International Journal of Research Studies in Science, Engineering and Technology
Volume 5, Issue 8, 2018, PP 14-26
ISSN : 2349-476X

Perse Performance and Heterosis of Quality Protein Maize (Zea mays L.) Inbred Lines Adapted to Mid-Altitude Sub-Humid Agro-Ecology of Ethiopia

***Dufera Tulu[1], Girum Azmach[2] and Bulti Tesso[3]**

[1]*EIAR- Ambo Agricultural Research Centre, P.O. Box 37, Ambo, Ethiopia*
[2]*EIAR- Bako National Research Centre, P.O. Box 2003, Addis Ababa, Ethiopia*
[3]*Department of Plant Sciences, Haramaya University, Haramaya, Ethiopia*

***Corresponding Author:** *Dufera Tulu, EIAR- Ambo Agricultural Research Centre, P.O. Box 37, Ambo, Ethiopia. Email:duferatulu@gmail.com*

ABSTRACT

Breeding efforts to convert elite mid-altitude conventional maize inbred lines to quality protein maize (QPM) have a recent history in Ethiopia. For a successful QPM hybrid variety development, generation of information on heterosis and per se performance of the new inbred lines is necessary.Thus, this study was conducted: to estimate the magnitudes of heterosis for grain yield and yield related traits in line x tester QPM hybrids andto evaluate the performances of the newly developed QPM inbred lines. The crossings and field experiment was conducted at Bako National Maize Research Center during the 2015 and 2016 main cropping season, respectively. Fifty test crosses obtained by crossing 25 inbred lines with two testers using line x tester mating design along with their parents and two standard checks were evaluated in two separate trials using alpha lattice design with three replications. Analysis of variance showed that mean squares due to genotypes and per se performances of parents were highly significant for most of the traits studied. The inbred lines L1, L3, L5, L14, L16, L18, L19 and L21 had higher grain yield than the mean and performed well for most of the studied traits. The highest mid- and better- parent heterosis for grain yield were obtained from L15 x T1 (169.4%) and L3 x T1 (85.67%) respectively. The results obtained in this study showed the promising potentials of the identified inbred lines for further breeding of QPM for the mid-altitude sub-humid agro-ecology of Ethiopia.

Keywords: *Better-parent, grain yield, mid-parent, Line x Tester, Test cross,*

INTRODUCTION

Maize has a significant importance in the diets of rural Ethiopia and has gradually penetrated into urban centers. This is particularly evidenced by green maize being sold at road sides throughout the country as a hunger-breaking food (Twumasi *et al.*, 2012). Now a days, maize mixed with tef is also widely used in towns for making injera. Despite its increased consumption, largely as a source of carbohydrates, maize, like all other cereals is known to be of poor protein quality. Protein malnutrition is therefore a problem, especially among children where maize and other cereal crops are the dominant staple foods. Lysine is the first limiting amino acid, followed by tryptophan and there onine in the diets of non-ruminants and humans (Shimada and Cline, 1974).Substituting normal maize with high lysine maize on an equal weight basis can maintain proper amino acid balance (Wilson, 1991).

Since maize is a primary crop in the majority of farming systems and staple food of the rural population in much of the mid-altitude sub-humid agro-ecologies of Ethiopia, substituting the conventional maize (CM) with quality protein maize (QPM) can substantially improve the protein status and greatly reduce the malnutrition problem of resource-poor farmers and low-income people that depend on maize as their staple food (Leta *et al.*, 2003). Cognizant of the benefit of QPM varieties, the National Maize Research Program of Ethiopia initiated systematic QPM research in the early 1990s, which lead to the identification and release of the first QPM hybrid, BHQP542 in 2002 (Legesse *et al.*, 2012) and Melkassa6Q in 2008 (Gezahegn *et al.*, 2012).

Heterosis is important in maize breeding and is dependent on level of dominance and differences in gene frequency. The manifestation of heterosis depends on genetic divergence of the two parental varieties

(Hallauer and Miranda, 1988). It is manifested as an increase in vigor, size, growth rate, yield or some other characteristics. But in some cases, the hybrid may be inferior to the weaker parent, which is also considered as heterosis. That means heterosis can be positive or negative. The interpretation of heterosis depends on the nature of trait under study and the way it is measured. Generally, heterosis is an important trait used by breeders to evaluate the performance of offspring in relation to their parents. It estimates the enhanced performance of hybrids compared to their parents. Often the superiority of F_1 is estimated over the average of the two parents, or the mid parent.

In Ethiopia, breeding efforts to convert elite mid-altitude CM inbred lines to QPM have a recent history. Many inbred lines have been developed at Bako National Maize Research Center (BNMRC), including the inbred lines used in this study, which were derived from backcrosses of elite QPM inbred lines and CM inbred lines. Like the procedures for non-QPM maize inbred lines development, the selected QPM inbred lines should be evaluated for their heterosis after the conversion. Hence, generation of information on heterosis and per se performance of the new QPM inbred lines is necessary for a successful QPM hybrid variety development. This will help breeders focus on those QPM inbred lines with better heterosis, which have the potential for developing high yielding and good performing new varieties for commercial use. Thus, this study wasconducted to estimate the magnitudes of heterosis for grain yield and yield related traits in line x tester QPM hybrids, andto evaluate the performance of newly developed QPM inbred lines.

MATERIALS AND METHODS

Descriptions of Experimental Site

The experiment was conducted at Bako National Maize Research Center (BNMRC) during 2016 main cropping season. The area is located in East Wollega Zone of the Oromia Regional State, Western Ethiopia. The center lies between 9^{0}6' North latitude and 37^{0}09' east longitude in the sub-humid agro-ecology,at average altitude of 1650 meters above sea level. The mean annual rainfall of the previous 56 years was 1239.4 mm and the mean annual rain fall during the season, 2016 was 1316.7mm (Bako Agricultural Research Center metrological data). The mean minimum, mean maximum and average air temperature is 13.3, 28.0, and 20.6^{0}C, respectively; and the relative humidity is 63.55%. The soil is reddish brown in color and clay loam in texture. According to USDA soil classification, the soil is *Alfisols* developed from basalt parent materials, and is deeply weathered and slightly acidic in reaction (Wakene 2001).

Experimental Materials

A total of 52 entries composed of 50 test crosses formed by crossing of 25 QPM inbred lines with two testers (referred to as tester A and tester B), and two standard checks (BHQPY545 and BH546) were used in this study. The testers and the inbred line parents were evaluated in adjacent plots for estimation of the magnitudes of mid- and better-parent heterosis for each test cross. The list and the pedigrees of the inbred lines used in the line x tester crosses and that of the testers are given in Table 1. The standard check BHQPY545 is medium maturing, yellow kernelled and relatively high yielding (8.0 to 9.5 t/ha) QPM hybrid, and the other check BH546 is also a medium maturing high yielding (8.5 to 11.5 t/ha) normal maize hybrid. Both checks were released by BNMRC for the mid-altitude sub-humid maize growing agro-ecologies of Ethiopia, which is the high potential maize production belt.

Table 1. *List of QPM inbred lines selected and used for cross formation and testers*

S/No	Lines Code	Pedigree	Origin (Source)
1	L1	(CML-142 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-12-1-2-1-1-1	BNMRC
2	L2	(CML-142 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-20-1-1-1-1-1	>>
3	L3	(CML-142 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-12-1-2-2-1-1	>>
4	L4	(CML-144 X SC-22(F2) x SC-22(F2) x SC-22)-B-44-2-1-2-1-1	>>
5	L5	(CML-142 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-12-1-1-2-1-1	>>
6	L6	(CML-144 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-25-1-1-1-1-2	>>
7	**L7**	(CML-142 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-40-1-1-1-1-1	>>
8	**L8**	(CML-142 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-15-1-2-2-1-1	>>
9	**L9**	(CML-144 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-32-1-1-2-1-3	>>
10	**L10**	(CML-142 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-12-1-3-3-1-1	>>

11	**L11**	(CML-144 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-25-1-1-1-1-1	>>
12	**L12**	(CML-142 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-12-1-3-2-1-1	>>
13	**L13**	(CML-142 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-12-1-3-1-2-1	>>
14	**L14**	(CML-142 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-20-1-1-3-1-1	>>
15	**L15**	(CML-142 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-15-1-1-1-1-1	>>
16	**L16**	BK02-Z-311-28(F2)-B-1 X CML-144(F2)-15-2-3-1-1	>>
17	**L17**	BK02-Z-311-28(F2)-B-1 X CML-144(F2)-15-1-1-1-1	>>

