

Standard Heterosis of Maize (*Zea mays* L.) Inbred Lines for Grain Yield and Yield Related Traits in Central Rift Valley of Ethiopia

Shushay welderufael abrha
[1]Department of plant science, Adigrat University, Adigrat, Ethiopia, p.o.box,50
Email address: shushay24@gmail.com

Standard Heterosis of Maize (Zea mays L.) Inbred Lines for Grain Yield and Yield Related Traits in Central Rift Valley of Ethiopia

Abstract
A line x tester analysis involving forty eight test-crosses generated by crossing 24 elite maize inbred lines with two testers and four standard checks was conducted for agronomic traits such as grain yield, thousand kernel weight, number of rows per ear, number of ears per plant, number of days to anthesis and silking, plant and ear heights during 2010 cropping season at Melkassa Agricultural Research Center. The objective of the study was to estimate the amount of standard heterosis of the hybrids for grain yield and yield related traits. The genotypes were evaluated in 6x9 alpha lattice design replicated twice. From this study, Substantial standard heterosis was noticed for all studied traits. For grain yield, the highest standard heterosis was recorded for L4 x T2 (89.24%) followed by L10 x T2 (78.53%) over BHQPY-545 and 131.20% and 118.12% over Melkassa-2, respectively, indicating the presence of substantial heterotic potential that could be exploited in maize breeding program and possibility of developing desirable cross combinations and synthetic varieties through crossing and or recombination of inbred lines with desirable traits of interest.
Keywords: Heterosis; line x tester; maize; yield

1. *Introduction*

Most tropical maize is produced under rain-fed conditions and many of the maize growing environments in eastern Africa are susceptible to drought (Edmeades *et al*., 1992). In the drought stressed areas of Ethiopia, which cover about half (46%) total arable land (Reddy and Kidane, 1993), maize is one of the most important food crops and is grown by almost all farmers. Drought stressed areas devoted to maize production occupy 38-42% of the maize growing area but contribute only 17% to the total maize production (Mandefro *et al.*, 1999). Unavailability of suitable maize varieties is one of the possible reasons responsible for such yield gap. Efforts are, therefore, required to be made to develop hybrids with high yield potential in order to increase production of maize.
Several studies have been conducted in the world on several sets of crosses of maize inbred lines and the results consistently showed the presence of considerable amount of heterosis and significant differences in combining abilities of cultivars of diverse genetic bases. Although such types of genetic studies have been made in highlands (Twumasi *et al.*, 2001) and mid altitudes (Legesse *et al*., 2009; Mossisa *et al.*, 2009) of high potential maize growing areas of Ethiopia, little efforts have been done on low lands of the country on the performance of maize inbred lines using line x tester analysis method.

2. Materials and Methods

The experiment was carried out in the 2010 main cropping season at Melkassa Agricultural Research Center (MARC) experimental farm of the Ethiopian Institute of Agricultural Research (EIAR). The center is located at $8^0$24’ N latitude and $39^0$21’ E longitude and an altitude of 1550 m.a.s.l. The climate of the area is characterized as semi-arid with mean monthly maximum and minimum temperature of 33^{o}C and 10.8^{o}C, respectively.

A total of fifty two entries including 48 test crosses produced by crossing twenty four elite inbred lines with two testers (CML312/CML442, tester A and CML202/CML395, tester B) and four standard checks (BH540, BHQPY-545, Melkassa-2, Melkassa-6Q) were used for the study.
The lines were obtained from MARC, but originally introduced from CIMMYT-Kenyan breeding program. List and pedigrees of the inbred lines used in the line x tester crosses are given in Table 1. The testers used in this study were identified by CIMMYT and are widely used in Africa by CIMMYT and many national maize breeding programs to study combining ability of newly generated maize inbred lines and at the same time to discriminate the inbred lines into heterotic groups. Among the checks, BH-540 and BHQPY-545 are medium maturing single cross hybrids released by Bako National Maize Research Project (BNMRP) for mid to high potential maize growing agro-ecologies of Ethiopia. BH-540 is normal maize while BHQPY-545 is quality protein maize (QPM) hybrid. Melkassa-2 and Melkassa-6Q are drought stress tolerant and early maturing,

respectively, open pollinated varieties (OPVs) released by MARC for drought prone areas of Ethiopia. Melkassa-2 is normal maize while Melkassa-6Q is a QPM OPV.

