivity like lack of high yielding and stable improved genotypes, drought, reduction in soil fertility, inappropriate agronomic practices, low adoption of improved agricultural technologies including varieties by farming communities, soil erosion, foliar diseases and weeds (especially *striga*).Those factors might largely attributed to the country to be one of the least developed and food unsecured countries in the world for many years.

As study by Golbashy *et al.* (2010) indicated, the most effective and direct way to solve maize yield gap is to breed varieties with high yielding potential and wide adaptability. Further studies have also proved that 52.9% of maize yield increment was attributed to varieties, and the rate of improvement was 89.1 kg ha^{-1} per year (Ci *et al.*, 2010). Bridging the yield gap has a whole benefit to producers, direct and indirect consumers, and the nation and the world at large. As yield increases, income of farmers' increases, food security is assured, and researchers are also activated to develop further improved technologies that are more productive than ever before.

So, knowledge combining ability and gene action used to improve productivity of maize, measures have to be taken to reduce the yield gap that causes frequent deficits and severe food shortages. The value of any inbred line in hybrid breeding ultimately depends on its ability to combine very well with other lines to produce superior hybrids. Combining ability also implies the capacity of a parent to produce superior progenies when crossed with another parents. GCA distinguishes when expressed as a deviation between the mean performances of parents in cross combinations and these deviations can be positive or negative depend on the type of trait whiles SCA is the deviation of individual crosses from the average performance of the parents involved. General combining ability corresponds to additive genetic variances whereas specific combining ability indicates none additive gene actions, which include dominance and epistatic deviations with respect to certain traits (Sprague, 1942).

The only way to increase maize production is to increase yield per unit area using improved hybrid maize genotypes and application of appropriate agronomic practices. The current study area is also considered major maize growing and high potential zone in Ethiopia. However, maize production and productivity has remained low due to use of low yield open maize varieties, shortage of elite parental inbred lines as a sources of hybrids, slow development of hybrids and evaluation of elite inbred lines using conventional plant breeding and weak adoption of hybrid maize varieties. Therefore, efforts are required to develop hybrids with high yield potential, farmers preference, stable, tolerance and resistance of biotic and abiotic factors in order to increase production of maize and to ensure food security in the country. Thus, this thesis work was initiated with the following objectives:

1. To estimate the general combining ability (GCA) and specific combining ability (SCA) of elite maize inbred lines and hybrids in respect to grain yield and yield components.
2. To identify the best single cross hybrids.
3. To determine the type of gene action that control expression of yield and yield related traits.

CHAPTER 2. MATERIALS AND METHODS

2.1 Description of study area and experimental treatments

The experiment was carried out in 2014 at Bako National Maize Research Center (BNMRC), representing the mid-altitude sub humid agro-ecological zone of western Ethiopia. The site lies at $9^0$06’N latitude and $37^0$09'E longitude, at an altitude of 1650 masl. Mean annual maximum temperature is 31 ^{0}C and the minimum being 11.2 ^{0}C with the total annual rainfall of the area ranges from 1040 to 1559 mm.

The study used two sets of maize parents consisting of eight female and six male inbred lines were crossed using design II schemes (line by tester) at BNMRC to generate 48 single cross hybrids. The crosses along with similarly maturing hybrid maize varieties of BH-546 and BH-547 as standard checks were evaluated, during 2014 main cropping season at Bako (Table1).

The 48 F_1 single maize crosses along with two standard hybrid checks (BH-546 and BH-547) were planted at Bako using an alpha lattice design of 5 x 10 genotype arrangement (0, 1) (Patterson and Willianms, 1976) with two replications. Each replication consisted of one-row plots, with the assumption that inter-genotypic competition from single-row plots is unlikely to substantially affecting the results (Bänziger *et al.*, 1995). Each entry was placed in a one-row plot of 5.1 m long at 75 cm and 30 cm inter and intra-row spacing, respectively. Experimental plots with in replications were separated each other by 75cm, while the replications were separated by 1m apart.

At the onset of the main rainfall, following reliable precipitation, seeds of the experimental materials were sown on May 26, 2014. Two seeds per hill were sown at prescribed inter and intra-row spacing. Thinning was done after germination to a single healthy seedling to attain a final plant density of 44,444 plants ha^{-1}. All the recommended agronomic practices were applied per recommended in the study area

Table 4.List of parental lines used to generate the single cross hybrids using line by tester mating design in 2014 at Bako

Code	Pedigree	Parental type	Kernel color	Sources of germplasm	Heterotic groups
L1	Szsyyna 99F2-7-2-1-1	Female/line	White	BNMRC	A
L2	ILO' 003E-47-2-3-1-1	Female/line	White	BNMRC	A
L3	30H83-7-1-3-1-1-1-1	Female/line	White	BNMRC	A
L4	Gibe-1-20-2-2-1-1-1	Female/line	White	BNMRC	A
L5	POOL 9A -128-5-1-1-1-1	female/line	White	BNMRC	A
L6	Gibe-1-91-1-1-1-1	Female/line	White	BNMRC	A
L7	POOL 9A-4-4-1-1-1	female/line	White	BNMRC	A
L8	Kuleni320-2-3-1-1-2-1-1	Female/line	White	BNMRC	A
T1	30H83-5-1-1-1-1-1	Male/tester	White	BNMRC	B
T2	ILO'00E-1-9-1-1-1-1-1	Male/tester	White	BNMRC	B
T3	DE-78-Z-126-3-2-2-1-1-1(g)	Male/tester	White	BNMRC	B
T4	DE-78-Z-126-3-2-2-1-1-1(P)	Male/tester	White	BNMRC	B
T5	30H83-5-1-2-1-1-1-1-1	Male/tester	White	BNMRC	B
T6	GIBE-1-178-2-1-2-1	Male/tester	White	BNMRC	B
V1	BH-546	Check	White	BNMRC	
V2	BH-547	Check	White	BNMRC	