Table 1. *continued.*

S/No	Lines Code	Pedigree	Origin (Source)
18	**L18**	BK02-Z-311-28(F2)-B-1 X CML-144(F2)-48-1-1-1-1	BNMRC
19	**L19**	BK02-Z-311-28(F2)-B-1 X CML-144(F2)-15-2-1-2-1	>>
20	**L20**	BK02-Z-311-28(F2)-B-1 X CML-144(F2)-15-2-3-2-1	>>
21	**L21**	(CML-144 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-32-1-1-2-1-1	>>
22	**L22**	(CML-142 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-15-1-2-1-1-1	>>
23	**L23**	(CML-142 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-15-1-1-2-1-1	>>
24	**L24**	(CML-142 X 144-7-b(F2) x 144-7-b(F2) x 144-7-b)-B-15-1-2-3-1-1	>>
25	**L25**	(CML-144 X SC-22(F2) x SC-22(F2) x SC-22)-B-44-2-1-1-1-1	>>
26	**T1**	CML144/CZLQ5	CIMMYT
27	**T2**	CZLQ2/CML511	>>

Experimental Design and Field Management

The experimental design was alpha lattice design (Patterson and Williams 1976). Each entry was planted in two rows of 5.1 m long each with spacing of 0.75 m between rows and 0.30 m between plants within a row. The hybrids (progenies) and the parents were planted adjacent to each other in the same field.The experimental materials were hand planted with two seeds per hill, which were later thinned to one plant to get a population density equivalent to 44, 444 plants per hectare.

Planting was conducted at the onset of the main rainy season after an adequate soil moisture level was reached to ensure good germination and seedling development. Other agronomic practices were carried out as per the recommendation for the area.

Data Collection

Data on grain yield and other important agronomic traits were collected on a plot and sampled plants/ears bases.

Data collected on a plot basis include:days to anthesis, days to silking,1000 kernel weight (g), field weight (kg/plot), ears per plant, total above ground biomass (t/ha) and harvest index while, Data collected on sampled plants/ears basis include: ear height (cm), plant height (cm), ear length (cm), ear diameter (cm),number of rows per ear and number of kernels per row. Yield in t/ha was calculated using CIMMYT field book software (Banziger and Vivek 2007).

Data Analysis

Analysis of variance (ANOVA) for all data of both the test crosses and parental trials were done using the PROC GLM procedure in SAS® computer program (SAS Institute 2004). Entry was used as a fixed factor while replication and incomplete blocks within replication were considered as random factors. Significant differences were further subjected to Duncan's new multiple range test (DMRT) for parental *per se* performance and Least Significant Difference (LSD) for hybrids trial mean separation.

Estimation of Heterosis

Better parent heterosis (BPH) and mid parent heterosis (MPH) in percent were calculated for those traits that showed statistically significant differences among genotypes as suggested by Falconer and Mackay (1996). These were computed as percentage increase or decrease of the cross performances over the mid parent, best parent and best standard check as follows.

$$\text{MPH (\%)} = \frac{(F1-MP)}{MP} * 100$$

$$\text{BPH (\%)} = \frac{(F1-BP)}{BP} * 100$$
Where,

F1 = Mean value of a cross

MP = Mean value of the two parents

BP = Mean value of the better parent

Test of significance for heterosis was made using the t-test. The standard errors of the difference for heterosis were calculated as follows:

SE(d) for BPH= $\pm\sqrt{2MSE/r}$

SE of mid parent heterosis = $\pm\sqrt{3MSE/2r}$

Where, *SE (d)* is standard error of the difference, MSeis error mean square and r is number of replications and calculated t value was compared against the tabulated t-value at degree of freedom for error.

t (Better Parent) = F1- BP /SE(d), t (Mid Parent) = F1-MP /SE(d) and t (standard check) = F1 – SV/SE(d)

Results And Discussion

The data collected were analyzed and significance tests were performed for each trait at 5% and 1% probability levels. The results are presented and discussed below.

Analysis of Variance

The analysis of variance showed highly significant differences among the genotypes for most of the traits, except for number of kernels per row (Table 2). In addition, mean squares due to parents were highly significant and significant for all traits studied, except for number of rows per ear, ear diameter and harvest index (Table 2).Significant differences were observed among the genotypes for most of the traits studied, indicating the presence of genetic variation among the materials for further improvement of the traits. In agreement with this finding, significant mean square due to genotypes for grain yield and yield related traits in maize were also reported by previous investigators (Gowada 2013; Tajwar et al.2013; Demissew 2014; Kumar et al. 2014; Amare et al. 2016).

Parents Perse performance and Mean Performance of hybrids

The perse performances of the parents (25 inbred lines and two testers) are given in Tables 3 and 4 respectively. Among the inbred lines, L19 had the highest yield (4.7 t/ha), followed by L25 (3.97t/ha) and L14 (3.8t/ha). On the other hand, L12 and L15 had the lowest grain yields of 1.15 and 1.51 t/ha, respectively. The mean grain yield for tester 1 (T1) was 6.77 t/ha and for tester 2 (T2) was 6.87t/ha. Days to anthesis (DA) ranged from 81.00 to 98.07 with over all mean of 92.02 days, this indicates almost all of the inbreed lines used in this study are late maturing and can be used to develop higher yielding varieties for the areas receiving long rainy season.

Plant height ranged from 136 (L20) to 205.7cm (L5) with mean values of 176.05cm. Some high yielding inbred lines had shorter PH, for instance: L19 (157.3cm) and L16 (174.7cm) were among high yielding inbred lines with shorter plant stature. This implies that these inbred lines could be used for developing high yielding varieties which may be resistant to lodging. Number of ears per plant ranged from 0.63(L24) to 1.82(T2), with an overall mean of 1.16. Only L14, L19 and both testers had number of ears per plant greater than 1.5,indicating the prolificacy of these inbred lines. The mean ear length (EL) for inbred lines and testers was 15.35cm. The highest and lowest EL values were 19.25 and 10cm, which were observed in L2 and L12 respectively. The mean ear diameter (ED) ranged from 2.97 (L2) to 4.74cm (T1) with over all mean of 3.81cm. Most of the inbred lines and testers with wider ED had high grain yield per hectare, indicating the direct contribution of this trait to grain yield.

The mean perse performance of the inbreed lines for number of kernels per row (KPR) is 25.19. The highest KPR was recorded for L15 (34.5 kernels) and the lowest for the line L12 (17.07 kernels). Ten inbred lines had KPR greater than the overall mean, while the testers T1 and T2 had 32.76 and32.13 kernels per row, respectively. The mean thousand kernel weight (TKW) of the inbreed linesis276.6 g. The inbred line L11 had the highest TKW (372 g),while the highest yielder L19 (210.7 g)scored the lowest TKW. Regarding above ground total biomass (TGB), the mean values for inbred lines ranged from 4.78 to 17.88 t/ha. Out of the 25inbreed lines, the high yielding lines L19, L25 and L14 had scored 10.65, 13.63 and 11.33 t/ha, respectively which is greater than the overall mean.

Table2. *Analysis of variance for grain yield and other agronomic traits of line by tester crosses involving 25 lines and 2 testers evaluated at Bako in 2016 cropping season.*

Traits	Hybrids					Parents				
	Rep=2	BLk=36	Entry=51	Error=66	CV (%)	Rep=2	BLk=24	Entry=26	Error=28	CV (%)
GY	33.48**	1.33	7.61**	0.86	10.91	1.84	1.29	3.63**	0.79	29.11

DA	26.33**	1.83*	5.79**	1.06	1.25	25.23**	4.22	26.55**	3.22	1.95
DS	30.47**	2.01	5.58**	1.34	1.41	37.64**	5.91	29.05**	4.38	2.26
PH	4757.35**	224.02**	411.79**	72.49	2.98	3301.38**	259.2	586.34**	214.42	8.32
EH	2239.62**	144.64**	188.43**	56.79	4.74	1564.98**	202.24**	332.4**	77.75	10.87
RPE	0.03	0.94	0.98*	0.62	5.67	1.83	0.99	1.26	1.21	9.09
KPR	98.09**	7.91	7.72	6.03	6.43	395.47**	34.04	59.83**	18.4	17.03
EL	43.39**	2.41**	3.74**	1.09	5.53	1.36	4.32	12.42**	2.89	11.07
ED	0.27**	0.03	0.05**	0.02	3.29	0.04	0.17	0.32	0.17	10.85
TKW	5397.3**	1159.2	2532.6**	906.3	8.66	2548	1344.6	3600.4**	1027.13	11.59
EPP	0.52**	0.03**	0.06**	0.01	8.22	0.58*	0.07	0.27*	0.12	29.52
TAGB	246.52**	9.74**	15.4**	4.7	9.24	44.86**	9.57	22.09**	7.12	28.52
HI	3.68	6.77	66.83**	7.39	7.52	120.52	76.23	87.88	53.38	22.56

**=0.05 and **= 0.01 significant probability level respectively.*

GY=Grain yield, DA = Days to anthesis, DS = Days to silking, ASI = Anthesis silking interval, DM = Days to maturity, EH = Ear height, PH = Plant height, PA=Plant aspect, EA=Ear aspect, ER=Ear rot, HC=Husk cover, EPP = Number of ears per plant, EL = Ear length, ED = Ear diameter, RPE = Number of rows per ear, KPR = Number of kernels per row, TKW=1000 kernel weight, DF = degrees of freedom.