*The experiment was planted in 6x9 alpha-lattice design (Patterson and Williams, 1976***)** *with two replications. Each plot comprised of 4 rows of 5.1 m long with the spacing of 0.75 m between rows and 0.30 m between plants.*

Table 5. Descriptions of the lines, testers and checks used line x tester at Melkassa in 2010

Line Code	Pedigree	Stock ID
L1	CML505-B	M22-1
L2	CML509-B	M22-2
L3	CML507-B	M22-3
L4	ZEWAc1F2-300-2-2-B-1-B*4-1-B-B	M22-4
L5	ZEWAc1F2-134-4-1-B-1-B*4-1-B-B	M22-5
L6	ZEWAc1F2-254-2-1-B-1-BB-1-B-B	M22-6
L7	ZEWBc1F2-216-2-2-B-2-B*4-1-B-B	M22-7
L8	MAS[MSR/312]-117-2-2-1-B*3-B	M22-8
L9	CML442-BB-B	M22-9
L10	CML444-BB-B	M22-10
L11	CML443-BB-B	M22-11
L12	CML395-BB-B	M22-12
L13	CML488-BB-B	M22-13
L14	CML489-BB-B	M22-14
L15	CML440-B	M22-15
L16	CML445-B	M22-16
L17	[CML444/CML395//ZM521B-66-4-1-1-1-BB]-3-3-1-1-B-B	M22-17
L18	[CML312/CML444//[DTP2WC4H255-1-2-2-BB/LATA-F2-138-1-3-1-B]-1-3-2-3-B]-2-1-2-BB-B-B	M22-18
L19	[CML442/CML197//[TUXPSEQ]C1F2/P49-SR]F2-45-7-3-2-BBB]-2-1-1-1-1-B*4-B	M22-19
L20	[CML442/CML197//[TUXPSEQ]C1F2/P49-SR]F2-45-7-3-2-BBB]-2-1-1-2-3-B*4-B	M22-20
L21	Pool15QPMFS57-B-5-B-#-B-B-B-B-B	M22-21
L22	Pool15QPMFS440-B-4-B-#-B-B-B-B-B	M22-22
L23	Pool15QPMFS309-B-1-B-B-B-B-B-B	M22-23
L24	Pool15QPMFS51-B-8-B-B-B-B-B-B	M22-24
Testers		
T1	CML312/CML442	Tester A
T2	CML202/CML395	Tester B
Checks		
BH-540	SC-22 x 124b-(113)	Medium maturing normal maize hybrid
Melkassa-2	ZM-521	Drought tolerant normal maize OPV
Melkassa-6Q	Pool15 C7 QPM	Drought tolerant QPM OPV
BHQPY-545	CML161 x CML165	Medium maturing QPM hybrid

Data on days to Anthesis (AD): Number of days from planting to when 50% of the plant in a plot shed pollen: Days to Silking (SD): Number of days from planting to when 50% of the plants in a plot produced 2-3 cm long silk. Thousand Kernel Weight (TKWT): 1000 randomly taken kernels were weighed from each plot using sensitive balance and was adjusted to 12.5 % moisture level. Grain Yield (GY): The total grain yield in kg per plot and adjusted to 12.5% moisture level. Plant Height (PH): The average height of five randomly selected plants measured in cm from base of the plant to the first tassel branch. Ear Height (EH): The average height of five randomly selected plants measured in cm from base of the plant to the node bearing the upper most ear of the same plants used to measure plant height. Number of Kernel Rows per Ear (KRE): The total number of kernel rows of the ear was counted from five randomly taken ears and the average value was used as kernel rows per ear.

