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Combining Ability of Elite Highland Maize (*Zea mays* L.) Inbred Lines at Jimma Dedo, South West Ethiopia

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Abstract

Breeding efforts to develop high yielding and improved maize varieties for highland areas (altitude of 1700-2400 m) has been recently, launched in Ethiopia. In Ethiopia, national average maize yield under farmer condition is far below attainable. Thirty-four crosses (seventeen inbred lines and two testers) along with two popular standard checks were evaluated for 17 traits in alpha lattice design at Jimma, Dedo. The objectives of this study were to evaluate top cross performance and to estimate combining abilities for grain yield and related traits. The inbred lines and crosses differ significantly for all of the studied traits except ASI, NPP and EPP. Among the crosses L5 × T1 and L16 × T2 showed higher grain yield, crosses L14 × T1 (158.13 cm), L6 × T2 (168.54 cm) expressed short plant height, crosses L4 × T1 (L16 × T1 (231.04 cm) and L14 × T1 (258.13 cm) expressed higher plant height. Crosses L5 × T1 (102.63 day) and L2 × T2 (107.95 day) displayed lowest an thesis date and crosses L5 × T1 (112.67 day), L2 × T2 (114.29 day) displayed lowest silking date. GCA mean squares due to lines were highly significant for most of the traits, while SCA mean squares were significant for some traits. The higher the percentage relative contribution of GCA sum square over SCA sum of square in all studied trait indicated the predominance of additive gene effect in controlling the inheritance of these traits. For grain yield inbred lines L5, L6, L16 and L17 were the top general combiner. Lines with positive and significant GCA effects for grain yield were generally considered as good general combiner for improvement of grain yield. L2, L5, L17 were the best general combiners for days to anthesis. L2, L5, L17, L12, L14 for days to silking and L11 for tallness, while L2, L6, L12, L13, L8, L5, L14 for shortness in plant height were the top general combiner. Future studies should explore the possibility of separating the inbred lines used in this study into distinct heterotic groups using divergent tester. By and large, the information from this study could be useful for researchers who need to develop high yielding varieties of maize adapted to the highland area of Ethiopia.

Keywords: Combining ability; Line × Tester; SCA; GCA; Maize inbred lines; Ethiopia

Introduction

Maize (*Zea mays* L.*)* is a diploid (2*n*=20) crop and one of the oldest food grains in the world. It is a member of order *Oales,* family *Poaceae*, and sub family *Panicoideae* tribe *maydeae*. It is believed that the crop is originated in Mexico and introduced to West Africa in the early 1500s by the Portuguese traders [1]. Maize is one of the most important cereal crops with a high rate of photosynthetic activity leading to high grain and biomass yield potential called C4 grain crop. It is predominantly a cross-pollinating species, a feature that has contributed to its broad morphological variability and geographical adaptability. Maize is currently produced on nearly 100 million hectares in 125 developing countries and is among the most widely grown crops in 75 of those countries [2]. Between now and 2050, the demand for maize in the developing world will double, and by 2025, maize production is expected to be highest globally, especially in the developing countries [3]. Production may not be able to meet out the demands without strong technological and policy interventions [3].

The average yield of maize in developed world is high (7.2 t ha^{-1}), the national average yield in Ethiopia is still as low as 3.2 t ha^{-1} [4] and thus, increasing maize productivity is a high national priority. The wide gap in the yield is attributed to an array of abiotic and biotic stresses, besides other factors. However, in spite of its wide adaptation and efforts made to develop improved maize technologies for different maize agro-ecological zones, still many biotic and a biotic constraint limit maize production and productivity in different maize producing area of Ethiopia [5]. However, breeding efforts to develop high yielding and improved maize varieties for highland areas (altitude of 1700-2400 m) has been recently, launched in Ethiopia, Jimma. Most of the varieties grown in south western highland part of Ethiopia are low yielding local cultivars with very tall in plant and ear height that result into root and stalk lodging, and also are late in physiological maturity and susceptibility to various foliar diseases, mainly grey leaf spot (GLS) (*Cercospora zeae maydis*), Northern corn leaf blight (NCLB) (*Exserohilum turcicum*) and common leaf rust (*Puccinia polysora*) which are the most important diseases [6]. It is estimated that the high altitude covers 20 % of land devoted annually to maize cultivation, and more than 30 % of small-scale farmers in the area depend on maize production for their livelihood [7].

Enhancement of maize production and productivity can be achieved by identifying elite parent materials, which could be used to develop high yielding varieties, and by forming broad based source population serving the breeding program. Line × tester mating design is a modified form of the top cross scheme proposed by Davis in 1927 for inbred lines evaluation [8]. Line × tester is useful in deciding the relative ability of female and male lines to produce desirable hybrid combinations. Kruvadi [9] reported Knowledge of GCA and SCA combining abilities influencing yield and its components has become increasingly important to plant breeders in the choice of suitable parents for developing potential hybrids in many crop plants.

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Large numbers of elite highland maize inbred lines and their F1 were developed by Ethiopian high land maize improvement project. Currently, these are available at different centers such as Ambo, Holetta, Kulumsa, Adet and Jimma Agricultural Research Center. To enhance hybrid formation and open pollinated variety development information on the magnitude of combining abilities is extremely important. However, there is little or no information on the magnitude of combining abilities of the 17 inbred lines used in this study. Therefore; the objectives of this study were: To evaluate top cross performance and estimate combining abilities for grain yield and other agronomic traits of seventeen elite highland maize inbred lines using line × tester mating design.

Materials and Methods

The experimental material for the study consisted of thirty-four lines by test crosses (L1 × T1, L1 × T2, L2 × T1, L2 × T2… L17 × T1 and L17 × T2) and three standard checks. The parents were crossed in Line × Tester mating design to generate 34 F1 hybrids at Ambo Agricultural Research Center, Ethiopia at main cropping season 2012. The experiment was conducted during the main cropping season of 2013 at the Jimma Dedo on F1 (Line × Tester crosses). Early generation highland maize lines originally introduced from CIMMYT-Mexico were advanced to S_5 stage through selection at Ambo highland maize breeding program, Ethiopia. Elite lines at S_5 stage of inbreeding were crossed to a well-adapted local inbred line, F215. Line development was re-initiated from the F2 populations of these crosses, and has been advanced to S3 level of inbreeding. The inbred lines were developed from germplasm collection of CIMMYT-Mexico and were bred for resistance to various biotic and abiotic stresses. The most important stresses against which the inbred lines were selected include susceptibility to various foliar diseases, mainly grey leaf spot (GLS) (*Cercospora zeae maydis*), Northern corn leaf blight (NCLB) (*Exserohilum turcicum*) and common leaf rust (*Puccinia polysora*) All 34 test crosses were evaluated along with two most popularly grown highland maize hybrids, Wenchi and Jibat. The two checks are released by Ambo agricultural research center recently.