The mean grain yields (GY) of the hybrids including checks ranged from 5.36 t/ha to 12.57 t/ha with overall mean of 8.52 t/ha. A total of four crosses out yielded the best check (BH546). The L3 x T1, which was the highest yielding cross (12.57 t/ha) out yielded the high yielding check, BH546 (10.46 t/ha) by 20.17%. On the other hand, the lowest yielding cross was L18 x T1 (5.36t/ha) followed by L19 x T1 (5.46t/ha), L20 x T1 (5.49t/ha), L25 x T2 (5.7t/ha), L17 x T1 (5.83t/ha) and L2 x T2 (5.99t/ha)(Table 4). The presence of crosses having mean values better than the standard checks indicate the possibility of obtaining good hybrid (s) for future use in breeding program or for direct release.

Days to anthesis and silkin granged from 79.33 to 85.33 and 79.33 to 85.33 with overall means of 82.18 and 82.31 days, respectively. The shortest number of days to anthesis and silking were recorded for crosses L22 x T2 (79.33) and L22 x T2 (79.33), respectively; whereas the longest number of days to anthesis and silking were recorded for crossesL5 x T1 (85.33days) and L18 x T1 (85.3 days), respectively. Most of the crosses showed longest number of days to anthesis and silking. This shows that those crosses could be grouped as late maturing types. Late maturing crosses are important in the breeding programs for development of high yielding hybrids in areas that receive sufficient rain fall (Girma et al.2015).Further evaluation and recommendation of this group of materials should be based on agro-ecological suitability. For days to anthesis and silking, except L20 x T2 and L22 x T2, all hybrids were late as compared to the check hybrid in the medium maturity range BH546 (79.33 and 82 days to anthesis and silking, respectively).

Plant and ear height ranged from 251 to 312.7cm and 131 to 180cm with mean values of 285.71cm and 159.05cm, respectively. The lowest mean values for both plant and ear heights were observed for the cross L20 x T1, while the highest mean values were measured from the crosses L3 x T1 for plant height and L15 x T2 for ear height. Six crosses were significantly taller than the check BH546.Of these crosses, three of them (L1 x T1, L3 x T1 and L15 x T1) gave higher grain yield than the best check BH546 (289.7cm). In line with this finding, Girma et al. (2015) reported higher GY from taller plants and the authors also suggested that this could be attributed to high photosynthetic products accumulation during long period for grain filling. Maize cultivars with too high ear placement are prone to lodging, while those with too short ear placement are prone to wild animals' attack.

Number of ears per plant ranged from 1.17(L21 xT2) to 1.95(BHQPY545), with an overall mean of 1.49. Forty two percent of the crosses had greater than 1.5ears per plant indicating the prolificacy of the crosses. About eight crosses exhibited significantly higher number of ears per plant than the best check, BH546. The mean ear length (EL) for genotypes was 18.9cm, with the highest and lowest values being 21.2 and 15.9cm, which were exhibited by crosses L24 x T1 and L19 x T2, respectively. The highest yielding cross (L3 x T1) produced 19.6cm long ears.

The mean ear diameter (ED) ranged from 4.34 to 5.05cm with over all mean of 4.76cm (Table 4). The check BHQPY545 had the narrowest (4.34cm) ear diameter as compared to other hybrids. Crosses L3 x T1 (5.05cm), L12x T1

(5.04cm) and L13 x T2 (5.02cm) had wider ED. Among these crosses, L3 x T1 was one of the crosses from which the highest mean grain yield was observed, indicating the direct contribution of this trait to the grain yield. Forty two crosses showed wider ED than BHQPY545, while only three crosses showed wider ED than the best check BH546. Mean thousand kernel weight ranged from 249.3g (BHQPY545) to 409.7g (L3xT2). Thirty two crosses showed TKW greater than the best check BH546. The number of rows per ear (RPE) ranged from 12 to 14.67 with an overall mean of 13.86. The highest RPE of 14.67 was recorded for eight crosses and both checks, while the lowest RPE of 12.00 was recorded for the cross L22 x T1 and all high yielding crosses recorded 14 for this trait.

Total above ground biomass (TAGB) of individual crosses ranged from 16.25 (L20 x T1) to 28.99 (L11 x T1) t/ha with an overall mean of 23.43 t/ha. The mean harvest index (HI) ranged from 28.08% (L25 x T2) to 48.16% (BH546) with an overall mean of 36.13%. In this study the high yielding crosses scored high TAGB as well as HI; for instance, L1 x T1, L3 x T1, L9 x T2 and L13 x T1 scored 26.03, 26.64, 25.98 and 26.15 t/ha for TAGB, and 45.64, 47.29, 45.26, and 46.24 % for HI, respectively. This indicates that improvement of these two traits could contribute to grain yield improvement, as also reported by Worku and Zelleke (2007)in a previous study.

Table 3. *Mean values of yield and agronomic traits of 25 inbred lines and two testers of maize genotypes evaluated at Bako in 2016 main cropping season*

Entries	GY (t/ha)	DA (days)	DS (days)	PH (cm)	EH (cm)	TAGB (t/hac)	HI (%)	EPP (#)	KPR (#)	EL (cm)	ED (cm)	TKW (g)
L1	3.38	95.67	96.00	200.00	99.33	9.18	36.96	1.00	19.50	14.87	3.90	302.70
L2	2.70	91.67	93.00	163.30	70.33	7.77	34.73	1.00	34.00	19.25	2.97	254.00
L3	3.17	95.00	95.67	203.00	97.33	7.92	41.53	0.97	25.57	16.17	4.15	300.00
L4	1.73	95.67	96.67	168.70	74.33	5.64	32.43	1.14	18.29	12.04	3.55	240.00
L5	3.25	95.67	95.67	205.70	93.00	10.51	31.04	1.05	28.22	16.72	4.54	304.00
L6	2.20	90.67	89.67	156.70	66.33	9.62	22.88	1.62	23.13	13.33	4.12	221.30
L7	2.73	91.33	91.00	149.30	66.67	8.37	32.42	1.12	22.17	14.86	3.41	301.70
L8	2.56	92.67	96.33	169.70	77.67	7.45	34.25	0.89	29.17	17.78	3.60	250.70
L9	2.72	94.00	94.33	178.30	87.00	9.9	26.46	1.02	20.82	17.4	3.73	277.30
L10	1.81	96.00	96.33	180.00	80.00	7.12	26.09	0.78	23.57	14.55	4.21	302.30
L11	1.94	94.33	96.00	160.30	92.67	9.23	21.72	0.73	25.50	16.69	3.92	372.00
L12	1.15	98.67	99.33	156.70	68.33	4.78	22.38	0.91	17.67	10.00	4.03	237.30
L13	2.58	92.00	92.00	177.30	81.00	7.15	35.49	1.22	20.90	14.15	3.81	2470
L14	3.8	91.33	91.00	191.30	95.00	11.33	33.91	1.64	27.38	15.99	3.25	237.00
L15	1.51	94.00	95.00	178.00	91.00	8.24	18.29	0.65	34.50	17.63	3.43	298.30
L16	3.88	89.00	88.67	174.70	70.67	9.17	40.7	1.44	24.98	14.23	3.96	244.30
L17	2.91	89.00	89.67	176.00	71.00	7.75	37.86	1.22	23.70	11.31	3.82	225.70
L18	3.69	93.00	93.33	184.70	80.67	10.27	35.34	1.35	25.19	15.01	3.60	252.00
L19	4.70	86.67	88.00	157.30	72.00	10.65	43.28	1.53	27.36	15.17	3.89	210.70
L20	2.19	89.00	89.67	136.00	44.00	6.84	34.67	1.21	25.83	12.78	3.64	267.00
L21	3.27	92.00	94.00	171	83.00	10.75	30.34	1.00	22.36	16.06	3.72	307.00
L22	1.83	93.67	94.00	166.30	80.67	6.91	26.5	1.32	27.61	16.50	3.48	317.70
L23	2.38	93.67	94.33	176.00	84.33	7.91	28.87	0.96	26.07	16.88	3.55	283.70
L24	2.57	91.00	93.00	191.00	89.67	8.88	26.77	0.63	23.30	17.87	3.72	262.30
L25	3.97	93.33	91.33	189.30	78.00	13.63	42.77	1.20	18.58	13.44	4.13	311.00
T1	6.77	81.00	81.67	197.00	94.33	17.88	38.51	1.79	32.76	18.17	4.74	332.70
T2	6.87	84.67	85.00	195.70	101.30	17.47	38.63	1.82	32.13	15.70	4.03	308.30
Mean	3.05	92.02	92.62	176.05	81.10	9.35	38.4	1.16	25.19	15.35	3.81	276.6
CV (%)	29.11	1.95	2.26	8.32	10.87	28.52	22.56	29.52	17.03	11.07	10.85	11.59
F-test	**	**	**	**	**	**	ns	*	**	**	ns	**