Key: L= Line; T=Tester, V= Hybrid Variety; BNMRC = Bako National Maize Research Center

2.2. *Methods of Data Analysis*

Yield and yield related traits were recorded based on plant basis (by taking the average value of five representatives tagged plants per plot and plot basis and subjected to SAS statistical package (SAS, 2002). Combining ability analysis was done using line x tester method (Kempthorne, 1957) and then general and specific combining abilities of lines were computed for characters that showed significant differences among crosses. Then significance of combining ability effects determined by using t- test at 0.05 and 0.01 level of probability. Mean separation was executed using Duncan's multiple range (DMRT).

The significance (F-test) of the lines and testers mean squares was tested against the line by tester mean square as an error term, while the line by tester was computed against mean square due to error for individual location analysis (Singh and Chaudary, 1999). The main effects due to lines and testers were considered as GCA effects while l x t interaction effects represented SCA effects. The following mathematical model for combining ability at single location was used.

$Yijk = \mu + rk + gi + gj + Sij + eijk$

Where, Yijk = the value of a character measured on cross of line (female parent) i by tester (male parent) j in kth replication, μ = Population mean, rk = Effect of kth replication,

gi = general combining ability (GCA) effects of ith line, gj = general combining ability (GCA) effect of the jth tester, Sij = specific combining ability (SCA) of ith line and jth testers such that Sij equal to Sji and eijk = Experimental error for ijkth observation

The significance of GCA and SCA effects were tested dividing the corresponding SCA and GCA values by their respective standard error and calculated as follows:

GCA effects (t-cal) = $\frac{GCA}{SE}$, SCA effects (t-cal) = $\frac{SCA}{SE}$ where, GCA = general combining ability effects, SCA= specific combining effects and SE= standard errors

The calculated values, then, were test for their significant using the calculated t with tabulated t-value at the error of degree of freedom at 0.05 and 0.01 levels of probabilities.

2.3.1 Estimation of General Combining Ability Effects

General combining ability of lines and testers was estimated as the following:

i. GCA of lines

$$gi = \frac{Y_{i..}}{tr} - \frac{Y_{...}}{ltr}$$

Where gi = gca effect for ith line (female parent), Yi.. = total of ith line over testers (male parent), Y… =grand total and ltr = number of lines, testers, and replications.

II. GCA of testers:

$$gj = \frac{Y_{.j.}}{lr} - \frac{Y_{...}}{ltr}$$

Where

gj = gca effect for jth tester(female parent), Y.j. = total of jth tester over lines(male parent), Y… =grand total, and ltr = number of lines, testers, and replications.

2.3.2. Estimation of Specific Combining Ability Effects

SCA effects was estimated as deviation of each cross mean from all hybrids mean adjusted for corresponding GCA of parents.

$$Sij = \frac{Yij.}{r} - \frac{Yi..}{rt} - \frac{Y.j.}{rl} - \frac{Y...}{rtl}$$

Where, Yij. = value of jth line with ith tester, Y… = grand total

Yi… =total of ith line over all testers, ltr = number of lines, testers, and replications.

Y.j. = total of jth tester over all lines

2.3.3. Proportional Contribution of Lines, Testers and their Interactions

Proportional contribution of lines, testers and their interaction was estimated as the followings:

i. Contribution of lines= $\frac{SSL}{SS(Crosses)}$ *100

ii. Contribution of testers = $\frac{SST}{SS(Crosses)}$ *100

iii. Contribution of l x t= $\frac{SSL\ x\ T}{SS(Crosses)}$ *100

Where: SSl=sum square of lines (females), SSt = sum square of testers (males), SS l x t = sum square of line by tester interaction

CHAPTER 3. RESULTS AND DISCUSSION

3.1. Analysis of Variance of Maize Genotypes for Grain Yield and Agronomic Traits

The ANOVA results showed significant genotypic differences between 50 maize genotypes (entries) comprising 48 F_1 crosses and two standard checks for all traits except number of ears per plant (EPP) (Table 2). This indicated the existence of variability among the materials in the field trials, which could be exploited for the improvement of the respective traits for further maize breeding. Sofi and Rather (2006) also found similar results of genotypic difference for ear length (cm), ear diameter (cm), kernel rows per ear, 100-seed weight (g) and grain yield per hectar. The predominant component of genetic variation determines the choice of an efficient breeding method for incorporation of concerned genes in to new materials (Dhabholkar *et al.,* 1989). Significant differences among the lines were found for all the traits except number of kernels per row, indicating the existence of substantial variability in the lines for these traits. Testers were also significantly varied for most traits except ear length, number of ears per plant and ear weight. In agreement of this finding Alemshet Lemma (2014) also reported significant tester GCA mean squares in most traits except in anthesis silking interval, ear height, ear diameter and thousand kernels weight. The non-significant mean square observed among lines and tester mean square observed for some traits suggest that the lines and testers used for the current study had comparable potential for these traits in question. Analysis of variance for line by tester interaction (l x t) revealed that the mean squares were significant for ear length, ear diameter, number of kernel rows per ear and grain yield per hectar. The significant variance of l × t interaction indicated the importance of specific combing ability. Joshi *et al.* (2002) in 90 hybrids of l x t also reported the estimation of SCA variance was much higher for grain yield, ear length and diameter the characters as compared to the respective GCA variance and he conclude there is greater importance of non-additive gene effects in inheritance of grain yield and it's related traits.