Experimental design and field managements

The experimental design used for the field evaluation was 12 × 3 alpha- lattice design replicated twice. Design and randomization of the trial was generated using CIMMYT's computer software known as Field book Bindiganavile et al. [10]. Spacing was 75 cm between rows and 25 cm between plants within the row. Each entry consisted of one rows of 5.25 m long. Two seeds were planted per hill to ensure uniform and enough stand and then thinning was performed at the three to five leaf stages to attain a final plant density of 53,000 plants hectar. As recommended by AARC, 100 kg DAP ha^{-1} and 75 kg Urea ha^{-1} applied at planting and additional 75 kg N hectarside dressed at 45 days after planting. Urea and dominium phosphate (DAP) used as sources of N and P_2O_5, respectively. Other crop management practices such as land preparation three times before sowing, weeding once per month and slashing in 15 days interval was applied following research recommendations for the site.

Statistical analysis and procedures

Data collection and analysis of variance (ANOVA): Data were recorded on seventeen quantitative characters. Data related to days to 50 % anthesis, 50 % days to silking, 50 % days to Maturity, 1000-kernel weight, grain yield and anthesis silking interval were recorded on the plot basis while data related to other characters were recorded on five randomly selected plants leaving border plants of each row. The mean values were subjected to line × tester analysis. Analyses of variances (ANOVA) were computed for grain yield and other agronomic traits by using SAS 9.2 software.

Combining ability analysis: Line × tester analysis was done for traits that showed statistically significant differences among the crosses using the adjusted means based on the method described by Kempthorne. General combining ability (GCA) and specific combining ability (SCA) effects for grain yield and other agronomic traits were calculated using the line × tester model. The F-test of mean square due to lines, testers and their interactions were computed against mean square due to error Significances of GCA and SCA effects of the lines and hybrids were determined by an F - test using the standard errors of GCA and SCA effects.

Results and Discussion

Analysis of variance

Analyses of variances were computed and presented in Table 1.

		Mean squares																
Source of Variation	DF	GY (t/ha)	AD (days)	SD (day)	ASI (day)	PH (cm)	EH (cm)	ED (cm)	EL (cm)	NPP (#)	EPP (#)	KPR (#)	RPE (#)	GM (%)	EA (#)	PA (#)	TKWT (gm)	MD (day)
Rep	1	10.31**	159.01**	105.13**	4.01	16.15	41.24	0.40**	0.33	34.72*	0.01	66.51**	0.11	14.05**	0.00	0.03	112.50	29.38**
Block	4	0.91	16.61	14.37	0.31	138.02	90.02	0.07*	4.14**	2.37	0.01	11.48**	0.18	5.68**	0.16	0.03	906.25	11.97*
Entry	35	3..56**	19.73**	18.62**	3.47	991.95**	451.37**	0.10**	1.85**	6.09	0.02	10.66**	1.34**	8.41**	0.24**	0.26**	5419.88**	13.46**
Crosses(Cr)	33	3.45**	19.32*	17.88**	4.17	951.28 **	383.91**	0.13**	2.38*	6.78	0.01	17.00**	1.69**	10.37**	0.24**	0.27**	5871.30**	11.68*
GCA line	16	4.39**	30.59**	29.62**	4.53	620.43**	443.12**	0.12**	2.57**	6.74	0.02	21.24**	1.09**	12.59**	0.33**	0.30**	8190.81**	13.53**
GCA tester	1	11.07**	41.31*	14.13	4.25	19111.76**	7.00**	1.60**	4.96**	31.12**	0.02	120.71**	28.99**	54.90**	0.94**	1.62**	52.94	91.77**
SCA	16	2.04**	6.68	6.38	3.81	147.11	2.00	0.04	2.04	5.31	0.01	6.28	0.58**	5.36**	0.12	0.17*	3915.44	4.84
Ck	1	1.55	0.00	1.00	1.00	3306.25	30.00	0.00	0.06	4.00	0.02	0.04	0.16**	0.20	0.06	0.25**	2025.00	56.25
Ck vs Cr	1	1.90	19.33	16.88	3.77	281.25	26.00	0.13	2.32	2.78	0.02	16.96	1.53**	10.17	0.19	0.02**	3846.00	14.57
Error	31	0.64	9.38	6.73	3.97	166.72	165.89	0.02	0.68	5.47	0.01	4.77	0.03	1.66	0.11	0.07	2487.50	4.66
% Cont. GCA		71.34	83.23	82.69	55.7	92.50 7.50	84.29	81.52	58.60	62.08	72.3	82.07 17.93	83.27	74.91	76.43	70.50	67.67 32.33	79.92
% Contr. SCA		28.66	16.77	17.31	44.3		15.71	17.78	41.40	37.92	24.7		16.73	25.09	23.57	29.50		20.08

**=Significant at P<0.01 level of probability; *=Significant at P<0.05 Level of probability; DF=Degrees of freedom; Rep= Replication; GY= Grain yield; AD=Number of days to anthesis; ED=Ear diameter; EH= Ear height; EL=Ear length; EPP= Number of ears per plant; NP=Number of plant per plot; KPR=Number of kernels per row; PH=Plant height; KRPE=Number of rows per ear; SD=Number of days to silking; TKWT=Thousand kernels weight; ASI=Anthesis silking interval; GM=Grain moisture; MD=Maturity date; PA=Plant aspect and EA=Ear aspect

Table 1: Analysis of variance for grain yield and other agronomic traits of line by tester crosses involving 17 lines and 2 testers evaluated at Jimma Dedo, south west Ethiopia in 2013 cropping season.

Highly significant differences *(P<0.01)* were obtained among the genotypes (entries) and crosses for all traits except ASI, NPP and EPP. In addition, mean squares due to checks and check vs. cross were highly significant (P<0.01) for RPE and PA. The rest of the traits had non-significant. Significant differences observed among the entries (genotypes) for most of the traits studied, indicating the presence of genetic variation among the materials, which makes possible for improvement of the traits. In consistence with this finding Dagne et al.[11], Teshale [12], Jemal [13], Amiruzzaman et al.[14], Hadji [15], Gudeta [16], Alamenesh [17] reported the presence of significant differences among genotypes for grain yield and other traits in different sets of maize parental inbred lines.