**=0.05 and **= 0.01 significant probability level. GY = Grain yield per hectare, DA = Days to anthesis, DS = Days to silking, EH = Ear height, PH= Plant height, KPR=Number of kernel per row, EL=Ear length, ED=Ear diameter, TKW=Thousand kernel weight, EPP=Ear per plant, TAGB = Total Above Ground Biomass, HI = Harvest Index and CV = Co-efficient of variation.*

Table 4. *Mean values of yield and agronomic traits of 50 test cross hybrids and two standard checks of maize genotypes evaluated at Bako in 2016 main cropping season*

Entries	GY (t/ha)	DA (days)	DS (days)	TAGB (t/ha)	HI (%)	PH (cm)	EH (cm)	RPE (#)	ER (%)	EL (cm)	TKW (g)	EPP (#)	ED (cm)
L1xT1	11.87	84.00	84.33	26.03	45.64	310.0	164.7	14.00	1.33	18.87	375.0	1.46	4.85
L1xT2	10.05	84.33	84.33	24.35	41.58	286.7	155.7	14.00	1.33	18.47	356.0	1.56	4.96
L2xT1	8.01	82.33	82.67	23.56	34.74	274.3	152.3	13.33	0.77	19.97	386.0	1.27	4.69
L2xT2	5.99	80.00	80.00	19.82	30.2	278.7	165.0	14.67	3.10	19.77	333.7	1.29	4.71
L3xT1	12.57	84.33	84.33	26.64	47.29	312.7	177.0	14.00	3.03	19.6	400.7	1.59	5.05
L3xT2	10.79	81.67	82.33	24.5	43.9	276.0	146.0	13.33	4.77	19.73	409.7	1.61	4.98
L4xT1	8.37	84.67	85.00	23.77	34.79	288.0	160.7	14.67	0.60	17.70	362.0	1.51	4.76
L4xT2	6.80	82.33	83.00	23.48	28.91	294.7	161.0	14.67	2.00	19.00	363.0	1.38	4.82
L5xT1	8.02	82.33	82.33	24.45	32.72	292.7	154.0	14.00	0.00	18.77	355.3	1.46	4.74
L5xT2	7.46	85.33	84.33	22.6	33.02	283.3	152.3	14.00	3.97	20.43	363.7	1.52	4.88
L6xT1	8.91	82.33	84.67	24.34	36.58	295.7	170.3	13.33	0.8	21.10	377.7	1.34	4.71
L6xT2	7.39	81.67	82.67	23.63	31.02	291.3	175.3	14.00	0.67	20.17	335.0	1.26	4.73
L7xT1	7.20	85.33	82.67	21.97	32.5	281.0	159.3	13.33	0.7	20.07	356.3	1.43	4.61
L7xT2	9.66	80.33	80.67	24.89	39.18	288.0	163.7	13.33	2.00	18.53	352.3	1.53	4.83
L8xT1	10.06	81.00	80.67	27.44	36.49	300.3	168.7	14.67	1.13	20.33	368.0	1.49	4.87
L8xT2	7.47	80.00	80.00	22.88	32.81	289.0	160.0	14.00	4.2	19.73	330.3	1.23	4.88
L9xT1	9.99	83.00	83.00	25.08	39.82	285.7	171.3	14.00	0.00	19.30	345.3	1.45	4.53
L9xT2	11.75	82.33	82.33	25.98	45.26	272.3	149.0	14.67	0.87	19.07	331.7	1.47	4.56
L10xT1	9.50	84.00	84.00	25.81	36.76	301.3	158.7	14.00	1.4	18.83	376.0	1.74	4.96
L10xT2	8.17	81.67	80.67	23.93	33.99	289.7	152.7	14.67	2.4	17.53	347.0	1.53	4.98
L11xT1	10.42	82.33	82.67	28.99	36	297.3	167.7	14.00	3.37	19.37	348.0	1.55	4.77
L11xT2	7.49	81.67	82.00	23.12	32.42	286.0	167.7	14.00	3.17	19.67	344.0	1.43	4.78
L12xT1	7.88	83.33	83.67	22.45	34.84	293.7	160.0	14.00	0.83	18.57	377.3	1.44	5.04
L12xT2	9.17	81.33	81.67	25.38	36.09	286.3	165.3	13.33	3.47	19.23	353.3	1.42	4.88
L13xT1	12.09	81.00	81.00	26.15	46.24	288.3	163.0	13.33	2.23	18.83	365.0	1.74	4.71
L13xT2	10.20	80.00	81.00	24.23	42.24	295	164.3	14.00	4.30	18.77	382.0	1.62	5.02
L14xT1	7.16	83.33	83.33	21.93	32.57	282.3	163.0	12.67	0.77	20.3	361.0	1.43	4.67
L14xT2	6.75	81.67	81.67	21.69	31.07	282.7	173.3	13.33	0.00	18.4	353.3	1.41	4.70
L15xT1	11.15	82.33	82.67	26.89	41.54	311.0	170.0	14.00	5.40	20.1	358.0	1.47	4.79
L15xT2	9.46	80.67	81.00	26.11	36.24	306.7	180.3	14.00	1.90	20.33	354.7	1.41	4.85

**=0.05 and **= 0.01 significant probability level.*

Table 4. *Continued.*

Entries	GY (t/ha)	DA (days)	DS (days)	TAGB (t/ha)	HI (%)	PH (cm)	EH (cm)	RPE (#)	ER (%)	EL (cm)	TKW (g)	EPP (#)	ED (cm)
L16xT1	6.89	83.00	82.67	19.95	34.35	263.7	150.0	13.33	1.57	18.53	323.7	1.70	4.52
L16xT2	8.56	82.33	81.67	21.58	39.65	262.7	147.7	14.00	0.00	17.30	394.3	1.86	4.80
L17xT1	5.83	83.67	83.67	19.5	29.8	261.3	145.0	13.33	3.03	16.63	271.3	1.67	4.45
L17xT2	7.68	81.33	80.67	21.04	36.78	269.0	150	14.00	0.53	16.03	280.3	1.77	4.63
L18xT1	5.36	85.00	85.33	18.69	28.67	267.7	147.7	14.00	2.03	17.23	321.0	1.52	4.69
L18xT2	8.05	81.00	80.33	23.51	34.31	284.0	154.0	14.00	1.90	17.83	372.7	1.57	4.94
L19xT1	5.46	83.33	83.00	17.68	30.31	261.3	131.3	13.33	2.00	17.78	282.7	1.54	4.59
L19xT2	7.77	82.33	80.67	21.99	35.15	255.7	135.7	14.00	0.00	15.90	259.3	1.82	4.55
L20xT1	5.49	83.67	83.33	16.25	33.72	251.0	131.0	14.00	0.67	17.57	319.7	1.55	4.57
L20xT2	9.26	79.67	79.33	23.31	39.69	272.7	151.3	14.00	2.30	17.07	336.0	1.80	4.75
L21xT1	8.82	84.00	84.00	25.31	34.8	287.7	169.3	14.67	0.00	19.60	352.7	1.45	4.58
L21xT2	6.30	83.33	84.00	21.09	29.75	272.0	154.0	13.33	2.73	19.30	336.3	1.17	4.77
L22xT1	7.51	82.00	82.00	23.13	31.98	304.7	176.3	12.00	0.80	19.80	374.0	1.31	4.83