Table 2. Line x tester analysis of variance of 48 hybrids for 14 traits in 2014 at Bako

SV	DF	AD	SD	ASI	MD	PH	EH	EL	ED	EP	Ewt	NRE	NKR	HKW	GY
genotypes	49	9.8**	11.4**	2.1*	15.4*	521.5**	345**	2.3**	0.1**	0.1	0.01**	2.6**	9.8*	54.4**	4.7**
L	7	14.38**	11.32**	7.44**	13.90	1450.2**	1528.5**	4.64**	0.32**	0.16**	0.004**	10.4**	7.96	201.9**	20.6**
T	5	51.32**	70.1**	3.12*	57.0**	2122.6**	333.3**	0.96	0.4**	0.08	0.001	3.04**	27.0**	103.5**	5.5**
L x T	35	3.12	3.45	0.64	10.50	127.30	83.58	2.2**	0.05**	0.04	0.0007	1.0*	8.08	19.40	1.66**
Error	47	2.49	2.40	1.21	7.50	102.20	57.18	0.85	0.02	0.05	0.0006	0.55	6.33	17.72	0.90

*Key: *and ** Significant at 0.05, 0.01 levels of probability, respectively, GY=grain yield, EPP= number of ears per plant, AD=days to anthesis, SD=days to silking, ASI=anthesis –silking interval, MD= days to maturity, PH=plant height, EH=ear height, EL=ear length, ED=ear diameter, EWt= ear weight, NRE=number of kernels rows per ear, NKR=number of kernels per row, HKW=hundred kernel weight.*

3.2. Estimation of Combining Ability Effects of Lines, Testers and Their Interactions

3.2.1. General combining Ability Effects for Lines and Testers

General combining ability estimates were computed for traits that showed significant differences due to mean squares of GCA. Inbred lines identified for good general combining ability could be utilized in maize grain improvement programs for improving the traits of interest as these lines have high potential to transfer desirable traits to their cross progenies.

Based on the GCA effects, L2, L4, L5, L7, T3 and T4 inbred lines had negative GCA effects for traits of days to anthesis, silking, maturity and anthesis silking interval, indicated contributed towards earliness in their respective crosses as compared their parents. This result is in agreement with Demissew Abakemal *et al.* (2011) and Gudeta Napir (2007) who reported significant positive and negative GCA effect and great contribution of additive gene action for a number of days to tasseling and silking.

In maize breeding, shorter plant height and medium ear placement is desirable for lodging resistance and mechanized agriculture over the longer ones because of their suitability for machine harvesting. So, regarding these traits, L6, L8, T2 and T6 showed positively significant GCA effects, indicating their poor combiners while L1 and L5 manifested negative GCA effects for PH and EH, indicating that these lines contributed to reduce plant stature or enhancing shortness in their crosses. Those parents even though their magnitudes are different there were parallelism between GCA effects for days to anthesis, silking, days to maturity, plant height, ear height. In addition this, Dagne Wegary (2008) indicated both line and tester GCA mean square were greater than the values of their interaction mean squares with environment for most of the studied traits showing that the main effect was important than their interaction effects. On other hand, Ali *et al.* (2012) showed greater ear height is undesirable because the ear placement at a greater height from the ground level exerts pressure on plant during grain filling and physiological maturity and causes lodging, which could ultimately affect the final yield.

Ear length is a major yield component and is directly proportional to grains ear^{-1}. The longer the ear length, the higher will be the grain yield. Ear length significantly differed among test crosses, lines, testers, and for line × tester effect in the current research. In ear length, positive general combining ability effect is desirable because increase in ear length is utmost important in improvement of maize yield. Female inbred lines of L1 and L4 were excellent general combiner by expressing the significant maximum positive general combining ability value. Similarly, Amiruzzaman *et al.* (2010) and Jumbo and Carena (2008) reported positive and negative significant GCA effect for ear length.

Concerning ear diameter, mean squares presented in table 2 showed that effect due to GCA and SCA were significant for ear diameter. Ear diameter is considered one of the major yield contributing components in maize, therefore, positive GCA and SCA are desirable. Both additive and non-additive gene effects were important as reported by Dagne Wegary and Gudeta Napir (2007). Line GCA effects ranged from -0.24 (L1) to 0.27 (L6). Six female inbred lines showed positive GCA effects. Two inbred lines (L6, and L8) showed significant and positive GCA effects, indicating the desirable performance of the lines for the trait (Table 2). In case of testers, T2 and T3 had significant positive and T4, T5 and T6 had significant negative GCA effects, implying good and poor general combiners respectively for this trait. The present study is in agreement with Amiruzzman *et al.* (2010), Jumbo and Carena (2008), Dagne Wegary *et al.* (2010) and Gudeta Napir (2007) who reported significant positive and negative GCA effects for ear diameter.