Percent standard heterosis was calculated for those traits that showed statistically significant differences among genotypes as suggested by Falconer (1996). This was computed as percentage increase or decrease of the cross performances over the best standard check as:

$$\text{SH (\%)} = \frac{F1 - SV}{SV} x100$$

Where,
F1 = Mean value of a cross
SV = Mean value of standard check variety

Test of significant for percent heterosis was made using the t-test. The standard errors of the difference for heterosis and t-value were computed as:

$$\text{t (standard cross)} = \frac{F1 - SV}{SE(d)}$$

SE (d) = $(2Me/r)^{1/2}$
Where, SE (d) = standard error of the difference
Me = error mean square
r = number of replications

The computed t value was tested against the t-value at degree of freedom for error.

3. Result and Discussions

The estimates of heterosis over the best standard check were computed for grain yield and yield related traits that showed significant differences among genotypes. BHQPY-545 was the best standard check as it produced highest mean grain yield per hectare. Since Melkassa-2 is the most popular variety being used by farmers in the rift valley areas of Ethiopia, it was also used as second standard check to estimate standard heterosis for all the traits. The results are depicted in Table 2 for BHQPY-545 and in Table 3 for Melkassa-2.

Among the 48 crosses, 31 crosses exhibited positive and significant to highly significant heterosis over the best standard check (BHQPY-545) for grain yield (Table 2). Standard heterosis for this trait ranged from 89.24 (L4 x T2) to -32.16% (L16 x T2). L4 x T2 (89.24%), L10 x T2 (78.53%), L8 x T2 (77.23%), L8 x T1 (76.98%) and L20 x T1 (75.41%) exhibited higher standard heterosis over BHQPY-545. Similarly, the standard heterosis over Melkassa-2 varied from 131.20 (L4 x T2) to -17.12% (L16 x T2) and L4 x T2 (131.20%), L10 x T2 (118.12%), L8 x T2 (116.53%), L8 x T1 (116.22%), L20 x T1 (114.31%) exhibited positive higher standard heterosis (Table 3). Positive heterosis is desirable as it indicates increased yield over the existing standard check. In crop breeding, in the sense those hybrids perform better than the best standard variety could be of commercial importance. In agreement with the current finding, the expression of grain yield heterosis above the standard check in maize has been reported by several investigators (Venugopal *et al.,* 2002; Tiwari, 2003; Twumasi *et al*., 2003; Amiruzzaman *et al.*, 2010; Wali *et al*., 2010).

For days to anthesis, all crosses exhibited negative and significant heterosis except L10 x T1, L19 x T1 and L14 x T2. The standard heterosis for this trait ranged from -1.86 (L14 x T2) to -13.04% (L6 x T2) over BHQPY-545 (Table 2). Over Melkassa-2, 42 crosses exhibited positive and significant heterosis. The standard heterosis for the trait ranged from -0.71 (L14 x T2 L6) to 12.06% (L6 x T2) (Table 3). Negative and significant standard

heterosis is desirable direction as it indicates earlier anthesis of the crosses than the standard check and the reverse is true for the crosses with positive and significant standard heterosis.
The extent of standard heterosis for the number of rows per ear varied from -9.82 (L11 x T1) to 26.55% (L7 x T1). For this trait, five crosses viz., L7 x T1(26.55%), L7 x T2 (17.82%), L12 x T2 (9.09%), L23 x T1 (19.27%) and L23 x T2 (9.09%) had positive and significant heterosis over BHQPY-545 (Table 2) indicating increased in number of rows per ear for these crosses as compared to the standard check. Cross L11 x T1 produced negative and highly significant heterosis indicating that the parents of the crosses contributed genes that negatively contributed to number of rows per ear. Over Melkassa-2, the magnitude of standard heterosis ranged from -13.89 (L11 x T1) to 20.83% (L7 x T1) and six crosses showed negative and three crosses positive and significant heterosis (Table 3). The current finding confirms with the previous reported by Gadad (2003) who observed significant positive and negative standard heterosis for number of rows per ear.

Standard heterosis for 1000 kernel weight varied from -40.1 (L13 x T1) to 24.35% (L17 x T1). Positive and significant standard heterosis manifested in six crosses. On the contrary, L13 x T1 showed negative and significant heterosis over BHQPY-545 (Table 2). Over melkassa-2, four crosses showed negative and significant heterosis ranging from -38.73 (L13 x T1) to 26.98% (L17 x T1) (Table 3). Similar to the current study, both undesirable and desirable heterosis for 1000 kernel weight in maize has been reported by previous investigators (Amiruzzaman*. et al.*, 2010; Wali *et al*., 2010).