Mean performance of F1 crosses (Line × Tester)

The overall mean performance of the 36 entries i.e., thirty-four crosses and two standard check evaluated for grain yield and related agronomic traits presented in Table 2. In current study, the overall mean grain yields (GY) of the entries were 5.61 t/ha ranging from 3.46 t/ha to 8.36 t/ha. Cross L5 × T1 (8.36 t/ha) and WENCHI (8.02 t/ha) expressed higher grain yield, while cross L1 × T2 (3.46 t/ha) and L7 × T2 (3.76 t/ha) showed lower GY. Overall mean for number of kernels per row (KPR) were 31.86 ranging from 26.86 to 36.80. Cross L15 × T1 (36.80), cross L1 × T1 (36.15) and L14 × T1 (35.88) displayed higher number of kernels per row. Cross L11 × T2 (26.68), cross L10 × T2 (27.75) and L16 × T2 (28.05) displayed lower number of KPR. Thousand kernels weight (TKW) ranging from 267.08 g cross (L2 × T1) to 492.08 g cross (L10 × T1) gm with overall mean of 387.71. Cross L10 × T1 (492.8 g), cross L13 × T1 (477.08 g) and cross L13 × T2 (452.08 g) expressed higher TKW, while cross L2 × T1 (267.08 g) and cross L7 × T1 (295.83 g) displayed lower TKW (Tables 2-5). In agreement with this study Dagne et al. [18], Zerihun [19], Alemenesh [17] in their studies reported that experimental varieties showed better performance than the best check for most of yield and other traits.

The overall mean values of number kernels per ear (KRPE) were 11.46 ranging from 10.03 to 13.07. Cross L3 × T1 (13.07), cross L5 × T1 (12.85) and WENCHI (12.80) had higher number of kernels per row, while cross L7 × T1 (10.03), cross L4 × T2 (10.05) and cross L8 × T2 (10.13) showed lower number of KRPE. Ear diameter (ED) were ranged from 3.47 cross (L4 × T2) to 4.55 cross (L10 × T1) cm, with overall mean of 4.07 cm. Cross L10 × T1 (4.55) cm, cross L16 × T1 (4.43) cm and cross L1 × T1 (4.38) cm were displayed higher ED, while cross L4 × T2 (3.47) cm and cross L7 × T2 (3.59) cm expressed lower ED. Mean value for ear length (EL) were 16.33 cm ranged from 14.19 cm cross (L7 × T2) to 17.85 cm WENCHI. For ear length standard check (WENCHI) displayed (17.85) cm (Tables 6-8). In agreement with this study Dagne et al. [18], Zerihun [19], Alemenesh [17] in their studies reported that experimental varieties showed better performance than the best check for most of yield and other traits.

Cross L14 × T1 (258.13) cm, cross L16 × T1 (231.01) cm and cross L10 × T1 (225.00) cm were showed higher plant height while cross L14 × T1 (158.13) cm, WENCHI (168.13) cm and cross L6 × T2 (168.54) cm expressed lower PH. Ear height (EH) ranged from 70.00 standard check (WENCHI) to 135.83 (L13 × T1) with a mean height of 101.72 cm. Cross L13 × T1 (135.83), cross L14 × T1 (134.79) and cross L16 × T1 (127.50) cm expressed higher ear height, while WENCHI (70.00), cross L7 × T2 (73.13) cm and cross L2 ×T2 (80.83) cm expressed lower

Genotypes	GY (t/ha	AD (days)	SD (day)	ASI (day)	PH (cm)	EH (cm)	ED (cm)	EL (cm)	NPP (#)	EPP (#)	KPR (#)	KPE (#)	GM (%)	EA (#)	PA (#)	TKW (gm)	MD (day)
L1 × T2	3.46	111.37	117.54	6.13	177.08	96.67	3.76	14.53	18.46	1.2	29.68	11.13	16.28	3.00	1.87	322.08	218.42
L2 × T2	5.05	107.95	114.29	6.33	184.37	80.83	4.03	16.84	20.54	1.2	32.88	11.38	19.65	2.46	1.92	372.08	220.29
L3 × T2	4.46	117.71	124.17	6.42	203.13	114.58	4.08	15.77	17.63	1.1	31.54	11.87	14.74	2.25	2.13	327.08	219.58
L4 × T2	6.31	111.13	117.67	6.54	175.83	110.42	3.47	16.02	19.37	1.2	28.22	10.05	17.38	2.71	2.16	432.08	221.62
L5 × T2	4.97	112.67	117.67	5.04	181.04	92.50	4.18	16.86	16.00	1.3	32.24	11.88	15.77	2.04	2.37	420.08	220.29
L6 × T2	5.97	118.67	124.67	6.04	168.54	100.00	3.88	15.91	20.50	1.1	32.94	11.08	21.52	2.04	1.75	410.83	221.29
L7 × T2	3.76	115.08	120.54	5.33	186.25	73.13	3.59	14.19	14.17	0.9	28.38	10.03	16.64	2.87	1.63	317.08	218.75
L8 × T2	3.77	111.37	117.54	6.13	169.58	84.17	3.83	16.29	15.46	1.1	31.58	10.13	17.78	3.00	2.29	392.08	220.42
L9 × T2	5.43	113.13	120.67	7.54	185.83	90.42	3.68	17.27	17.37	1.3	30.82	10.25	19.24	1.71	2.37	367.08	224.63
L10 × T2	5.75	117.58	122.54	4.83	178.75	88.13	4.24	16.55	15.17	1.1	27.75	11.63	22.89	2.37	2.00	362.08	219.75
L11 × T2	5.05	117.46	124.29	6.83	186.87	88.33	3.88	15.84	17.04	1.3	26.68	10.58	18.45	2.21	2.25	312.08	221.29
L12 × T2	3.87	111.58	117.04	5.33	171.25	83.13	3.95	16.55	16.17	1.3	31.75	10.63	20.59	2.37	1.87	447.08	217.75
L13 × T2	4.19	118.21	123.17	4.92	158.13	87.08	4.04	16.92	16.63	1.2	30.14	10.47	18.09	2.75	1.92	452.08	217.08
L14 × T2	5.38	111.13	117.17	6.04	180.83	90.42	3.78	17.72	19.87	1.1	32.57	10.25	19.94	1.96	2.13	427.08	220.62
L15 × T2	4.04	114.96	120.29	5.33	184.37	98.33	4.01	17.29	18.04	1.4	33.68	10.38	15.89	1.96	2.16	387.08	218.29
L16 × T2	7.89	114.08	119.04	4.83	191.25	95.63	4.17	14.95	19.17	1.3	28.05	10.23	21.04	2.13	2.37	417.08	225.25
L17 × T2	7.49	111.21	116.17	4.92	193.13	104.58	4.18	16.07	20.63	1.2	34.24	10.87	21.69	2.25	1.75	407.08	224.58
L1 × T1	5.99	112.04	119.91	8.04	216.67	110.21	4.38	15.56	19.87	1.2	30.66	11.83	18.37	2.37	1.63	425.83	223.83
L2 ×T1	5.98	110.33	116.41	5.92	217.50	91.87	3.79	16.82	17.25	1.3	33.52	12.72	19.44	2.67	2.29	267.08	224.04
L3 × T1	6.58	114.71	119.67	4.92	213.13	127.08	4.30	15.57	20.13	1.0	34.74	13.07	20.34	2.00	2.37	367.08	220.08
L4 × T1	5.05	111.54	121.41	10.04	219.17	127.08	4.23	16.60	17.37	1.0	29.26	12.43	19.77	2.13	2.00	385.83	222.83
L5 × T1	8.36	102.63	112.67	10.04	203.33	105.42	4.33	14.62	21.37	1.3	30.12	12.85	20.28	1.71	2.25	377.08	225.13
L6 × T1	7.74	115.37	123.04	7.63	192.08	99.17	4.10	15.75	19.56	1.2	33.48	11.33	20.18	2.00	1.87	342.08	222.42
L7 × T1	4.36	113.67	121.17	5.54	208.54	102.50	4.15	14.67	17.50	1.1	32.14	11.48	19.32	2.54	1.92	295.83	220.29
L8 × T1	6.47	112.33	117.42	4.42	205.00	101.87	4.13	17.62	20.75	1.2	32.92	12.32	19.44	2.17	2.13	412.08	219.54