For grain yield (GY) trait, mean squares of GCA and SCA effects were significant but the sum square of lines and testers were greater than sum square of line by tester interaction. Beyene Yoseph *et al.* (2011) also reported that in maize GCA sum of squares component for grain yield was five times greater than SCA, suggesting that variation among crosses was mainly due to additive rather than non-additive gene effects. Regarding GCA effect, five of the inbred lines and two of the testers showed high and positive GCA effect in desired direction while the remaining one inbred lines and four testers expressed negative GCA effects. GCA estimates of parental lines showed that line (female parent) L6 was the best general combiner for GY with a highly significant ($P<0.01$) and positive GCA effect of 1.47 t ha^{-1} followed by L4 with GCA effect of 0.99 t ha^{-1} (Table 2). Inbred lines, L4 also showed highly significant ($P\leq0.01$) and positive GCA effects of 5.77 for hundred kernels weight (HKW) and 0.04 for ear weight (EWt). L6 also had positive effect of GCA for traits of ear diameter, ear weight and number of kernel rows per ear. Whereas L5 exhibited the lowest GCA effect of -2.47tone ha^{-1}, indicating the existence of poorest general combiners in the group of inbred lines studied. Similar results have also been reported by Narro *et al.* 2003 and Sofi and Rather (2006). Regarding testers, T2 had positive and significant effect on grain yield. But T3, T4, T5 and T6 were recorded negative GCA effect on this character and have less desirable characters for grain yield breeding materials. The proportional contribution of tester and line GCA sum of squares to the cross sum of squares was higher (74.8 %), indicating the higher share of additive gene effects to the total variation observed in crosses for GY in this particular set of cross combinations. In agreement to this, Ojo *et al.* (2007) reported that the GCA mean squares for lines and testers were highly significant and highly contributed for grain yield and ear diameter. Mean while in the current study the GCA/SCA ratio was larger than unity for all the studied traits, indicating that the GCA was more important than SCA in the inheritance of these traits (Table 3).

Hundred kernels weight is considered as one of the yield contributing components in maize, hence positive effects of GCA and SCA are desirable. Mean square values for GCA were highly significant ($p \leq 0.01$) but non significant for SCA (Table 3). Six of the inbred lines showed positive GCA effects out of which L2, L4 and L8 had significant GCA effect for an increase of hundred kernels weight. From the tester side T6 showed highly significant positive GCA effect for an increase of hundred kernels weight while T1, T2, T3 and T4 manifested poor GCA effects for 100-kernels weight. As report of Bernardo (2002) showed, parents with high GCA or additive gene effects for hundred kernels weight trait would theoretically respond favorably to selection. Improvement of a variety can start with those having high GCA estimates. For number of kernel rows per ear (NRE), L3 showed significant positive GCA effect, where as L1 and L2 showed significant negative GCA effect (Table 3). The positive GCA effect is desired for number of kernel rows per ear as it is the most important yield component that directly contributes to increased grain yield. Hence, inbred lines with high GCA effect for this trait could be suitable parents for hybrid formation as well as for inclusion in future breeding programs. Such parents contribute favorable alleles in the process of synthesis of new varieties. On the tester side, T2 had significant positive GCA effect on this character. Generally, L5, L6, L7, L8, T1, T3 and T6 with L3 and T2 showed positive and significant positive GCA effect respectively and simultaneously possessed high mean values indicating that the *per se* performance of the parents could prove as an useful index for combining ability. Hussain *et al.* (2003) Uddin *et al.* (2006) also observed the similar phenomenon. In addition the above researchers, Mohammed (2009) and Meseka *et al.* (2006) found that the predominance of additive gene action for the majority of traits in the study of line x tester design of 24 test crosses of maize.

Table 3. Estimates of GCA effects for maize grain yield, related traits and major diseases incidences in 2014 at Bako

Parents	AD	SD	MD	PH	EH	EL	ED	Ewt	NRE	HKW	GY
L1	0.33	1.09*	1.58*	-15.45**	-7.8**	0.74**	-0.24**	-0.02	-1.31**	-2.34*	-0.65*
L2	-0.25	-0.49	1.33	-2.45	-7.74**	-0.01	0.004	0.0008	-0.83**	3.36**	0.43
L3	1.33**	0.93*	-1.42	7.10*	2.76	-0.22	-0.08	-0.02	1.84**	-7.61**	0.32
L4	-0.42	-0.90*	-0.42	7.60*	-0.04	0.84**	0.08	0.04**	-0.36	5.77**	0.99**
L5	-0.83	-0.99*	-0.75	-12.75**	-15.11**	-1.08**	-0.10*	-0.01	0.36	-1.66	-2.72**
L6	1.58**	1.34**	0.67	1.88	12.53**	0.02	0.27**	0.02*	0.14	0.44	1.47**
L7	-1.75**	-0.16	-0.25	-3.62	-3.48	-0.46	-0.08	0.004	0.01	-0.53	-0.55*
L8	0.00	-0.82	-0.75	17.71**	19.09**	0.17	0.16**	0.0008	0.14	2.57*	0.70*
SE lines	0.46	0.43	0.76	3.09	2.09	0.25	0.04	0.01	0.20	1.13	0.26
T1	-0.04	0.49	2.64**	1.28	-4.09*	-0.07	0.01	0.0004	0.28	-1.74	0.06
T2	1.77**	1.55**	0.46	3.77	4.99**	-0.24	0.22**	-0.01	0.48*	-1.91	1.13**
T3	-2.35**	-2.89**	-1.92**	-16.48**	-2.98	-0.32	0.16**	0.004	0.14	-1.12	-0.30
T4	-1.98**	-2.39**	-2.04**	-9.4**	-4.55*	0.24	-0.09*	-0.01	-0.76**	-0.73	-0.36
T5	1.46**	1.74*8	1.29*	4.48	0.98	0.17	-0.18**	0.001	-0.21	0.65	-0.47*
T6	1.15**	1.49**	-0.67	16.35**	5.65**	0.22	-0.13*	0.01	0.07	4.84**	-0.06
SE Tester	0.39	0.49	0.64	2.60	1.78	0.21	0.04	0.01	0.17	0.95	0.22