For ears per plant standard heterosis varying from -12.15 (L12 x T1) to 42.99% (L13 x T2) was recorded. Nine crosses exhibited positive and significant heterosis over BHQPY-545. This indicates more prolificacy of the test crosses over the standard check. The standard heterosis computed for this trait over Melkassa-2 showed that only L13 x T1 showed positive and significant heterosis while seven crosses had negative and significant heterosis. The range of heterosis over this standard check was -25.90 (L12 x T1) to 20.05% (L13 x T1). The results of this study are in conformity with the findings of Saleh *et al.* (2002).

For ear height, standard heterosis ranged from -21.74 (L5 x T1, L5 x T2 and L8 x T1) to 34.78% (L10 x T2). 10 of the crosses showed positive and highly significant standard heterosis, whereas four crosses exhibited negative and highly significant heterosis over BHQPY-545 (Table 2). 30 crosses showed positive and significant heterosis over Melkassa-2 with a range of -5.26 (L5 x T1, L5 x T2 and L8 x T1) to 63.16% (L10 x T2) (Table 3). Negative heterosis is favorable for this trait as short statured hybrids are resistant to lodging. Similar results have previously been reported by earlier researchers (Saleh *et al.*, 2002; Gadad, 2003).

The magnitude of standard heterosis for plant height ranged from -41.75% (L19 x T1) to 6.32 (L1 x T1, L1 x T2, L16 x T1 and L12 x T1) (Table 2). For this trait, 19 crosses showed negative and significant heterosis. This implies that large number of crosses were shorter in plant height than BHQPY-545, which is favorable trait for lodging resistance. This result is in agreement with the findings of Saleh *et al.* (2002). On the other hand, 42 crosses showed positive and significant heterosis over Melkassa-2 (Table 3). Only L19 x T1 showed negative and significant heterosis over this check and ranged from -21.1 (L19 x T1) to 42.5% (L1 x T1, L1 x T2, L12 x T1 and L16 x T1). Similar to the current findings, Gadad (2003) and Mahantesh (2006) reported positive and significant heterosis for plant height.

For days to silking, all crosses showed negative heterosis ranging from -12.35% (L6 x T2) to - 0.62 (L14 x T2) (Table 2). Among these crosses, 38 of the crosses manifested significant standard heterosis over BHQPY-545. Similar to that of days to anthesis, 42 crosses exhibited positive and significant heterosis, over Melkass-2. The standard heterosis for the trait ranged from 0.0 (L6 x T2) to 12.06% (L14 x T2) (Table 3). The negative standard heterosis is in desired direction because it indicates earlier anthesis of the crosses than the standard check and the reverse is true for the positive heterosis. In line with the current finding both positive and negative and significant level of heterosis for days to silking also reported by Pandey and Kumar (2001) and Amaregouda (2007).

Table 2. Standard heterosis of the test crosses over BHQPY-545 for grain yield and related traits of maize crosses evaluated at Melkassa in 2010.