L22xT2	9.66	79.33	79.33	24.47	39.42	299.7	168.3	14.00	1.73	19.23	352.7	1.19	4.88
L23xT1	9.73	82.67	82.67	26.68	36.4	305.7	169.3	12.67	1.83	19.92	371.0	1.43	4.61
L23xT2	7.50	80.00	81.33	24.72	30.3	290.7	165.7	12.67	4.27	20.07	347.7	1.33	4.68
L24xT1	8.73	81.67	82.00	26.31	33.16	302.7	164.3	14.00	1.50	21.20	384.0	1.28	4.90
L24xT2	9.20	80.67	80.67	24.87	37.05	292.7	164.3	14.00	4.2	19.87	344.7	1.30	4.85
L25xT1	7.34	83.00	83.00	21.48	34.34	286.7	155.7	14.67	0.77	18.80	358.0	1.35	4.85
L25xT2	5.70	81.33	81.00	21.8	28.08	289.7	155.7	14.00	1.37	17.30	326.3	1.37	4.65
BH546	10.46	79.33	82.00	21.7	48.16	289.7	151.0	14.67	0.73	18.53	298.7	1.44	4.73
BHQPY545	9.97	80.33	81.00	21.43	46.52	265.3	143.3	14.67	14.6	16.33	249.3	1.95	4.34
Mean	8.52	82.18	82.31	23.43	36.13	285.71	159.1	13.86	2.10	18.90	347.6	1.49	4.76
CV (%)	10.91	1.25	1.41	9.24	7.52	2.98	4.74	5.67	47.8	5.53	8.70	8.22	3.29
LSD($_{0.05)}$	1.52	1.68	1.89	3.53	4.43	13.88	12.29	1.28	3.90	1.70	49.08	0.20	0.26
F-test	**	**	**	**	**	**	**	*	**	**	**	**	**

*=0.05 and **= 0.01 significant probability level. GY= Grain yield per hectare, DA= Days to anthesis, DS= Days to silking,TAGB=Total Above Ground Biomass, HI=Harvest Index,EH= Ear height, PH= Plant height,RPE=Number of rows per ear, TKW=Thousand kernel weight, EPP=Ear per plant, EL=Ear length, ED=Ear Diameter, LSD = Least significant difference,CV = Co-efficient of variation.

Mid and Better-parent Heterosis

The estimates of mid parent heterosis (MPH) and best parent heterosis (BPH) were computed for grain yield and yield related traits that showed significant variations (Table 5). For GY, MPH and BPH ranged from -4.85 to 169.4% and -20.83 to 85.67%, respectively. The highest significant positive heterosis over the mid parent for GY was estimated for L15 x T1 (169.4%), followed by L13x T1 (158.68%), L3 x T1 (152.92) and L9 x T2 (145.05).The highest significant positive heterosis over the best parent for GY was estimated for L3 x T1 (85.67%), followed by L13 x T1 (78.63%) and L1 x T1 (75.28%).

In general, 40 crosses had positive and highly significant heterosis over the mid parent and 19 crosses displayed positive and highly significant heterosis over the better parent. Crosses L1 x T1, L1 x T2, L3 x T1, L3 x T2, L7 x T2, L8 x T1, L9 x T1, L9 x T2, L10 x T1, L11 x T1, L12 x T2, L13 x T1, L15 x T1, L15 x T2, L20 x T2, L20 x T2, L22 x T2 and L24 x T2 showed positive and highly significant heterosis over both the mid parent and the best parent for GY. Several authors have also reported similar results (Malik et al. 2004;Ram et al. 2015). However, low MPH and BPH for GY were also reported (Amanullah et al. 2011; Ali et al. 2014). Especially, Ali et al.(2014) observed lower magnitude of heterosis (-51.36%) and (-52.94%) over the mid parent and the better parent, respectively. The difference in heterosis in various reports involving different inbred parents, however is mainly attributed to the stage of inbreeding of the materials used, the environmental conditions in which they were exposed and the performance of the parental inbred lines.

The MPH ranged from -11.28 to -0.6% and -11.76 to -1.17% for DA and DS, respectively, while the BPH ranged from -6.31 to 5.35% for DA and -6.67 to 4.48% for DS. The lowest negative MPH values for DA and DS were observed in L12 x T2 (-11.28%) and L8 x T2 (-11.76%), respectively. Similarly, the lowest values of BPH were observed in L22 x T2 (-6.31%) for DA, and L22 x T2 (-6.67%) for DS. The negative heterosis for these traits indicates earliness of the crosses as compared to the mean performances of the parents, thus the hybrids take less number of days to flower than their respective parents. This finding is in conformity with that of Dagne et al. (2013).

The MPH and BPH for PH ranged from 38.45% (L3 x T2) to 67.74% (L22 x T1) and 41.03% (L3 x T2) to 100.51% (L20 x T2), respectively. Similarly, the MPH and BPH for EH ranged from 47.01% (L3 x T2) to 111.63% (L6 x T1) and 50.01% (L3 x T2) to 243.18% (L20 x T2), respectively (Table 5). Berhanu (2009)reported positive MPH for PH and EH in all crosses he studied and suggested that, the positive and significant heterosis observed for PH is an evidence for the increase of plant vigor up on crossing. In addition, this result is in agreement with Bayisa et al. (2005) and Dagne et al. (2007). However, the present result disagrees with the findings of Amanullah et al.(2011) who reported non-significant and negative heterosis and hetero beltosis for both PH and EH in most of the crosses studied.

For the number of rows per ear (RPE), MPH ranged from -5.25% to 18.9% and BPH ranged from -9.98% to 10.05%. All crosses showed non-significant heterosis over the better parent, whereas 17 crosses depicted positive and significant heterosis over mid parent for this trait (RPE). In agreement with the present finding, Dagne et al.(2007) reported MPH values ranging from -6.38% to 15.83%, and BPH values ranging from -13.07% to 10.05% for this trait. On the contrary,Ali et al.(2014) reported negative and highly significant BPH and MPH for RPE for almost all of the crosses he studied.

MPH value for ear length (EL) ranged from 3.01% (L19 x T2) to 49.65% (L12 x T2) and BPH for the same trait ranged from -8.48% (L17 x T1) to 28.47% (L6 x T2). Out of the 50 crosses, 45 and 26 crosses showed significant and positive MPH and BPH, respectively for this trait. Crosses that manifested highly significant and positive heterosis for this trait could be used for improvement of this trait in the future quality protein maize breeding program. In line with the present finding, several authors reported significant and positive MPH and BPH for EL (Dagne et al. 2007; Habtamu, 2015).Habtamu (2015) reported that almost all crosses included in his study manifested positive and significant mid and better parent heterosis for this trait (EL). In contrast to the current finding, Ali et al.(2014) observed significant and negative MPH and BPH for EL in his study of heterosis for grain yield and its attributing components in maize using line x tester analysis method. This difference may be attributed to the stages of the inbred lines used and the difference in environmental condition where the experiments were conducted.

MPH and BPH for thousand kernel weight (TKW) ranged from -2.81% (L17 x T1) to 42.7% (L16 x T2) and -18.44% (L17 xT1) to 32.87% (L3 x T2), respectively. Out of the 50 crosses, 30 crosses had significant and positive MPH and only eight crosses had significant and positive BPH for this trait. The present study is in agreement with the findings of Amanullah et al.(2011) who observed positive and negative MPH and BPH for TKW the crosses evaluated in his study.

Regarding the number of ears per plant (EPP), MPH ranged from -26.74% (L6 x T2) to 35.41% (L10 x T1), where as the BPH ranged from -35.71% (L21 x T2) to 2.2% (L16 x T2). Out of the 50 crosses evaluated, seven and 39 crosses revealed significant and negative MPH and BPH for this trait respectively (Table 9). Nine crosses showed significant and positive heterosis over mid parent, indicating the prolificacy of these crosses as compared to the parental lines. In agreement with the present finding, Malik et al.(2004) reported negative MPH and BPH for most of the crosses he studied for this trait. Negative heterosis for number of ears per plant indicates that the parents bear more number of ears than their progenies.