Key: SE= standard error of line GCA effect, SEd = standard error of the difference between any two GCA effects, GY=grain yield, EPP= ears per plant, AD=days to anthesis, SD=days to silking, ASI=Anthesis – silking interval, MD= days to maturity, PH=plant height, EH=ear height, EL=ear length, ED=ear diameter, EWt= ear weight, NRE=number of rows per ear, NKR=number of kernels per row, HKW=hundred kernels weight

3.3.2. Specific Combining Ability Effects for L x T Interaction

The specific combining ability effect was computed and given as follows for traits that showed significant mean squares due to specific combining ability in genetic analysis of line by tester (Table 4). Significant mean squares due to SCA were found for grain yield, ear length, ear diameter and number of kernel rows per ear and this implied that dominance or non additive variance was important for these traits. Lack of significant SCA effects for most traits indicates that progeny performance of the inbred lines can be adequately predicted on the basis of GCA effects of the parents and but may be heterosis cannot be exploited for these traits. In line with this Gichuru *et al.* (2011) suggested that where SCA mean squares were not significant, the performance of single crosses could be predicted on the basis of GCA effects. Positive SCA effects tend to imply that lines were in different and complimentary heterotic groups, while negative SCA tend to indicate that lines were in the same heterotic group.

In grain yield, more than 60% of the crosses found to combine well in positive direction out of which three crosses namely L5 x T6, L4 x T5 and L7 x T6 exhibited highest and desirable significant SCA effect, signifying that these crosses had increased grain yield than the expected mean performance of its parents and showed genetic diversity and hence heterosis. On the other hand twenty crosses expressed negative SCA effect for this trait in undesired direction and out of those three crosses of L4 x T6, L6 x T6 and L7 x T3 contained poor specific combiner for grain yield trait (Table 4), especially cross L4 xT6 gave the highest negative value (−1.4) for grain yield, indicating that this hybrid reduced grain yield than the expected mean performance of its parents; signifying close relationships and hence inbreeding depression. Such lines could not be used in a hybrid production program. While, L4 x T2, L6 x T4 and L6 x T2 contained continuously positive SCA effects for ear length, ear diameter, number of kernel rows per ear and grain yield on this study. L1 x T5, L6 x T2, and L7 x T1 crosses were proved to be the excellent specific combiners for ear diameter and number of kernel rows per ear. L4 x T5, L5 x T6, and L7 x T6 crosses also selected as good specific combiner for grain yield. Generally, high grain yield forms the major objective in any crop breeding program. The GCA variance was more pronounced than that of SCA variance; hence the grain yield was largely under the control of additive gene action, indicating the possibility of increasing grain yield through the desirable traits of parents. The present findings are in agreement with Dagne Wegary (2008) who conducted combining ability studies on QPM x QPM under optimum and stressed environments and highlighted the importance of additive gene action for most traits**.** Nuruzzaman *et al.* (2002) also gave a direction, the presence of heterosis and SCA effects for yield and its related traits are important for yield improvement.

Additionally, crosses L2 x T4, L4 x T1, L5 x T6, L1 x T5, L4 x T1, L6 x T2, L6 x T3, L6 x T4, L7 x T6, L8 x T4 and L8 x T 6 also considered the best specific combers for the chracters of ear diameter, number of kernel rows per ear and grain yield. Besides, Deitos *et al.* (2006) reported that good general combining parent does not always show high SCA effects in their hybrid combinations.

Table 4. Specific combining ability of 48 test Cross hybrids of maize for 4 traits in 2014 at Bako