Crosses	GY	AD	PH	SD	RPE	TKWT	EPP	EH
L1 x T1	30.75**	-4.35**	6.32	-3.70*	2.55	-21.15	10.28	13.04
L1 xT2	31.87**	-3.73*	6.32	-3.09*	7.64	8.99	13.08	8.72
L2 xT1	-11.56	-3.11*	-4.21	-2.47	7.64	-11.54	3.74	4.35
L2 x T2	37.13**	-5.59**	-2.11	-4.94**	0.36	-4.14	15.89	19.57**
L3 x T1	73.72**	-8.07**	-5.26	-7.41**	3.64	17.98	-0.93	2.17
L3 x T2	19.22*	-9.94**	-6.32	-8.64**	-1.09	-4.80	7.48	8.70
L4 x T1	72.22**	-8.07**	-20.00**	-7.41**	2.55	21.49	7.48	-10.87
L4 x T2	89.24**	-9.32**	-13.68**	-8.64**	0.36	4.11	9.35	-6.52
L5 xT1	68.42**	-11.18**	-1.60	-10.49**	-2.55	13.44	5.61	-21.74**
L5 x T2	25.48*	-11.80**	-9.47*	-9.26**	-6.18	20.35	21.50*	-21.74**
L6 x T1	48.76**	-11.80**	-18.95**	-10.49**	-1.09	19.50	12.15	28.26**
L6 x T2	33.78**	-13.04**	-14.74**	-12.35**	1.82	12.83	-3.74	-15.22*
L7 x T1	2.55	-8.70**	-2.11	-7.41**	26.55**	-14.31	6.54	8.70
L7 x T2	36.27**	-9.32**	-7.37	-8.64**	17.82**	-28.66*	0.93	4.35
L8 x T1	76.98**	-8.70**	-16.84**	-7.41**	0.36	-16.46	7.48	-21.74**
L8 x T2	77.23**	-6.21*	-3.16	-5.56**	0.36	21.13	3.74	8.70
L9 x T1	9.53	-3.11*	-12.63**	-2.47**	-4.00	-21.95	9.35	-6.52
L9 x T2	63.27**	-4.35**	2.11	-3.70*	7.64	14.37	10.28	4.35
L10 x T1	60.28**	-2.48	-8.42*	-1.85	4.73	-0.48	11.21	2.17
L10 x T2	78.53**	-3.11*	0.00	-1.85	4.73	16.96	9.35	34.78**
L11 x T1	35.16**	-5.59**	-17.89**	-4.94**	-9.82*	2.39	29.91**	-4.35
L11 x T2	36.69**	-6.83**	-4.21	-5.56**	-2.55	15.08	15.89	26.09**
L12 x T1	73.21**	-3.73*	6.32	-1.85	0.36	7.12	-12.15	26.09**
L12 x T2	-1.50	-3.11*	-1.05	-1.85	9.09*	-10.21	0.00	4.35
L13 x T1	8.53	-4.97**	1.05	-4.32**	1.82	-40.0**	9.35	19.57**
L13 x T2	-13.97	-4.97**	-11.58**	-4.32**	-3.27	8.48	42.99**	-2.17
L14 x T1	54.26**	-3.11*	-3.16	-1.85	7.64	9.01	11.21	0.00
L14 x T2	51.74**	-1.86	-5.26	-0.62	-8.36	15.14	15.89	19.57**
L15 x T1	41.75**	-11.80**	-8.42*	-9.26**	7.64	-9.38	2.80	-8.70
L15 x T2	-2.83	-8.07**	-16.84**	-6.79**	4.73	-15.75	-2.88	-10.87
L16 x T1	-32.16**	-5.59**	6.32	-4.32**	3.27	-20.67	-1.87	28.26**
L16 x T2	27.43*	-3.73*	-3.16	-3.70*	1.82	-10.33	7.01	2.17
L17 x T1	29.64*	-4.97*	-2.11	-4.32**	-6.18	24.35*	8.88	0.00
L17 x T2	6.23	-6.83**	-10.53**	-5.56**	-1.09	-4.89	-7.48	-8.72
L18 x T1	61.05**	-6.83**	-6.32	-5.56**	3.27	-6.79	1.87	-2.17
L18 x T2	-1.14	-4.35**	-8.42*	-3.70*	1.82	-14.77	-0.93	2.17
L19 x T1	5.66	-4.35**	-41.74**	-3.70*	0.36	-10.21	25.23**	-6.52
L19 x T1	50.93**	-2.48	0.00	-1.23	-6.91	-24.20*	15.89	8.7.00
L20 x T1	75.41**	-3.11*	3.16	-1.85	-6.91	7.21	36.45**	6.52
L20 x T2	64.15**	-3.73*	1.05	-3.09	6.18	-6.94	33.64**	19.57**
L21 x T1	20.37*	-8.70**	-15.79**	-8.02**	0.36	9.97	-10.28	-10.87
L21 x T2	-14.05	-8.07**	-17.89**	-7.41**	-0.36	-3.72	5.61	-8.70
L22 x T1	12.78	-9.32**	-7.37*	-8.64**	3.27	-29.38*	33.64**	-8.70
L22 x T2	-6.25	-9.94**	-5.26	-8.64**	-3.27	1.39	8.41	-6.52
L23 x T1	21.39*	-8.70**	-5.26	-9.26**	19.27**	-19.71	8.41	2.17
L23 x T 2	23.28*	-8.07**	-2.11	-8.02**	9.09*	-17.17	9.35	13.04
L24 x T1	9.26	-8.70**	-9.47*	-7.41**	1.82	7.58	27.10**	-6.52
L24 x T2	13.81	-4.97**	0.00	-4.32**	1.09	5.82	29.91**	19.57**
SE(d)	**509.0**	**1.18**	**9.33**	**1.15**	**0.62**	**39.56**	**0.10**	**7.95**