GY=Grain yield; AD=Number of days to anthesis; ED=Ear diameter; EH=Ear height; EL=Ear length; EPP=Number of ears per plant; NPP=Number of plant per plot; KPR=Number of kernels per row; PH=Plant height; KRPE=Number of rows per ear; SD=Number of days to silking; TKWT=Thousand kernels weight; ASI=Anthesis silking interval; GM=Grain moisture; MD=Maturity date; PA=Plant aspect and EA=Ear aspect

Table 2: (Continued) Estimates of mean values for grain yield and related traits at Jimma Dedo, south west Ethiopia during 2013 cropping season.

Line	GY (t/ha)	AD (days)	SD (day)	PH (cm)	EH (cm)	ED (cm)	EL (cm)	NPP (#)	KPR (#)	KRPE (#)	GM (%)	EA (#)	PA (#)	TKWT (gm)	MD (day)
L1	-0.78**	-1.10	-0.28	3.08	4.03	-0.02	-0.86**	0.93	-1.15*	0.12	-2.71**	0.53**	0.37**	-13.97	-0.84
L2	0.00	-4.35**	-4.28**	4.34	-10.97**	-0.18**	0.49	0.43	1.45*	0.62**	0.19	0.28**	0.24**	-71.47**	0.91
L3	0.01	2.89**	2.47**	18.08**	22.78**	0.02	-0.13	0.43	2.25**	1.02**	-2.33**	-0.09	-0.26**	-51.47**	-1.08
L4	0.17	-1.60	0.47	0.58	-13.47**	-0.22**	-0.11	0.17	-3.45**	-0.08	-1.48**	0.28**	-0.26**	26.03*	-0.34
L5	1.15**	-5.35**	-4.03**	-8.41*	0.28	0.24**	-0.71*	0.43	-1.00	1.02**	-1.48**	-0.35**	-0.38**	18.53	0.41
L6	1.34**	4.15**	4.72**	-16.91**	-1.97	-0.03	-0.11	1.93**	1.89**	-0.18	1.37**	-0.22*	0.12	-8.97	0.16
L7	-1.45**	0.39	0.72	-4.41	-10.97**	-0.12**	-1.96**	-2.32**	-1.65**	-0.58**	-0.91*	0.40**	0.37**	-73.97**	-2.34**
L8	-0.39	-0.60	-1.28	-8.16*	-7.22*	-0.07	1.04**	-0.57	1.09	-0.28*	-0.78	0.28**	0.12	8.53	-0.84
L9	-0.00	0.65	0.97	-1.66	0.28	-0.13**	0.36	-0.57	-0.65	-0.28*	-1.11**	-0.35**	-0.13	3.53	1.91**
L10	0.19	3.65**	1.22	1.84	4.03	0.37**	0.54	-2.57**	-3.05**	0.32*	2.64**	-0.22*	-0.26**	38.53**	-1.84**
L11	-0.87**	3.65**	4.72**	6.84*	0.28	-0.22**	-0.96**	-1.07	-4.05**	0.32*	-0.71	0.03	0.49**	-78.97**	0.16
L12	-0.98**	-1.35	-2.03*	-13.16**	-5.97*	-0.04	0.29	-0.57	0.89	-0.48**	2.42**	-0.09	0.12	58.53**	-1.34**
L13	-1.31**	1.39	0.72	-16.91**	-9.72**	-0.03	0.36	-1.07	-0.50	-0.88**	0.49	0.15	0.24**	71.03**	-1.34**
L14	-0.55*	-1.60	-2.03*	-8.16*	-5.97*	-0.07	0.51	1.17*	1.92**	-0.28*	1.07**	-0.35**	-0.26**	8.53	-0.84
L15	-0.41*	2.15**	2.47**	1.84	1.53	0.02	1.01**	0.17	3.05**	-0.08	-1.48**	-0.35**	-0.13	6.03	-0.84
L16	2.07**	-0.35	-1.03	9.34**	12.78**	0.31**	-0.58*	1.17*	-0.90	-0.28*	2.54**	-0.09	-0.26**	36.03**	4.41**
L17	1.81**	-2.60**	-3.53**	31.84**	20.28**	0.14**	0.82**	1.93**	3.87**	0.02	2.29**	0.15	-0.13	23.53	3.66**
SE	0.19	0.81	0.70	3.08	2.87	0.04	0.26	0.55	0.54	0.12	0.37	0.08	0.07	12.06	0.60
SED	0.27	1.14	0.99	4.36	4.06	0.06	0.37	0.78	0.77	0.17	0.53	0.12	0.10	17.06	0.85

**=Significant at P<0.01 level of probability; *=Significant at P<0.05 Level of Probability; GY= Grain yield; AD=Number of days to anthesis; ED=Ear diameter; EH=Ear height; EL=Ear length; NPP=Number of plant per plot; KPR=Number of kernels Per row; PH=Plant height; KRPE=Number of rows per ear; SD=Number of days to silking; TKWT=Thousand kernels weight; GM=Grain moisture; MD=Maturity date; PA=Plant aspect and EA=Ear aspect

Table 3: Estimates of General combining ability effects (GCA) for line by tester crosses of maize inbred lines evaluated at Jimma, Dedo 2013.