Entry No	Crosses		Characters				cont'd	Entry No	crosses		Characters			
	Line	Tester	EL	ED	NRE	GY			Line	Tester	EL	ED	NRE	GY
1	1	1	1.34*	-0.41**	-0.9*	0.03		26	5	2	0.33	0.01	0.2	-0.2
2	1	2	-0.6	-0.1	-0.4	0.31		27	5	3	0.4	0.05	-0.6	0.2
3	1	3	-1	0.08	-0.1	-1		28	5	4	-1.6**	-0.2*	-0.5	-0.8
4	1	4	-1.1	0.15	0.21	-0.8		29	5	5	0.91	-0	-0.2	0.55
5	1	5	-0.6	0.22*	1.26*	0.49		30	5	6	0.96	0.06	-0.1	1.26*
6	1	6	1.95*	0.04	-0	0.95		31	6	1	-0.6	-0	-0.9*	0.34
7	2	1	0.39	-0.1	0.29	0.93		32	6	2	2.33**	0.28**	0.92*	0.72
8	2	2	-0.3	0.04	-0.5	0.38		33	6	3	0.002	-0.01	0.46	1.02
9	2	3	-0.4	0.11	0.43	-0.5		34	6	4	0.64	0.06	0.76	0.33
10	2	4	-0.1	-0	0.53	0.8		35	6	5	-0.7	-0.1	-1*	-1.1
11	2	5	0.95	-0	-0.6	-0.5		36	6	6	-1.6**	-0.2*	-0.3	-1.3*
12	2	6	-0.5	-0.1	-0.1	-1.1		37	7	1	-0.2	0.27**	1.45*	1.08
13	3	1	0.7	-0.03	-0.8	-0.7		38	7	2	0.51	-0.3**	-1.75*	-0.8
14	3	2	-1.6**	-0.02	1.02*	0.23		39	7	3	-0.01	-0.2*	-0.4	-1.3*
15	3	3	0.75	0.05	0.16	0.98		40	7	4	-0.4	-0.1	0.09	0.03
16	3	4	1.39*	-0.01	-0.5	0.26		41	7	5	0.2	0.08	-0.1	-0.2
17	3	5	-1.1	0.05	0.11	-0.8		42	7	6	-0.2	0.26*	0.67	1.19*
18	3	6	-0.1	-0.04	0.03	0.03		43	8	1	-0.5	-0.1	-0.5	-1.1
19	4	1	-0.1	0.26**	0.22	0.35		44	8	2	-0.6	-0.1	0.12	-1.1
20	4	2	0.01	0.11	0.42	0.49		45	8	3	0.55	0.03	-0.1	0.63
21	4	3	-0.3	-0.1	0.16	-0.1		46	8	4	0.09	0.18*	0.36	0.74
22	4	4	1.02	-0.1	-0.9*	-0.6		47	8	5	-0.3	-0.2*	0.01	0.42
23	4	5	0.7	-0.1	0.51	1.14*		48	8	6	0.81	0.09	0.13	0.35
24	4	6	-1.4*	-0.2	-0.4	-1.4*			SEij+-		0.56	0.09	0.45	0.57
25	5	1	-1.1	0.09	1.1*	-1			SEd(Sij-Skl)		0.92	0.15	0.74	0.96

3.3.3. Proportional Contribution of Lines, Testers and their Interaction

Proportional contribution of lines, testers and their interactions revealed that female line contributed higher compared to male under the present study in four very crucial studied traits such as ear height (70%), number of kernel rows per ear (57.9%), hundred kernels weight (54.1%) and grain yield (62.8%). On the other hand testers have a very important role towards two characters *i.e.* days to anthesis (55%) and days to silking (63.7 %), indicating the paternal influence for these traits. So, smaller contribution of interaction of the line x tester and indicating higher estimates of GCA. While line x tester (parental and maternal interaction) was more important for days to maturity (49.1%) and ear length (66.8%) (Table 5). These results are similar to those obtained by Sarker *et al.* (2002) and Zhang *et al.* (2002). It is evident from the table 5 that for plant height contribution of both lines and testers was almost equally important. Berhanu Tadesse (2009) reported grain yield showed significant different due to GCA of lines and testers as well as SCA of line by tester ($P\leq0.01$) and depicted high proportional contribution of lines and tester GCA (74.8%), indicating the higher share of additive gene effects to the total variation observed in crosses for grain yield in this particular set of cross combinations. Similar to the finding of the current study, several researchers such as Leta Tulu *et al. (*1998) and Vacaro *et al.* (2002) have indicated the importance of additive gene effect in the inheritance of different agronomic traits in maize populations.

As table 5 indicated, the ratio of GCA to SCA variances was greater than unity for all studied traits and showed the predominant role of additive action in the inheritance and that selection will be useful to bring genetic improvement in this trait. Novoselovic *et al.* (2004) and other most literature about corn, suggests that additive effects of genes with partial to complete dominance are more important than dominance effects in determining grain yield. The proportional contribution of lines to the total variances was much higher than that of tester and interaction of line x tester for ear length and 100-kernels weight indicating higher estimates of variance due to general combining ability (Table 5). Sarker *et al.* (2002) also found similar GCA estimates in maize and rice, respectively. Therefore, it could be concluded that selection procedures based on the accumulation of additive effects would be successful in improving these traits and female parents should be considered more for a successful plant breeding programs under this conditions.

Table 5. Mean sums of squares and estimates of proportional contribution and gene action for 14 characters in maize hybrids in 2014 at Bako