Table 3. Standard heterosis over Melkassa-2 for grain yield and yield related traits of maize crosses evaluated at Melkassa in 2010.

Crosses	GY	AD	PH	SD	RPE	TKWT	EPP	EH
L1 x T1	59.74**	9.22**	42.25**	9.86**	-2.08	-19.48	-7.09	36.84**
L1 x T2	61.11**	9.93**	42.25**	10.56**	2.78	11.30	-4.72	31.58**
L2 xT1	8.05	10.64**	28.17**	11.27**	2.78	-9.67	-12.60	26.32**
L2 x T2	67.54**	7.80**	30.99**	8.45**	-4.17	-2.11	-2.36	44.74**
L3 x T1	112.24**	4.96**	26.76**	5.63**	-1.04	20.48	-16.50*	23.68**
L3 x T2	45.65**	2.84	25.35**	4.23**	-5.56	-2.79	-9.45	31.58**
L4 x T1	110.40**	4.96**	7.04	5.63**	-2.08	24.07*	-9.45	7.89
L4 x T2	131.20**	3.55*	15.49**	4.23*	-4.17	6.31	-7.87	13.16
L5 xT1	105.76**	1.42	7.04	2.11	-6.94	16.00	-11.02	-5.26
L5 x T2	53.30**	0.71	21.13**	3.52*	-10.42*	22.90	2.36	-5.26
L6 x T1	81.74**	0.71	8.45	2.11	-5.56	22.03	-5.51	55.26**
L6 x T2	63.44**	-0.71	14.08**	0.00	-2.78	15.22	-18.9*	2.63
L7 x T1	25.29**	4.26*	30.99**	5.63**	20.83**	-12.49	-10.24	31.58**
L7 x T2	66.49**	3.55*	23.94**	4.23*	12.50**	-27.15*	-14.96	26.32**
L8 x T1	116.22**	4.26*	11.27*	5.63**	-4.17	14.85	-9.45	-5.26
L8 x T2	116.53**	7.09**	29.58**	7.75**	-4.17	23.70	-12.60	31.58**
L9 x T1	33.81**	10.64**	16.90**	11.27**	-8.33	-20.30	-7.87	13.16
L9 x T2	99.47**	9.22**	36.62**	9.86**	2.78	16.79	-7.09	26.32**
L10 x T1	95.82**	11.35**	22.54**	11.97**	0.00	1.63	-6.30	23.68**
L10 x T2	118.12**	10.64**	33.80**	11.97**	0.00	19.43	-7.87	63.16**
L11x T1	65.13**	7.80**	9.86	8.45**	-13.89**	4.56	9.45	15.79
L11 x T2	67.00**	6.38**	28.17**	7.75**	-6.94	17.51	-2.36	52.63**
L12 x T1	111.62**	9.93**	42.25**	11.97**	-4.17	9.48	-25.9**	52.63**
L12 x T2	20.32*	10.64**	32.39**	11.97**	4.17	-8.31	-15.75	26.32**
L13 x T1	32.59**	8.51**	35.21**	9.15**	-2.78	-38.7*	-7.87	44.74**
L13 x T2	-5.10	8.51**	18.31**	9.15**	-7.64	10.78	20.47*	18.42*
L14 x T1	88.46**	10.64**	29.58**	11.97**	2.78	11.31	-6.30	21.05*
L14 x T2	85.38**	12.06**	26.76**	13.38**	-12.50**	17.58	-2.36	44.74
L15 x T1	73.19**	0.71	22.54**	3.52*	2.78	-7.46	-13.39	10.53
L15 x T2	18.72*	4.96**	11.27**	6.34**	0.00	-13.97	-18.11*	7.89
L16 x T1	-17.12*	7.80**	42.25**	9.15**	-1.39	-18.99	-17.32*	55.26**
L16 x T2	55.69**	9.93**	29.58**	9.86**	-2.78	-8.43	-9.84	23.68**
L17 x T1	58.39**	8.51**	30.99**	9.15**	-10.42*	26.98*	-8.27	21.05*
L17x T2	29.79**	6.38**	19.72**	7.75**	-5.56	-2.87	-22.1**	10.53
L18 x T1	96.76**	6.38**	25.35**	7.75**	-1.39	-4.82	-14.17	18.42*
L18 x T2	20.78*	9.22**	22.54**	9.86**	-2.78	-12.85	-16.54	23.68**
L19 x T1	29.09**	9.22**	14.08**	9.86**	-4.17	-8.31	5.51	13.16
L19 x T1	84.40	11.35**	-21.1**	12.68**	-11.11*	-22.49	-2.36	31.58**
L20 x T1	114.31**	10.64**	38.03**	11.97**	-11.11*	9.48	14.96	28.95**
L20 x T2	100.65**	9.93**	35.21**	10.56**	1.39	-4.97	12.60	44.74**
L21 x T1	47.07**	4.26*	12.68*	4.93**	-4.17	12.30	24.41*	7.89
L21 x T2	5.01	4.96**	9.86	5.63**	-4.86	-1.68	-11.02	10.53
L22 x T1	37.79**	3.55*	23.94**	4.23*	-1.39	-27.89*	12.60	10.53
L22 x T2	14.53	2.84**	26.76**	4.23*	-7.64	3.54	-8.66	13.16
L23 x T1	48.31**	4.26*	26.76**	3.52*	13.89**	-18.01	-8.66	23.68**
L23 x T2	50.62**	4.96**	30.99**	4.93**	4.17	-15.42	-7.87	36.84**
L24 x T1	33.49	4.26*	21.13**	5.63**	-2.78	9.86	7.09	13.16
L24 x T2	14.31	8.51**	33.80**	9.15**	-3.47	8.06	9.45	44.74**
SE(d)	**509.0**	**1.18**	**9.33**	**1.15**	**0.62**	**9.56**	**0.10**	**7.95**