Cross	GY (t/ha)	KRPE (#)	GM (%)	PA (#)
L1 × T1	0.86	-0.15	0.13	0.03
L1 × T2	-0.86	0.15	-0.13	-0.03
L2 × T1	0.06	-0.05	-0.42	-0.09
L2 × T2	-0.06	0.05	0.42	0.09
L3 × T1	0.66	-0.05	1.90*	-0.09
L3 × T2	-0.66	0.05	-1.90*	0.09
L4 × T1	-1.03	-0.65*	0.30	-0.59**
L4 × T2	1.03	0.65*	-0.30	0.59**
L5 × T1	1.29	-0.25	0.80	-0.22
L5 × T2	-1.29	0.25	-0.80	0.22
L6 × T1	0.48	-0.65*	-2.09**	0.03
L6 × T2	-0.48	0.65*	2.09**	-0.03
L7 × T1	-0.10	0.15	0.37	0.28
L7 × T2	0.10	-0.15	-0.37	-0.28
L8 × T1	0.94	0.45	0.55	0.03
L8 × T2	-0.94	-0.45	-0.55	-0.03
L9 × T1	-0.32	0.25	-1.17	-0.22
L9 × T2	0.32	-0.25	1.17	0.22
L10 × T1	-0.45	-0.55*	-2.32**	0.15
L10 × T2	0.45	0.55*	2.32**	-0.15
L11 × T1	-0.82	0.45	-0.12	0.15
L11 × T2	0.82	-0.45	0.12	-0.15
L12 × T1	0.25	-0.35	-0.25	0.03
L12 × T2	-0.25	0.35	0.25	-0.03
L13 × T1	-0.38	-0.55*	1.37	0.15
L13 × T2	0.38	0.55*	-1.37	-0.15
L14 × T1	-0.82	0.25	0.30	0.15
L14 × T2	0.82	-0.25	-0.30	-0.15
L15 × T1	0.67	0.25	1.65*	0.03
L15 × T2	-0.67	-0.25	-1.65*	-0.03
L16 × T1	0.72	0.25	-0.57	0.15
L16 × T2	-0.71	-0.25	0.57	-0.15
L17 × T1	-0.57	-0.05	-0.42	0.03
L17 × T1	0.57	0.05	0.42	-0.03
SE	0.75	0.24	0.75	0.14
SED	1.06	0.35	1.06	0.20

**=Significant at P<0.01 level of probability; *=Significant at P<0.05 Level of probability; KRPE=Number of rows per ear; GM=Grain moisture; MD=Maturity date and PA=Plant aspect

Table 4: Estimates of specific combining ability effects (SCA) for line by tester crosses of maize inbred lines evaluated at Jimma, Dedo 2012/13.

GY (t/ha)		TKW (gm)		KPE(#)		KPR(#)		ED(cm)		EL(cm)	
Bottom five mean values from smallest to largest											
L1 × T2	3.46	L2 × T1	267.08	L7 × T2	10.03	L11 × T2	26.68	L4 × T2	3.47	L7 × T2	14.19
L7 × T2	3.76	L7 × T1	295.83	L4 × T2	10.05	L10 × T2	27.75	L7 × T2	3.59	L1 × T2	14.53
L8 × T2	3.77	L11 × T1	300.83	L8 × T2	10.13	L16 × T2	28.05	L9 × T2	3.68	L5 × T1	14.62
L12 ×T2	3.87	L11 × T2	312.08	L16 × T2	10.23	L4 × T2	28.22	L1 × T2	3.76	L7 × T1	14.67
L15 × T2	4.04	L7 × T2	317.08	L9 × T2	10.25	L7 × T2	28.38	L14 × T2	3.78	L11 × T1	14.90
Top five mean values from smallest to largest											
L17 × T2	7.49	L12 × T2	447.08	L11 × T1	12.63	L17 × T2	34.24	L3 × T1	4.30	L15 × T1	17.57
L6 × T1	7.74	L17 × T2	447.08	L2 × T1	12.72	L3 × T1	34.74	L5 × T1	4.33	JIBAT	17.60
L16 × T2	7.89	L13 × T2	452.08	WENCHI	12.80	L14 × T1	35.88	L1 × T1	4.38	L8 × T1	17.62
WENCHI	8.02	L13 × T1	477.08	L5 × T1	12.85	L1 × T1	36.15	L16 × T1	4.43	L14 × T2	17.72
L5 × T1	8.36	L10 × T1	492.08	L3 × T1	13.07	L15 × T1	36.80	L10 × T1	4.55	WENCHI	17.85
Mean	5.61		387.71		11.46		31.86		4.07		16.33
LSD (5 %)	0.96		59.58		0.57		2.61		0.20		0.98
CV	14.35		12.87		4.17		6.86		3.93		5.07

Table 5: Top and bottom five mean values of genotypes for GY, TKW, KPE, KPR, ED and EL location Jimma, Dedo 2012/13.

PH(cm)		EH(cm)		PA (1-5)		EA (1-5)		NPP(#)		EPP(#)	
Bottom five mean values from smallest to largest											
L14 × T1	158.13	WENCHI	70.00	L4 × T1	1.54	L15 × T1	1.63	L7 × T2	14.17	L3× T1	0.90
WENCHI	168.13	L7 × T2	73.13	L5 × T1	1.68		1.71	L10 × T2 & WENCHI	15.17	L4 × T1	1.00
L6 × T2	168.54	L2 × T2	80.83	L3 × T1	2.02	L5 × T1	1.71	L8 × T2	15.46	L10 × T2	1.00
L8 × T2	169.58	L10 × T2	83.13	L9 × T1	2.04	L14 × T1	1.75	L5 × T2	16.00	L12 × T1	1.00
L12 × T2	171.25	L8 × T2	84.17	JIBAT	2.04	L9 × T1	1.87	L12 × T2	16.17	L15 × T1	1.00
Top five mean values from smallest to largest											
L4 × T1	219.17	L3 × T1	127.08	L2 × T2	2.94	L4 × T2	2.71	L6 × T2	20.50	L5 × T2	1.30
JIBAT	221.67	L4 × T1	127.08	L4 × T2	2.94	L13 × T2	2.75	L2 × T2	20.54	L9 × T2	130
L10 × T1	225.00	L16 × T1	127.50	L1 × T2	3.02	L7 × T2	2.87	L17 × T2	20.63	L13 × T1	1.30
L16 × T1	231.04	L14 × T1	134.79	L7 × T1	3.04	L1 × T2	3.00	L8 × T1	20.75	L14 × T1	1.30
L14 × T1	258.13	L13 × T1	135.83	L11 × T1	3.04	L8 × T2	3.00	L5 × T1	21.37	L15 × T2	1.40
Mean	197.02		101.72		2.50		2.23		17.99		1.17
LSD (5%)	0.17		0.20		0.34		0.39		2.79		14.1
CV	6.28		17.39		11.27		15.13		12.76		15.38

Table 6: Top and bottom five mean values of genotypes for PH, EH, PA, EA, NPPP and NPPE location Jimma, Dedo2012/13.