SV	df	AD	SD	ASI	MD	PH	EH	EL	ED	EPP	Ewt	NRE	NKR	HKW	GY
Line	7	14.38**	11.3**	7.4**	13.9	1450.2**	1528.5**	4.64**	0.32**	0.2**	0.004**	10.42**	8.97	201.9**	20.6**
Tester	5	51.3**	70.1**	3.2	57.0**	2122.6**	333.3**	0.96	0.4**	0.1	0.001	3.04**	27**	103.5**	5.5**
L x T	35	3.12	3.45	0.5	10.5	127.3	83.58	2.15**	0.054**	0.04	0.001	1.0*	8.1	19.4	1.66**
error	47	2.5	2.4	1.2	7.5	102.2	57.2	0.85	0.02	0.04	0.001	0.55	6.3	17.7	0.9
Cont L%		21.6	14.6	57.8	12.9	40.3	70	28.9	36	38.7	49.5	57.9	11.8	54.1	62.8
Con T %		55	63.7	17.3	38	42.1	10.9	4.3	33.3	14.3	9.6	12.1	28.5	19.8	12
Cont l x t		23.4	21.9	24.9	49.1	17.7	19.1	66.8	30.8	47.0	40.2	30	59.7	26	25.2
GCA		65.5	81.2	10.5	70.1	3563.7	1855.8	5.45	0.73	0.2	0.005	13.38	34.4	7.92	303.9
SCA		13.16	10.12	1.9	10.08	1399.1	1499.9	4.22	0.31	0.0	0.004	10.15	20.7	5.55	193
GCA/SCA		4.98	8.02	5.5	6.95	2.55	1.24	1.29	2.34	5.9	1.31	1.32	1.7	1.43	1.57

*Key: * and ** indicates significant at P=0.05 and P=0.01 levels, respectively, SV=sources of variation, r=replication, Lx T=line by testers, Cont L%=contribution of lines(%), Con T %= contribution of testers(%),Cont l x t =contribution of line by testers(%), GCA=general combining ability, SCA=specific combining ability, gca/sca=ratio of general combining ability to specific combining ability of each traits.*

Chapter 4. CONCLUSION AND RECOMMENDATIONS

The present study proposed combining ability and gene action is essential to identify good combiner inbred lines and high yielding potential hybrids to improve maize production and productivity. Hence, Lines with greater SCA used for hybrid development as well as to classify inbred lines into heterotic groups, while GCA could be used for synthetic cultivar development. Ratio of GCA to SCA variance was greater than one for all the studied traits, hence all traits largely under the control of additive gene action, indicating the possibility of increasing grain yield through the desirable traits of parents.

Even if study was single year and location result the following inbredlines and hybrids identified and need further work has to be done: Inbred lines that combine well for grain yield and related traits i.e L4, L6, L8 and T2 and cross combinations that showed high and positive SCA for each trait such as L6 x T2, L4 x T2, L6 x T3, L2 x T2, L6 x T1, L4 x T5, L6 x T4, L2 xT1, L4 x T1, and L8 x T4 as selected were recommended for further evaluation for grain yield to confirm their yield superiority and good disease resistances.

However, further evaluation of these breeding materials across locations and year is advisable to confirm the promising results observed in the present study. Since, further testing and selection at research station and in farmers' fields can be improve and increase experimental uniformity. This is important because only 14 inbred lines were incorporated in this study. But, the maize program can engage in hybridization and synthetic variety formation based on the information of inbred lines with high GCA for grain yield and diseases resistant traits identified in this study. In general, the information from this study will be useful for researchers who intend to develop varieties with high grain yield.

Conflict of Interest

The author(s) have not declared any conflict of interests.

AKNOWLEDGEMENTS

This research was conducted in partial fulfillment of the M.Sc degree at Bahir Dar University by the first author. Funding was provided by Tigray Agricultural Research Institute.

5. References

Ali F, Shah IA, Rahman H, Noor M, Durrishahwar, Khan MY, Ullah I, Yan JB. 2012. Heterosis for yield and agronomic attributes in diverse maize germplasm. Aust J Crop Sci. 6: 1283-1289.

Alemshet L.2014. Combining Ability of elite Maize (Zea Mays L.) Inbred Lines for Intercropping Compatibility With Common Bean (Phaseolus Vulgaris L.) In Central Rift Valley of Ethiopia. MSc. Thesis presented to the School of Graduate Studies, Haromaya University, Ethiopia. p132.

Amiruzzaman M. Islam M.A. Hassan L. and. Rohman M.M. 2010. Combining ability and heterosis for yield and Component characters in maize. Academic Journal of plant science 3(2): 79-84.

Bernardo R.2002. Breeding for quantitative Traits in Plants. Stemma Press, Woodbury, MN. pp91.

Berhanu T. 2009. Heterosis and Combining Ability for Yield, Yield Related Parameters and Stover Quality Traits for Food-Feed in maize (*Zea Mays L.*) adapted to the mid-altitude agro-ecology of Ethiopia. MSc. Thesis presented to the School of Graduate Studies, Haramaya University, Ethiopia, pp89-152.

Ci Xiao-ke, Zhang S-H, Xie Z-J, Xu J-S, Lu Z-Y, Ru G-L, Zhang D-G, Li X-H, Xie C-X, Bai L, Li M-S, Dong S-T (2010). Comparison of analysis method of genetic yield gain for the single-cross hybrids released during 1970s–2000s. Acta Agron. Sin., 36(12): 2185-2190

Dagne Wegary. 2008. Genotypic variability and combining ability of quality protein maize inbred lines under stress and optimal conditions. PhD thesis, University of the Free State, South Africa, p321.

Dagne Wegary, Vivek BS, Birhnau Tadesse, Koste Abdissa, Mosisa Worku, 2010. Combining ability and heterotic relationship between CIMMYT and Ethiopia inbred line Ethiopia J Agric Sci 20: 82-93.

Deitos, A., E. Arnhold, and G.V. Miranda. 2006. Yield and combining ability of maize cultivars under different eco geographic conditions. Crop Breeding and Applied Biotechnology 6:222-227

FAO (Food and Agriculture Organization of the United Nations). 2010. Ethiopia country brief. Retrieved from www.fao.org/countries/55528/en/eth/,retrieved on 1 Friday 2015.