* and** = significant and highly significant, respectively, AD = days to anthesis (days), EH= ear height(cm), EPP = number of ears per plant (No), GY = grain yield (kg/ha), PH = plant height (cm), RPE = number of kernel rows per ear (No), SD = days to silking (days) and TKWT = 1000 kernel weight (g)

3. Conclusion

In this study, considerable standard heterosis over the best standard check (BHQPY-545) for grain yield obtained from crosses L4 x T2 (89.24%) and L10 x T2 (78.53%). The same crosses showed standard heterosis of 131.20% and 118.12% respectively, over Melkassa-2, showing the presence of exploitable heterosis essential for this trait. The entire test crosses evaluated manifested negative standard heterosis over BHQPY-545 for days to anthesis and silking ity except L8 x T1 and L14 x T1 which did not showed heterosis. This finding indicates that most of the crosses were earlier than the standard check; and hence, escape terminal moisture stress than standard variety being cultivated commercially. Similarly, most of the crosses showed negative heterosis for plant and ear height which is desirable as shorter statured crosses are preferred lodging resistance. Maximum standard heterosis was recorded for L17 x T1 (24.35%) for 1000 kernel weight, over BHQPY-545. Over Melkassa-2, the standard heterosis values for this crosse wase 26.98%. Crosses L13 x T2 (42.99%) and L23 x T1 (19.27%) had the highest standard heterosis for number of ears per plant and number of rows per ear over BHQPY-545, respectively. Over Melkassa-2 the values were 20.47% and 13.89% over, respectively. This indicates the presence of substantial heterotic potential that could be exploited in maize breeding program and possibility of developing desirable cross combinations and synthetic varieties through crossing and or recombination of inbred lines with desirable traits of interest.