AD (day)		SD (day)		ASI (day)		MD (day)		GM (%)	
Bottom five mean values from smallest to largest									
L5 × T1	102.63	L5 × T1	112.67	L10 × T1	2.42	L13 × T2	217.08	L3 × T2	14.74
L2 × T2	107.95	L2 × T2	114.29	L8 × T1	4.42	L12 × T2	217.75	L5 × T2	15.77
L14 × T1	108.87	L14 × T1	114.54	L10 × T2	4.83	L15 × T2	218.29	L15 × T2	15.89
L14 × T2	111.13	L14 × T2	114.79	L16 × T2	4.83	L1 × T2	218.42	L1 × T2	16.28
WENCHI	111.00	WENCHI	115.29	L17 × T2	4.92	L10 × T1	218.54	L7 × T2	16.64
Top five mean values from smallest to largest									
L11 × T1	117.54	L13 × T2	123.17	L6 × T1	7.63	JIBAT	225.00	L12 × T1	21.84
L10 × T2	117.58	L3 × T2	124.17	L15 × T1	7.75	L5 × T1	225.13	L14 × T1	22.28
L3 × T2	117.71	L11 × T2	124.29	L1 × T1	8.04	L16 × T2	225.25	L13 × T1	22.69
L13 × T2	118.21	L6 × T2	124.67	L4 × T1	10.04	L14 × T1	226.67	L10 × T2	22.89
L6 × T2	118.67	L11 × T1	124.91	L5 × T1	10.04	L16 × T1	227.29	L14 × T1	22.97
Mean	112.97		119.12		6.06		221.76		19.58
LSD (5%)	3.67		3.11		2.38		2.59		1.54
CV	2.71		2.18		32.85		0.97		6.85

Table 7: Top and bottom five mean values of genotypes for AD, SD, ASI, MD, and GM location Jimma, Dedo 2012/13.

EH. The overall mean values for plant aspect (PA) of entries were 2.50 % ranging from 1.54 % to 3.04 %. Cross L11 × T1 and cross L7 × T1 (3.04) % and cross L1 × T2 (3.02) % showed higher % of plant aspect, while cross L4 × T1 (1.54 %) and cross L5 × T1 (1.68.54) % showed lower PA. The overall mean for ear aspect (EA) of the entries were 2.23 % ranging from 1.63 % to 3.00 %. Cross L8 × T2 and L1 × T2 (3.00) % and cross L7 × T21 (2.87) %) expressed higher % of ear aspect while cross L15 × T1 (1.63) % and cross L9 × T2 (1.71) % showed lower EA. Mean value for number of plant per plot (NPP) were 17.99 ranged from 14.17 (L7 × T1) to 21.37 (L5 × T1). Cross L5 × T1 (21.37), cross L8 × T1

Value	GY (t/ha)	AD (days)	SD (day)	ASI (day)	PH (cm)	EH (cm)	ED (cm)	EL (cm)	NPP (#)	EPP (#)	KPR (#)	KPE (#)	GM (%)	EA (#)	PA (#)	TKWT (gm)	MD (day)
Location Jimma, Dedo																	
Cr mean	5.51	113.09	119.27	6.09	197.06	101.97	4.07	16.25	18.34	1.17	31.77	11.39	19.60	2.24	2.20	386.84	221.77
Ck mean	7.24	111.11	116.61	5.65	194.90	99.00	4.16	17.43	18.04	1.17	33.23	12.46	19.67	2.00	2.29	395.83	223.00
Mean	5.61	112.97	119.12	6.06	197.02	101.72	4.07	16.33	17.99	1.17	31.86	11.46	19.58	2.23	2.50	387.71	221.76
Min	3.46	102.63	114.29	2.42	158.13	72.79	3.47	14.19	14.17	0.90	27.75	10.13	14.74	1.63	1.54	267.08	217.08
Max	8.36	118.67	124.91	10.04	258.13	135.83	4.55	17.72	21.37	1.40	36.80	13.07	22.97	3.00	3.04	492.08	227.29
LSD (5%)	0.96	3.67	3.11	2.38	0.17	0.20	0.20	0.98	2.79	0.30	2.61	0.57	1.54	0.39	0.34	59.58	2.59
CV	14.35	2.71	2.17	32.85	6.28	17.39	3.93	5.07	12.76	14.1	6.86	4.17	6.58	15.13	11.27	12.87	0.97

Table 8: Mean, maximum and minimum values of entries (genotypes) for grain yield and yield related traits Jimma, Dedo 2012/2013.

(20.75) and cross L17 × T2 (20.63) expressed higher number of plants per plot, while cross L7 × T2 (14.17), cross L10 × T2 and WENCHI (15.17) showed lower NPP. Mean value for EPP were 1.17 ranged from 0.90 cross (L3 × T1) to 1.40 cross (L15 × T2). Days to anthesis (AD) were ranged between 102.63 cross (L5 × T1) and 118.67 cross (L6 × T2) with overall mean of 112.97. Cross L6 × T2 (118.67), cross L13 × T2 (118.21) and cross L3 × T2 (117.71) showed higher anthesis date while cross L5 × T1 (102.63), cross L2 × T2 (107.95) and L14 × T1 (168.87) showed lower AD (Tables 6-8). In agreement with this Dagne et al. [18], Zerihun [19], Alemenesh [17] in their studies reported that experimental varieties showed better performance than the best check for most of yield and other traits.

Overall, mean values of days to silking (SD) of the entries (genotypes) were 119.12 with a range of 112.67 cross (L5 × T1) to 124.91 cross (L11 × T1). Cross L11 × T1 (124.91), cross L6 × T2 (124.67) and cross L11 × T2 (124.29) expressed higher silking date while cross L5 × T1 (112.67), cross L2 × T2 (114.29) and cross L14 × T1 (114.54) displayed lower SD. Overall mean values of days to maturity (MD) of the entries (genotypes) were 221.76 with a range 217.08 (L13 × T2) to 227.29 (L16 × T1). Cross L16 × T1 (227.29), cross L14 × T1 (226.67) and JIBAT (226.33) showed higher record for days to maturity while cross L13 × T2 (217.08), cross L12 × T2 (217.75) and cross L15 × T2 (218.29) showed lower record for days to maturity. Grain moisture at harvest (GM) ranged between 14.74 % (L3 × T2) and 22.97 % (L14 × T1) with over all mean of 19.58%. Cross L14 × T1 (22.97) %, cross L10 × T2 (22.89) % and cross L13 × T1 (22.69) % expressed higher grain moisture at harvest, while cross L3 × T2 (14.74) %, cross L5 v T2 (15.77) and cross L15 × T2 (15.87) displayed lower grain moisture.