Table 5. *Mid and better parent heterosis for grain yield and yield related traits of hybrids evaluated at Bako in the 2016 main season.*

Crosses	GY		DA		DS		PH		EH		TAGB		HI	
	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
L1xT1	133.83**	75.28**	-4.91**	3.70**	-5.07**	3.26*	56.17**	57.36**	70.4**	74.92**	92.39**	45.58**	20.95**	18.51**
L1xT2	96.03**	46.24**	-6.48**	-0.40	-6.82**	-0.79	44.91**	46.50**	55.51**	57.05**	82.74**	39.38**	10.01	7.64
L2xT1	69.10**	18.27	-4.64**	1.64	-5.34**	1.22	52.26**	67.97**	84.62**	116.12**	83.7**	31.77**	-5.13	-9.79
L2xT2	25.11	-12.86	-9.27**	-5.52**	-10.11**	-5.88**	55.26**	70.67**	92.27**	134.61**	57.05**	13.45	-17.67**	-21.82**
L3xT1	152.92**	85.67**	-4.17**	4.11**	-4.89**	3.26*	56.35**	58.73**	84.7**	87.64**	106.51**	48.99**	18.17**	13.87*
L3xT2	114.94**	57.06**	-9.09**	-3.54**	-8.86**	-3.14**	38.45**	41.03**	47.01**	50.01**	92.99**	40.24**	9.53*	5.71
L4xT1	97.02**	23.68	-4.15**	4.53**	-4.68**	4.08**	57.51**	70.72**	90.92**	116.6**	102.13**	32.94**	-1.92	-9.66
L4xT2	58.14**	-1.02	-8.69**	-2.76*	-8.63**	-2.35	61.75**	74.69**	83.34**	116.6**	103.2**	34.4**	-18.63**	-25.16**
L5xT1	60.08**	18.46	-6.8**	1.64	-7.10**	0.81	45.37**	48.58**	64.42**	65.59**	72.24**	36.74**	-5.91	-15.04*
L5xT2	47.5**	8.64	-5.37**	0.78	-6.65**	-0.79	41.16**	44.76**	56.46**	63.44**	61.54**	29.36**	-5.21	-14.52*
L6xT1	98.66**	31.61*	-4.08**	1.64	-1.17	3.67**	67.2**	88.70**	111.6**	156.29**	77.02**	36.13**	19.17**	-5.01
L6xT2	62.88**	7.52	-6.84**	-3.54**	-5.34**	-2.74*	65.32**	85.90**	108.8**	163.83**	74.46**	35.26**	0.86	-19.7**
L7xT1	51.65**	6.40	-0.97	5.35**	-4.25**	1.22	62.29**	88.21**	97.52**	138.49**	67.39**	22.87*	-8.36	-15.61**
L7xT2	101.18**	40.56**	-8.72**	-5.13**	-8.33**	-5.09**	66.96**	92.9**	95.27**	145.99**	92.65**	42.47**	10.29	1.42
L8xT1	115.65**	48.6**	-6.72**	0.00	-9.36**	-1.22	63.79**	76.96**	96.51**	117.59**	116.66**	53.47**	0.3	-5.25
L8xT2	58.50**	8.78	-9.78**	-5.52**	-11.76**	-5.88**	58.18**	70.30**	78.80**	106.00**	83.63**	30.97**	-9.96	-15.07*

L9xT1	110.47**	47.51**	-5.14**	2.47*	-5.68**	1.63	52.25**	60.24**	88.61**	96.55**	80.56**	40.27**	22.67**	3.4
L9xT2	145.05**	71.03**	-7.84**	-2.76*	-8.18**	-3.14**	45.61**	52.72**	58.26**	71.26**	89.84**	48.71**	39.18**	17.16**
L10xT1	121.45**	40.32**	-5.08**	3.70**	-5.60**	2.85*	59.84**	67.39**	82.41**	98.75**	106.48**	44.35**	13.81*	-4.54
L10xT2	88.25**	18.92	-9.59**	-3.54**	-11.01**	-5.09**	54.22**	60.94**	68.78**	91.25**	94.63**	36.98**	5.04	-12.01*
L11xT1	139.34**	53.96**	-6.09**	1.64	-6.94**	1.22	66.41**	85.46**	79.68**	81.29**	113.87**	62.14**	19.54**	-6.52
L11xT2	69.96**	8.98	-8.75**	-3.54**	-9.39**	-3.53**	60.67**	78.42**	73.22**	81.29**	73.18**	32.34**	7.44	-16.08**
L12xT1	99.07**	16.44	-7.24**	2.88*	-7.55**	2.45	66.07**	87.43**	96.73**	134.16**	98.15**	25.56*	14.44*	-9.53
L12xT2	128.68**	33.48**	-11.28**	-3.94**	-11.39**	-3.92**	62.49**	82.71**	94.54**	141.48**	128.13**	45.28**	18.31**	-6.58
L13xT1	158.68**	78.63**	-6.36**	0.00	-6.72**	-0.82	54.05**	62.61**	85.94**	101.23**	108.95**	46.25**	24.97**	20.07**
L13xT2	115.8**	48.42**	-9.44**	-5.52**	-8.47**	-4.71**	58.18**	66.38**	79.92**	102.47**	96.83**	38.69**	13.98**	9.35
L14xT1	35.54*	5.81	-3.29**	2.88*	-3.48**	2.03	45.40**	47.57**	72.19**	72.80**	50.15**	22.65*	-10.05	-15.42**

**=0.05 and **= 0.01 significant probability level.GY=Grail Yield, DA=Days to anthesis, DS = Days Silking PH=Plant height, EH=Ear height, TAGB = Total Above Ground Biomass, HI= Harvest Index, MPH=mid parent heterosis, BPH=Best parent heterosis, SE (d)=Standard error of difference*

Table 5. Continued.

Crosses	GY		DA		DS		PH		EH		TAGB		HI	
	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
L14xT2	26.58	-1.70	-7.19**	-3.54**	-7.19**	-3.92**	46.10**	47.78**	76.26**	82.11**	50.63**	24.16*	-14.34**	-19.57**
L15xT1	169.4**	64.75**	-5.91**	1.64	-6.41**	1.22	65.87**	74.72**	83.46**	86.81**	105.9**	50.39**	46.27**	7.87
L15xT2	125.78**	37.7**	-9.7**	-4.72**	-10.00**	-4.71**	64.14**	72.3**	87.21**	97.80**	103.11**	49.46**	27.34**	-6.19
L16xT1	29.39*	1.77	-2.35*	2.47*	-2.94**	1.22	41.89**	50.94**	81.82**	112.25**	47.5**	11.58	-13.27**	-15.6**
L16xT2	59.26**	24.6*	-5.19**	-2.76*	-5.95**	-3.92**	41.85**	50.37**	72.12**	109.42**	62.01**	23.53*	-0.04	-2.58
L17xT1	20.39	-13.93	-1.56	3.30**	-2.33*	2.45	40.11**	48.47**	75.41**	104.23**	52.17**	9.06	-21.96**	-22.62**
L17xT2	57.12**	11.84	-6.34**	-3.94**	-7.63**	-5.09**	44.74**	52.84**	74.11**	111.27**	66.85**	20.44*	-3.83	-4.79
L18xT1	2.49	-20.83	-2.30*	4.94**	-2.48*	4.48**	40.27**	44.94**	69.14**	83.46**	32.79**	4.53NS	-22.36**	-25.55**
L18xT2	52.4**	17.13	-8.82**	-4.33**	-9.91**	-5.49**	49.32**	53.76**	69.26**	90.90**	69.5**	34.57**	-7.23	-11.18
L19xT1	-4.85	-19.40	-0.60	2.88*	-2.16*	1.63	47.5**	66.12**	57.52**	81.94**	23.94*	-1.12	-25.88**	-29.97**
L19xT2	34.37**	13.15	-3.90**	-2.76*	-6.74**	-5.09**	44.87**	62.56**	56.95**	88.89**	56.4**	25.87*	-14.17**	-18.78**
L20xT1	22.54	-18.91	-1.56	3.30**	-2.73**	2.03	50.75**	84.56**	89.40**	197.73**	31.47*	-9.12NS	-7.84	-12.44*
L20xT2	104.49**	34.84**	-8.25**	-5.91**	-9.17**	-6.67**	64.43**	100.51**	107.85**	243.18**	91.77**	33.43**	8.29	2.74
L21xT1	75.7**	30.28*	-2.89**	3.70**	-4.37**	2.85*	56.36**	68.25**	90.61**	103.61**	76.81**	41.55**	1.09	-9.63
L21xT2	24.26	-8.30	-5.67**	-1.58	-6.15**	-1.18	48.35**	59.06**	67.12**	85.54**	49.47**	20.72*	-13.73*	-22.99**
L22xT1	74.65**	10.93	-6.11**	1.23	-6.64**	0.40	67.74**	83.22**	101.14**	118.17**	86.61**	29.36**	-1.62	-16.96**
L22xT2	122.07**	40.61**	-11.04**	-6.31**	-11.36**	-6.67**	65.58**	80.22**	84.65**	108.26**	100.74**	40.07**	21.05**	2.05
L23xT1	112.61**	43.67**	-5.34**	2.06	-6.06**	1.22	63.91**	73.69**	89.22**	100.47**	106.9**	49.22**	8.04	-5.48
L23xT2	62.16**	9.17	-10.28**	-5.52**	-9.29**	-4.32**	56.42**	65.17**	78.88**	96.92**	94.8**	41.5**	-10.22	-21.56**
L24XT1	86.87**	28.9*	-5.03**	0.83	-6.11**	0.4	56.03**	58.48**	78.26**	82.89**	96.64**	47.15**	1.59	-13.89*
L24xT2	94.99**	33.96**	-8.16**	-4.72**	-9.34**	-5.09**	51.38**	53.25**	69.66**	80.66**	88.77**	42.36**	13.3*	-4.09
L25xT1	36.62**	8.37	-4.78**	2.47*	-4.05**	1.63	48.43**	51.45**	81.05**	100.00**	36.34**	20.13*	-15.5**	-19.71**
L25xT2	5.17	-17.03	-8.62**	-3.94**	-8.13**	-4.71**	50.49**	53.04**	74.01**	100.00**	40.19**	24.79*	-31.01**	-34.35**
SE(d)	0.66	0.76	0.73	0.84	0.82	0.95	6.02	6.95	5.33	6.15	1.53	1.77	1.92	2.23