4. References

Amaregouda H.M. 2007. Combining ability analysis of S2 lines derived from yellow pool population in Rabi maize. M.Sc. Thesis. University of Agricultural Sciences, Dharwad. 102p.

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

Edmeades G.O. Bolaños and J. Lafitte H.R. 1992. Progress in breeding for drought tolerance in maize. P 93-111. In: Wilkinson, D.(ed.). Proceedings of the 47th Annual Corn and Sorghum Industrial Research conference, 1992. ASTA, Washington, DC.

Gadad S.K. 2003. Genetic analysis for quantitative traits, starch and oil in single cross hybrids of maize (*Zea mays* L.). M.Sc. Thesis. University of Agricultural Sciences, Dharwad.

Falconer D.S. and. Mackay T.F.C. 1996. Introduction to quantitative genetics. 4th ed. Longman, London.

Legesse B.W. Pixley K.V. Mybur A.A. Twumasi S.A and. Botha A.M. 2009. Combining ability and heterotic grouping of highland transition maize inbred lines. *African Crop Science Conference Proceedings,* 9: 487- 491.

Mahantesh. 2006. Combining ability of and heterosis analysis for grain yield components in single cross hybrids of maize (*Zea mays* L.). M.Sc. Thesis. College of agriculture, Dharwad University of agricultural sciences. 103p.

Mandefro N. 1999. Heterosis, Combining ability and correlation in 8 x 8 diallel crosses of drought tolerant maize (Z*ea mays* L.) population. M.Sc. Thesis. School of Graduate studies, Alemaya University, Ethiopia.

Mossisa W. Wonde A. Berhanu T. Legesse W. Dagne W. and Grum, A. 2009. Performance of variety cross hybrids of maize (*Zea mays* L.) in the mid- altitude and high land transitional areas of Ethiopia. *East African Journal of science* 3(1): 80-84.

Pandey B.P. and P. Kumar. 2001, heterosis in varietal crosses of maize. Diamond Jubilee Symposium, ISG and PB, New Delhi, 6-9. 129p.

Patterson H.D. and Williams E.R. 1976. A new class resolvable incomplete block designs. *Biometrika* 63: 83-92.

Reddy M.S. and Kidane G. 1993. Dry land Farming in Ethiopia. Review Past and Trust in the Nineties. Institute of Agricultural Research. Addis Ababa, Ethiopia.

Saleh G.B. Abdullah D. and Anuar A.R. 2002, Performance of heterosis and heritability in selected, tropical maize single, double and three way cross hybrids. *Journal of Agricultural Sciences* 138: 21-28.

Tiwari V.K. 2003, Studies on heterosis, combining ability, inbreeding tolerance and phenotypic stability in intra- and inter-group single cross hybrids of maize (*Zea mays* L.). Ph.D. Thesis. GBPUA and T, Pantnagar, India. pp. 173-197.

Twumasi A.S. Habtamu Z. Kassa Y. Bayisa A. Sewagegne T. 2001. Development and improvement o highland maize in Ethiopia. pp. 31-38. In: Proc. Second Natl. Maize Research

Workshop of Ethiopia. 12-16 November 2001. Addis Abeba, Ethiopia.

Twumasi A.S. Kassa Y. and Gudeta N. 2003. Exploitation of Combining Ability and Heterotic

Responses in Maize Germplasm to Develop Cultivars for the Eastern Africa Highlands. pp. 282-283. CIMMYT, 2003. Book of Abstracts: A. R. Hallauer International symposium on Plant Breeding, 17-22 August 2003, Mexico City, Mexico, D. F.

Venugopal M. Ansani N.A. and Murthy G.K. 2002. Heterosis and its component characters in maize (*Zea mays* L.). *Crop Research* 3: 72-74.

Wali M.C. Kachapur R.M. Chandrashekhar C.P. Kulkarni V.R. and Devaranavadagi S.B. 2010. Gene action and combining ability studies in single cross hybrids of maize (*Zea mays* L.). *Karnataka, Journal of Agricultural Sciences* 23(4): 557-562.