A number of crosses showed better performances for more than one trait. Therefore, crosses that had high grain yield could be used in further across location breeding program to improve grain yield and other traits of interest. Hence, a hybrid expressed earlier in anthesis and silking, medium in ear and plant heights, better performance in ear and plant aspect could be used as sources of genes for development of high yielder, early maturing varieties. This study gives a clue for highland maize breeding program to design appropriate breeding strategies. In agreement with this study Dagne et al. [18], Zerihun [19], Alemenesh [17] in their studies reported that experimental varieties showed better performance than the best check for most of yield and other traits.

Combining ability analysis

In this study the contribution of general combining ability variance was much greater than those of specific combining ability variance for all the characters studied. The higher percentage relative contribution of GCA sum of square over SCA sum of square showed the predominance role of additive gene action over non-additive action in the inheritance of all traits studied. For the evaluation of an inbred line in the production of hybrid maize two factors are considered i.e., characteristics of the line itself and behavior of the line in a particular hybrid combination. As revealed from the present study results, the inbred lines displayed superior performance in their GCA effects especially for grain yield and other prominent traits contributing towards grain yield i.e., AD, SD, PH, EH, ED, EL, KPR, RPE, EA, PA and TKWT.

Grain yield (GY)

Line by tester analysis of variance (ANOVA) of combining ability for grain yield and related traits is given in Table 1. Line GCA, tester GCA and SCA means squares were highly significant *($p < 0.01$)* for grain yield. Significant GCA and SCA mean square indicated the importance of both additive and non-additive gene actions in governing grain yield. In agreement with the present study, Hadji found highly significant mean squares due to GCA and SCA for grain yield in diallel study of quality protein maize inbred lines. In addition, both the role of additive and non-additive gene actions in governing grain yield in maize was reported by other works Mandefro and Habtamu [20], Dagne et al. [11], Demissew et al. [21] On the other hand, Bayisa [22] found non-significant GCA effects for grain yield in line × tester study of transition highland inbred lines at Kulumsa [16] carried out line × tester analysis of QPM versions of early generation highland maize inbred lines and reported significant GCA mean squares due to lines at Holeta and Kulumsa but non-significant GCA mean squares at Ambo and Haramaya.

Thousand kernels weight (TKWT)

Mean squares due to line GCA for thousand kernels weight were highly significant *($P < 0.01$)* Table 1. In this study the result observed indicates the predominant role of additive gene effect in governing this trait. However, tester GCA and SCA mean square were no significant for the same trait. In agreement with this study, reported non-significant SCA mean squares for TKWT. In addition, Joshi et al. [23] observed importance of additive genetic variance for this trait.

Anthesis and silking days (AD and SD)

For number of days to anthesis (AD) and silking (SD), mean squares due to line GCA were highly significant*($p<0.01$)*. Mean squares due to tester GCA for number of days to anthesis (AD) were significant *($p<0.05$)* (Table 1). In line with this finding, Gudeta [16] reported significant GCA effects due to testers at Ambo. The predominance effect of GCA mean of squares over SCA mean squares for these traits indicates the relative importance of additive gene action to non-additive gene action for these traits. Similar to this study Shewangizaw [24], Leta et al. [25] reported the highest contribution of GCA than SCA for days to silking. In line with this study, Ahmad and Saleem [26] reported the preponderance of additive gene action in the inheritance of days to an thesis and days to silking. Also Legesse et al. [27] reported the predominance role of additive gene action in inheritance of days to silking.

Kernel rows per ear (KRPE)

For number of kernel rows per ear mean squares due to line GCA and tester GCA and SCA were highly significant *(p<0.01)* (Table 1). In this study, the effects of additive and non additive gene action for the inheritance of KRPE were identified. In agreement with this study, Hadji [15], Dagne et al. [11] reported both additive and non-additive were important for this trait. In disagreement with this finding Petrovic [28], Mathur et al. [29] observed a significant GCA effect and the predominance role of additive gene action for KRPE. On the other hand, Pal and Prodhan [30], Dehghanapour et al. [31], Kumar et al. [32] reported the more importance of non-additive gene effects in the inheritance of this trait.

Kernels per row (KPR)

For number of kernels per row mean squares due to line GCA and tester GCA were highly significant *(p<0.01)* (Table 1). Significant GCA mean square were implied the importance of additive gene action in controlling the inheritance of KPR. In line with this study, Dagne [33], Gudeta [16] reported the importance of additive gene action for controlling (number of kernels per row) in maize. In addition, Mathur et al. [29] observed the predominance of additive genetic in the inheritance of this trait unlike Dehghanapour et al. [31] was reported the more importance of non-additive component effects for this trait.

Ear length and ear diameter (EL and ED)

Line GCA and tester GCA mean squares were highly significantly *(P < 0.01)* for ear diameter and ear length found (Table 1). In this finding the predominant role of additive gene effect in the inheritance of both EL and ED were observed. Similarly, Mandefro [34] reported no importance of non- additive gene action for ear length. As opposite to this result Dagne [33], Hadji [15], Gudeta [16] observed the importance of both additive and non-additive gene effects in the inheritance of ear diameter.

Plant height and ear height (PH and EH)

Combining ability analysis revealed highly significant *(p<0.01)* mean squares due to line GCA and tester GCA effects of lines for plant and ear height (Table 1) while, SCA mean squares were not significant for both traits. Plant height and ear height are important morphological traits affecting the final yield of maize crop. Extremely dwarf varieties have the problem of crowded canopy, aeration and transmission of sun light to the lower parts resulting in drastic reduction in yield while the high stature plants are highly susceptible to lodging. 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. In this study the result obtained indicated the predominance role of additive gene effect in controlling the inheritance of both PH and EH. In line with these findings, Leta et al. [25] found significant GCA effect and non-significant SCA effect for plant- and-ear height. On the other hand, Gudeta [16] reported significant GCA and non-significant SCA mean squares for plant height.

Plant aspect and ear aspect (PA and EA)

Mean squares due to line GCA and tester GCA were highly significant *(p<0.01)* for both plant and ear aspect (Table 1) while, SCA mean square was significant (*p<0.05)* for plant aspect only. In this study only the relevance of additive gene effect in controlling the inheritance of EA was observed. The role of additive and non additive gene action showed the presence of variation among lines and crosses. Nevertheless, Significant GCA and SCA mean squares implied the importance of additive and non additive gene action in controlling PA in maize. Based on the view of the farmers at Jimma, Dedo the farm wants maize hybrid having good physical appearance such as medium height, strong and thick stalk, upward leave branching, free and resistance to wards any pest and disease, variety having good husk cover, good kernel per ear and row and variety having two ear per plant.