**=0.05 and **= 0.01 significant probability level, GY=Grail Yield, DA=Days to anthesis, DS = Days Silking PH=Plant height, EH=Ear height, TAGB = Total Above Ground Biomass, HI= Harvest Index, MPH=mid parent heterosis, BPH=Best parent heterosis, SE(d)=Standard error of difference*

Table 5. *Continued.*

Crosses	ED		RPE		EL		TKW		EPP	
	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
L1xT1	12.96**	2.95	10.54*	5.03	14.23**	3.85	18.05*	12.72	4.66	-18.44**
L1xT2	25.09**	23.08**	7.69	0.00	20.84**	17.64**	16.53*	15.46	10.64	-14.29*
L2xT1	29.18**	5.06	11.08*	0.00	6.73	3.74	31.59**	16.03*	-8.96	-29.05**
L2xT2	43.43**	24.57**	18.9**	4.79	13.13**	2.70	18.67*	8.22	-8.51	-29.12**
L3xT1	9.79**	2.95	13.5**	5.03	14.15**	7.87	26.66**	20.44**	15.22*	-11.17
L3xT2	21.76**	20.00**	5.25	-4.79	23.82**	22.02**	34.69**	32.87**	15.41*	-11.54
L4xT1	16.93**	2.25	12.9**	10.05	17.18**	-2.59	26.43**	8.82	3.07	-15.64*
L4xT2	23.48**	16.13**	10.01*	4.79	36.99**	21.02**	32.4**	17.73*	-6.76	-24.18**
L5xT1	5.17	2.95	13.5**	5.03	7.60	3.30	11.62	6.81	2.82	-18.44**
L5xT2	13.89**	7.49*	10.54*	0.00	26.03**	22.19**	18.78*	17.95*	5.92	-16.48*
L6xT1	9.41**	2.25	2.54	0.00	33.97**	16.13**	36.34**	13.53	-21.41**	-25.14**
L6xT2	15.5**	14.24**	4.99	0.00	38.96**	28.47**	26.5**	8.65	-26.74**	-30.77**
L7xT1	15.34**	-0.84	5.25	0.00	21.53**	10.46*	12.35	7.11	-1.72	-20.11**
L7xT2	29.75**	19.77**	2.54	-4.79	21.27**	18.03**	15.52*	14.27	4.08	-15.93*
L8xT1	14.63**	0.84	12.9**	10.05	13.1**	11.89*	26.17**	10.62	11.19	-16.76*
L8xT2	24.07**	17.45**	4.99	0.00	17.86**	10.97*	18.19*	7.14	-9.23	-32.42**
L9xT1	12.55**	0.56	5.02	5.03	8.52*	6.22	13.22	3.81	3.20	-18.99**
L9xT2	17.53**	13.15**	7.35	4.79	15.23**	9.60*	13.26	7.57	3.52	-19.23**
L10xT1	5.92*	0.00	7.69	5.03	15.10**	3.63	18.43**	13.02	35.41**	-2.79
L10xT2	17.8**	15.28**	10.00*	4.79	15.90**	11.66*	13.65	12.54	17.69*	-15.93*
L11xT1	16.55**	6.47*	10.50*	5.03	11.13**	6.60	-1.23	-6.45	23.02**	-13.41*
L11xT2	18.57**	16.96**	7.69	0.00	21.46**	17.86**	1.127	-7.53	12.16	-21.43**
L12xT1	14.94**	6.33*	13.50**	5.03	31.84**	2.20	32.40**	13.42	6.67	-19.55**
L12xT2	23.08**	23.08**	5.25	-4.79	49.65**	22.48**	29.51**	14.59	4.03	-21.98**
L13xT1	12.12**	1.12	2.54	0.00	16.52**	3.63	25.93**	9.72	15.61*	-2.79
L13xT2	17.56**	14.35**	4.99	0.00	25.76**	19.55**	37.58**	23.89**	6.58	-10.99
L14xT1	20.82**	1.83	2.76	-4.95	18.85**	11.72*	26.74**	8.52	-16.62**	-20.11**
L14xT2	33.7**	20.76**	5.25	-4.79	16.12**	15.07**	29.58**	14.59	-18.5**	-22.53**
L15xT1	19.95**	3.38	7.98	5.03	12.29**	10.62*	13.47	7.61	20.49*	-17.88**
L15xT2	25.65**	16.3**	5.26	0.00	21.99**	15.31**	16.93*	15.03	14.17	-22.53**
L16xT1	7.43**	-1.41	5.25	0.00	14.38**	1.98	12.19	-2.71	5.26	-5.03
L16xT2	15.48**	14.47**	7.69	0.00	15.6**	10.19	42.7**	27.89**	14.11*	2.20
L17xT1	11.37**	0.56	2.54	0.00	12.82*	-8.48	-2.81	-18.44*	10.96	-6.70
L17xT2	20.08**	16.96**	4.99	0.00	18.70**	2.10	4.993	-9.08	16.45*	-2.75

**=0.05 and **= 0.01 significant probability level,*

Table 5. *Continued.*

Crosses	ED		RPE		EL		TKW		EPP	
	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
L18xT1	9.83**	-3.38	13.50**	5.03	3.86	-5.17	9.81	-3.51	-3.18	-15.08*
L18xT2	18.83**	12.49**	10.54*	0.00	16.12**	13.57*	33.02**	20.87*	-0.95	-13.74*
L19xT1	7.69**	-1.97	5.25	0.00	6.66	-2.15	4.05	-15.03	-7.23	-13.97*
L19xT2	21.72**	19.6**	7.69	0.00	3.01	1.27	-0.07	-15.89	8.66	0.00
L20xT1	10.42**	-2.39	16.70**	5.03	13.54**	-3.30	6.62	-3.91	3.33	-13.41*
L20xT2	18.56**	12.82**	13.50**	0.00	19.87**	8.73	16.8*	8.97	18.81**	-1.10
L21xT1	13.48**	1.27	15.80**	10.05	14.52**	7.87	10.27	6.01	3.94	-18.99**
L21xT2	22.5**	17.78**	2.54	-4.79	21.54**	20.17**	9.32	9.08	-17.02*	-35.71**
L22xT1	20.19**	4.22	-5.25	-9.98	14.22**	8.97	15.02*	12.42	-15.76*	-26.82**
L22xT2	29.25**	20.43**	7.69	0.00	19.44**	16.55**	12.67	11.02	-24.2**	-34.62**
L23xT1	14.84**	0.42	2.76	-4.95	13.67**	9.63*	20.39**	11.52	4.00	-20.11**
L23xT2	17.5**	10.5**	0.04	-9.50	23.2**	18.9**	17.46*	12.76	-4.32	-26.92**
L24xT1	8.55**	-3.13	10.54*	5.03	17.65**	16.68**	29.08**	15.43*	5.79	-28.49**
L24xT2	16.65**	12.16**	7.69	0.00	18.38**	11.19*	20.8**	11.79	6.12	-28.57**
L25xT1	2.97	-3.66	15.80**	10.05	18.95**	3.47	11.24	7.61	-9.70	-24.58**
L25xT2	14.87**	13.48**	7.69	0.00	18.74**	10.19	5.38	4.93	-9.27	-24.73**

SE(d)	**0.10**	**0.12**	**0.56**	**0.64**	**0.74**	**0.85**	**21.29**	**24.58**	**0.07**	**0.08**

**=0.05 and **= 0.01 significant probability level,*

ED=Ear Diameter, RPE=Number of rows per ears, EL=Ear length, TKW=Thousand kernel weight, EPP=Ear per plant, MPH=mid parent heterosis, BPH=Best parent heterosis, SE(d)=standard error of difference

Conclusion

The study identified a number of high yielding quality protein maize inbred lines (L19, L25, L16, L14 and L18). Having these QPM inbred lines in Ethiopia where most of rural populations use maize as their staple food is very crucial.