FAO.2011.World Agricultural Production.[online]Available at: http://faostat.fao.org/default.aspx. Accessed 2 june. 2012.

FAO (World Food Organization). 2012. The State Of Food Insecurity in the World: Undernourishment around the World in 2012. P 8-14.

GICHURU, L., NJORONJE, K., ININDA, J., & PETER, L. 2011. Combining ability of grain and agronomic traits in diverse maize lines with maize streak virus resistance for Eastern Africa region. *Agriculture and Biology journal of North America*. 2, 432-439.

Golbashy M, Ebrahimi M, Khorasani SKi, Choukan R.. 2010. Evaluation of drought tolerance of some corn (*Zea mays* L.) hybrids in Iran. *Afr. J. Agric. Res*., 5(19): 2714- 2719.

Gudeta, N., 2007. Heterosis and combining abilities in QPM varieties of early generation high land maize (Zea mays L.) inbred lines. M.Sc. Thesis. Haramaya University of agriculture, school of graduate studies. Haramaya, Ethiopia.185p.

Hussain, S. A., M. Amiruzzaman and Z. Hossain. 2003. Combining ability estimates in maize. Bangladesh J. Agricultural Research. 28(3):435-440.

Kempthorne, O. 1957. An introduction to genetic statistics. John Wiley and Sons, New work. p 545.

Leta, T. and Ramachandrappa, B.K. 1998. Combining ability of some traits in a seven parent diallel cross of selected maize (*Zeal mays* L.) Populations. *Crop Research* 15(2 and 3): 232-237.

Meseka SK, Menkir A, Ibrahim AES, Ajala S, 2006. Genetic analysis of performance of maize inbred lines selected for tolerance to drought under low soil nitrogen. Maydica 51: 487 –495.

Mohammed MI, 2009. Line x tester analysis across locations and years in Sudanese x exotic lines of forage sorghum. Journal of Plant Breeding and Crop Science. 9: 311 – 319.

Narro, L., S. Pandey, J. Crossa, C. D. Leon, and F. Salazar. 2003. Using line × tester interaction for the formation of yellow maize synthetics tolerance to acid soils. Crop Sci. 43: 1717-1728.

Novoselovic D, Baric M, Drezner G, Gunjaca J, Lalic A .2004. Quantitative inheritance of some wheat plant traits. Gen. Mol. Bio., 27(1): 92-98.

Nuruzzamman, M., M. F. Alam, M. G. Ahmed, A. M. Shohad, M K. Biswas, M. R. Amin and M. M. Hossain.

2002. Studies on parental variability and heterosis in maize. Pak. J. Bio. Sci., 5 (10): 1006-1009.

Ojo, G. O. S., Adedzwa, D. K. and Bello, L. L. 2007. Combining ability estimates and heterosis for grain yield and yield components in maize (Zea mays L.). Journal of Sustainable Development in Agriculture and Environment.3:50-57.

PATTERSON H.D., E.R. WILLIAMS.1976. *A new class resolvable incomplete block designs*. Biometrika 63:83-92.

Paul, S.K. and R.K. Duara.1991. Combining ability studies in maize (Zea *mays* L.). Intl. J. Tropics. Agric. 9(4):250-254.

PIPERNO, D. R. & FLANNERY, K. V. 2001. The earliest archaeological maize (Zea mays L.) from highland Mexico: new acceleratior mass spectrometry dates and their inplications. Proceedings of National Academy of Sciences, 98, 2101-2103.

Prasanna. 2011. Meeting the challenges of global climate change and food security through innovative maize research. Proceedings of the third National Maize Workshop of Ethiopia, April 18-20, and Addis Ababa, Ethiopia, Pp. 33-42.

Rao, C. R. 1952. *Advanced Statistical Method in Biometric Research*. 2nd Ed . John Wiley and Sons, New York. Pp. 36-38.

Sarker, U., P.S. Biswas, B. Prasad and M.A. Khaleque Mian. 2002. Heterosis and genetic analysis in rice hybrids. Pak. J. Biol. Sci., 5(1): 1-5.

Sofi, P. and A. G.Rather. 2006. Genetic analysis of yield trails in local and CIMMYT inbred line crosses using Line x tester analysis in maize (*Zea mays* L.). Asian J. Plant Sci.,5 (6): 1039-1042.

Sprague, G.F. and L.A. Tatum. 1942. General versus specific combining ability in single cross of corn. J. Agron. 34: 923–32.

Uddin SM, Firoza KS, Ahmed Ali MR, Shamim AB, Bangladesh J. Bot., 2006 35(2), 109-116.

VACARO E., J.F. BARBOSA-NETO, D.G. PEGORARO, C.N. NUSS, L.D.H. CONCEICAO, 2002 Combining ability of twelve maize populations. Pesquisa-agropecuaria-Brasileira **37:** 67-72.

Zhang, R., J.S. Ming, C.W. Xu, L.S. Yang, Y.S. Bai, C.Q. Sun and X.K. Wanc. 2002. Heterosis and combining ability of hybrid rice and its relation to Japonica-index of parents. http://143.48.220.116/newsletter/rice ge netics/rgn 14/V14p34.html.

CALL FOR JOURNAL PAPERS

MORE RESOURCES

IISTE Knowledge Sharing Partners