Grain moisture at harvest (GM)

For grain moisture at harvest mean squares due to line GCA, tester GCA and SCA were highly significant *(p<0.01)* (Table 1). In this study the importance of both additive and non-additive gene action were found in controlling grain moisture at harvest. Therefore, the result obtained indicated the improvement of this trait through exploitation of both additive and non-additive gene action. In contrary to this study, Saad et al. [35] in his finding observed highly significant GCA mean squares for trait grain moisture while SCA mean square were not significant for grain moisture at harvest and reported the importance of both of additive and non additive gene action.

Number of plant per plot (NPP)

For trait number of plant per plot mean square due to tester GCA were highly significant (p<0.01) (Table 1) while, line GCA and SCA mean square were not significant. In the current finding the role of additive gene action in controlling the inheritance of NPP was indicated. In contrary to this finding Alemnesh [17] found no significant mean square due to tester GCA.

Days to maturity (DM)

For maturity date mean squares due to line GCA were significant at *(p<0.05)* and tester GCA were highly significant at *(p<0.01)* while, non significant SCA was observed (Table 1). In this study additive gene actions are important in governing this trait. Similarly, the predominant roles of additive gene effect in controlling maturity dates were reported by Dagne [33], Hadji [15] Absence of significant SCA mean squares at this location makes the current finding similar with the previous work of Mandefro [34], Jemal [13] in which non-significant SCA effect for days to maturity was reported. Also, Legesse et al. [27] reported highly significant (P < 0.01) line GCA mean squares for days to maturity.

Conclusion and Recommendation

The present study consisted of 34 entries(crosses) along with two popular standard check were evaluated at Jimma, Dedo Ethiopia during the 2013 cropping season with the objectives of evaluating top cross performance and estimating combining abilities for 17 characters. The analysis of variance showed highly significantly (p<0.01) differences for all the characters except for ASI, NPP and EPP. Further, significant differences were not recorded among the checks and checks vs crosses for most traits. Line GCA means squares were highly significant for the studied traits except ASI, NPP and EPP. Testers GCA mean squares were significant for most of studied traits except SD, ASI, EPP and TKWT. SCA mean squares were significant mainly for GY, RPE, GM and PA. Significant GCA mean squares for all traits indicated the predominant role of additive gene actions in determining the inheritance of these traits. Generally, GCA sum of squares component was greater than SCA sum of squares for all of the studied traits, suggesting that variations among crosses were mainly due to additive rather than non-additive gene effects; and hence, selection would be effective in improving grain yield and other agronomic traits.

Based on GCA analysis L5, L6, L16 and L17 were the top general combiners for grain yield and these inbred lines can be used for variety development in the future highland maize improvement program. Inbred lines L2, L5, and L17 were the best general combiners for days to anthesis and silking, respectively, indicating these lines had favorable allele frequency for earliness and could be used to develop early maturing varieties. Inbred lines L2, L3, L5, L10 and L11 and L6, L14, L15 and L17 were the best general combiners for number of rows per ear and number of kernel per row, respectively. These lines had favorable allele are to improve RPE and KPR to enhance grain yield. For ear diameter L5, L10, L16, and L17 were good general combiner, indicating these lines had the tendency to increase ear diameter. For ear length L8, L15, and L17 were good general combiner indicating these lines had the tendency to increase ear length. For thousand-kernel weight L4, L10, L12, L13 and L16 were the top general combiners as such line had the tendency to increase thousand kernel weights.

An inbred line L2, L5, L6, L8, L12, L13 and L14 were top general combiners for shorter plant height, which are desirable for lodging resistance. On the other hand, L11, L13, L16 and L17 were the top general combiners for increased plant height. An inbred line L2, L4, L7, L12 and L13 was top general combiners for enhancing shortness of ear height. On the other hand, L3, L16 and L17 were the top general combiners for increased ear height. Among the lines L1, L2, L4, L7, L11 and L13 were the best general combiner for plant aspect since these line indicated a tendency to improve this trait in future hybrids development program. An inbred line L1, L2, L3, L7 and L8 were top general combiners for enhancing better ear aspect since these line indicated a tendency to improve this trait in future hybrids development program. Among the lines L7, L10, L12 and L13 were the top general combiners for enhancing early maturity. Among the crosses L5 × T1 (8.36 t/ha) and L16 × T2 (7.89 t/ha) were showed higher grain yield (t/ha). These hybrids could be included in further investigation for grain yield and related traits and could be possible candidates of future release.

For plant height crosses L14 × T1 (158.13 cm), L6 × T2 (168.54 cm), L8 × T2 (169.25 cm) and L12 × T2 (171.25 cm) expressed short plant height and these crosses were the best specific combiner for shortness whereas crosses L4 × T1 (219.17 cm), L10 × T1 (225.00 cm), L16 × T1 (231.04 cm) and L14 × T1 (258.13 cm) expressed higher plant height indicated these crosses where the best specific combiner for tallness. Among crosses L5 × T1 (102.63 day), L2 × T2 (107.95 day), L14 × T1 (108.87 day) and L14 × T2 (102.63 day) displayed lowest an thesis date. These crosses were the best crosses for development of early matured hybrids. Among Crosses L5 × T1 (112.67 day), L2 × T2 (114.29 day), L14 × T1 (114.54 day) and L14 × T1 (114,79 day) displayed lowest silking date. These crosses were the best specific crosses for development of early matured hybrid. For number kernels per ear, only four crosses (L4 × T2, L6 × T2, L10 × T2 and L13 × T2) showed positive and significant ($p<0.05$) SCA effects in desired direction. This result indicates these crosses were good specific combiner for the improvement of this trait. For trait grain moisture crosses (L6 × T1 and L0 × T1) displayed negative and highly significant SCA effect ($p<0.01$) for this trait. For improvement of this trait, these crosses were appropriate specific crosses combiner. For plant aspect cross (L4 × T2) showed positive and significant SCA affect and this cross was the good specific combiner for this trait. For plant aspect cross (L4 × T2) expressed positive and highly significant *($p<0.05$)* SCA effect was displayed and this cross is the best specific combiner for this trait.

From these finding better performing testcrosses, inbred lines with desirable GCA effects for grain yield and other grain yield related traits were successfully identified. These germplasm constitute a source of valuable genetic material that could be used for future highland maize improvement program. Generally, the results of this study could be useful for researchers who need to develop high yielding variety of maize adapted to highland areas of Ethiopia.

However, the present study was conducted at one location and the result is only an indication and we cannot reach at definite conclusion. Therefore, it is advisable to continue with this study over many years and locations. Moreover, future studies should explore the possibility of separating the inbred lines used in this study in to distinct heterotic groups by using divergent tester.

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