These inbred lines should be retested for their tryptophan content and used in future breeding work and/or variety development for commercial use. The study also identified crosses with significant positive mid and better parent heterosis for GY, EH, PH, EL, TKW and EPP. Accordingly, the highest and significant positive heterosis over mid parent for GY was scored from L15 x T1 (169.4%) and L13 x T1 (158.68%). Similarly, maximum and significant positive heterosis over the better parent for GY was scored from L3 x T1 (85.67%) and L13 x T1 (78.63%).

Many crosses showed significant negative mid and better parent heterosis for DA and DS. The negative heterosis for DA and DS indicated earliness of the crosses as compared to the mean performance of the parents. This implies potential to decrease days to maturity through hybridization to develop early maturing hybrids.

Heterosis in the positive direction is desirable for GY and traits that directly contribute to yield. On the other hand, heterosis in the negative direction is desirable for traits like DA, DS, PH, EH, and HC. Generally, the selected QPM inbred lines are useful genetic resources for the maize breeding program of Ethiopia.

Acknowledgements

We would like to express our sincere appreciation to the maize research staff at Bako agricultural research center for hosting the trials and collecting data. We also extend our thanks to the Ethiopian Institute of Agricultural Research (EIAR) for their financial support.

References

[1] Ali A, Urrahman H, Shah L, Shah K. A. Rehman S(2014) Heterosis for grain yield and its attributing components in maize variety azam using line x tester analysis method. Ac. J. Agri. Res. 2: 225-230.

[2] Amanullah S J, Mansoor M, Khan MA(2011) Heterosis studies in diallel crosses of maize. Sarhad Journal of Agriculture, 27: 207-211.

[3] Amare Seyoum, Dagne Wegary, Sentayehu Alamerew(2016) Combining ability of elite highland maize (Zea mays L.) inbred lines at Jimma Dedo, South West Ethiopia. Advances in Crop Science and Technology**,** 1-9.

[4] Banziger M, Vivek BS(2007) Fieldbook: Software for Managing a Maize Breeding Program. CIMMYT.

[5] Bayisa Asefa, Hussein Mohammed,Habtamu Zelleke(2005) Combining ability of highland maize inbred lines. Ethiopian Journal of Agricultural Science, 18(2): 181-189

[6] Dagne Wegary, Habtamu Zelleke, Labuschagne M, Hussien T, Singh H(2007) Heterosis and combining ability for grain yield and its components in selected maize inbred lines. South African Journal of Plant and Soil, 24: 133-137.

[7] Dagne Wegary, Vivek B,Labuschagne M (2013) Association of parental genetic distance with heterosis and specific combining ability in quality protein maize. Euphytica, 191: 205-216.

[8] Demissew Abakemal Ababulgu(2014)Genetic diversity and combining ability of selected quality protein maize (QPM) inbred lines adapted to the highland agro-ecology of Ethiopia. PhD Dissertation, University of the Kwazulu-Natal, Republic of South Africa.

[9] Falconer DS Mackay TF(1996)Introduction to quantitative genetics,4th edition. Longman, London, UK.

[10] GezahegnBogale, DagneWegaryet al(2012) Maize Improvement for Low-Moisture Stress Areas of Ethiopia: Achievements and Progress in the Last Decade. pp: 35-46. In: Worku M, Twumasi Afriyie Set al (eds.),18-20 April 21012. Proceedings of the 3rd National Maize Workshop of Ethiopia. Addis Ababa, Ethiopia.

[11] Girma Chemada, Sentayehu Alamerew, Berhanu Tadesse, Temesgen Menamo(2015) Test cross performance and combining ability of maize (Zea mays L.) inbred lines at Bako, Western Ethiopia. Global Journal of Science Frontier Research,1-24

[12] GowadaRK, Kage U, Lohithaswa HC, Shekara, BG Shobha D(2013) Combining ability studies in maize (Zea mays L.), Molecular Plant Breeding, 3(14): 116-127 doi:10.5376/ijh.2013.03.0014

[13] Habtamu Zeleke(2015) Heterosis and combining ability for grain yield and yield component traits of maize in eastern Ethiopia. Science, Technology and Arts Research Journal, 4(3):32-37

[14] Hallauer AR, Miranda,JB(1988)Quantitative genetics in maize breeding, 2nd edition. Iowa State University Press, Iowa, Ames.Kumar P, Reddy N, Kumar S, Rao V(2014)Combining ability studies in newly developed inbred lines in maize (Zea mays L.). International Journal of Plant, Animal and Environmental Sciences, 4(4): 229-234

[15] Legesse Wolde, Mosisa Worku, Berhanu Tadesseet al. (2012) Genetic improvement of maize for mid-altitude and lowland sub-humid agro-ecologies of Ethiopia. P: 24-34: In: Worku M, Twumasi-Afriyie S, et al (eds.),18-20 April 2012. Proceedings of the Third National Maize Workshop of Ethiopia. Addis Ababa, Ethiopia.

[16] Leta Tulu, GelanaSeboksa, JemalAbdurhaman, Dagne Wagary, S. Twumasi Afriyie(2003) Historical Perspectives, Current status, and Strategies for Quality Protein Maize Breeding in Ethiopia. Pp. 124-125. In:CIMMYT 2003. Book of Abstracts: ArnelR.Halauer Internal Symposium on Plant Breeding, 22 August 2003, CIMMY, Mexico.

[17] Malik H, Malik S, Chughtai S, Javed H(2004) Estimates of heterosis among temperate, subtropical and tropical maize germplasm. Asian Journal of Plant Sciences, 3: 6-10.

[18] Patterson HD, Williams ER(1976). A new class resolvable incomplete block designs. Biometrika, 63: 83-92.

[19] Ram L, Singh R, Singh S,Srivastava R(2015)Heterosis and combining ability studies for quality protein maize. Ekin Journal of Crop Breeding and Genetics**,** 1-2.

[20] SAS (Statistical Analysis System). 2004. SAS Institute Inc., Cary,NC, USA.

[21] Shimada A,Cline TR (1974) Limiting amino acids of triticale for the growing rat and pig. Journal ofAnimal Science. 38:941-946.

[22] Tajwar Izhar, ChakrabortyM(2013). Combining ability and heterosis for grain yield and its components in maize inbreds over environments (Zea mays L.). African journal ofAgricultyral Research, 8(25): 3276-86doi: 10.5897/AJAR2013.7109

[23] Twumasi AS, DemissewA, Gezahegn B et al (2012) A Decade of Quality Protein Maize Research Progress in Ethiopia (2001–2011). p. 47-57. In: MosisaW.,Twumasi, A. S. et al (eds.),Proceedings of the Third National Maize Workshop of Ethiopia.Addis Ababa, Ethiopia. 18-20 April 2011. Ethiopian Institute of Agricultural Research (EIAR) and CIMMYT, Addis Ababa, Ethiopia.

[24] Wakene Negassa(2001) Assessment of important physio-chemical properties of dystricudalf (dystricNitosols) under different management systems in Bako area, Western Ethiopia. MSc. Thesis, Haramaya University, Ethiopia.

[25] Wilson CM(1991) Multiple zeins from maize endosperms characterized by reverse phase high performance liquid chromatography. Plant Physiology, 95:777-786.

[26] Worku M, Zelleke H(2007) Advances in improving harvest index and grain yield of maize in Ethiopia. East African Journal of Sciences, 1**,** 112-119.

Citation: *Dufera Tulu, Girum Azmach and Bulti Tesso" Perse Performance and Heterosis of Quality Protein Maize (Zea mays L.) Inbred Lines Adapted to Mid-Altitude Sub-Humid Agro-Ecology of Ethiopia",International Journal of Research Studies in Science, Engineering and Technology, vol. 5, no. 8, pp. 14-26, 2018.*

Copyright: *© 2018 Dufera Tulu. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.*