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Review paper

Standard Heterosis for Grain Yield and Yield Related Traits of Maize (*Zea mays* L.) Inbred Lines at Haramaya Eastern Ethiopia

Woldu Mogesse[1]*, Habtamu Zelleke [1] and Mandefro Nigussie[2]

[1.]School of Plant Science, College of Agriculture and Environmental Sciences (CAES), Haramaya University (HU), P.O. Box: 138, Dire Dawa, Ethiopia.
[2.] Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia.

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Determination of heterosis in maize hybrids is necessary for their commercial exploitation. Therefore, this study was conducted to estimate the amount of standard heterosis of the hybrids for yield and yield-related traits. The experimental material comprised twenty-eight F_1 hybrids along with two standard checks (BHQPY 545 and MH 138) were evaluated using Alpha-Lattice Design with three replications during 2018 main cropping season at Haramaya University Research Site (Raare). The highest percentage of standard heterosis for grain yield was retained from the crosses L3×L6 (20.58%), L3×L8 (7.65%), over BHQPY 545 and L3×L6 (49.20%), L3×L8 (33.20%), over MH138, indicating these hybrids superior for commercial cultivation. Maximum standard heterosis was recorded for L3 × L6 (25.75%), L1 × L4 (16.99%) and L3 ×L6 (37.82%) for 1000 kernel weight, number of kernels per row and biomass yield, respectively over BHQPY-545, and L3 × L6 (54.79%), L1 × L4 (16.90%) and L3 ×L6 (48.90%), for 1000 kernel weight, number of kernels per row and biomass yield, respectively over MH-138.

Key word*:* Grain yield; Heterosis; Maize

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INTRODUCTION

Maize is an important cereal crop and the demand for its grain is increasing every year because of its diverse uses. Maize is the queen of cereal crops with highest grain yield potential and wider adaptability. Heterosis or hybrid vigour is the enhancement in size, growth, fertility and yield in progeny compared with their inbred parents (Thiemann *et al*., 2014; JIBAN *et al*., 2018). The biological phenomenon of heterosis is described by the trait-specific performance of highly heterozygous F_1 hybrids with respect to the average (mid-parent) or high parent performance of their genetically distinct homozygous parents in measurable characters (Paschold *et al*., 2010). Similarly, heterosis is a phenomenon in which an F_1 hybrid of two genetically dissimilar parents shows superiority over the standard commercial check variety. Therefore, it is also called economic heterosis or superiority over checks. Therefore, a new maize hybrid must be superior to existing cultivars for grain yield and other economic traits. Thus, heterosis in reference to a standard check (Standard heterosis) is important for commercialization of maize hybrids. Hybrid breeders have always been interested in the selection of potential lines among the available parental lines which are expected to give heterotic hybrids to develop higher yielding, better performing hybrids; Hence, the magnitude of heterosis provides information on extent of genetic diversity of parents in developing superior F_1s so as to exploit hybrid vigour and has direct bearing on the breeding methodology to be adapted for varietal improvement and their commercial utilization (Amanullah *et al*., 2011). Therefore in light of this back ground information the objective where set in to estimate the amount of standard heterosis of the hybrids for yield and yield-related traits.

MATERIALS AND METHODS

Description of Study Area

The study was conducted at Haramaya University main campus (Raare research site) in 2017/2018 cropping seasons. The study area is located at an altitude of 1980m.a.s.l. and lies at 9° 26' N latitude and 42°3' E longitude. The area receives average annual rainfall during 2018 main cropping season was 727 mm. The minimum and maximum mean annual temperatures were 8.99°C and 25.15°C, respectively (Haramaya University Weather Station, 2018).

Experimental Materials

The planting materials were comprised of eight maize inbred lines which were crossed in 8×8 half diallel mating design to produce twenty eight F_1 hybrids. The resulting 28 F_1 hybrids and two standard checks (BHQPY 545 and MH 138) were tested in 2017/2018 cropping seasons at Haramaya University main campus (Raare Research Site). List of lines used in the diallel cross is depicted in Table 1.

Table 1: List of inbred lines used in the diallel cross

	Inbred Lines
Code	**Pedigree**
L1	[POOL9Ac7-SR(BC2)]FS211-1SR-1-1-1-#/CML144(BC2)-14-8-4-2-2-1-#-1-B-2
L2	[KIT/SNsyn[N3/TUX]]c1F1-##(GLS=2.5)-32-1-1-#/CML176BC1F1-12-1-3-4-2-#-2-B-1
L3	[POOL9Ac7-SR(BC2)]FS211-1SR-1-1-1-#/CML144(BC2)-14-8-4-3-3-4-#-1-B-4
L4	[POOL9Ac7-SR(BC2)]FS48-1-1-1-1-1-#/CML144(BC2)-6-22-1-1-1-4-#-3-B-1
L5	[POOL9Ac7-SR(BC2)]FS211-1SR-1-1-1-#/CML144(BC2)-14-8-4-3-2-2-#-1-B-1
L6	[POOL9Ac7-SR(BC2)]FS211-1SR-1-1-1-#/CML144(BC2)-14-21-1-3-2-2-#-2-B-4
L7	[POOL9Ac7-SR(BC2)]FS59-2-2-1-1-#/CML144(BC1)F1-3-2-1-2-1-#-1-B-2
L8	[KIT/SNsyn[N3/TUX]]c1F1-##(GLS=2.5)-17-1-1-#/CML144(BC1)F1-5-1-2-1-1-#-2-B-1

Source: Haramaya university maize research program 2017.

Experimental Design and Field Management

The resulting twenty eight F_1 progenies derived from the diallel cross of eight inbred lines along with two commercial hybrid checks (BHQPY545, MH138) were planted using alpha-lattice designs with three replications at Haramaya University main campus (Raare research site) during 2017/2018 cropping seasons. In all cases, two rows per plots were used, where the length of each row was 5.1 m with spacing of 0.75 m between rows and 0.3 m within rows, using three replications. An alley of 1.5m left between the blocks. At planting, two seeds were planted per hill to ensure enough stand, and then thinned to one plant per hill after two weeks of emergence (when seedlings were 3-4 leaf stage) to attain a population density of 44,444 plants per hectare. Urea and NPS fertilizers were applied at the rates of 140kg/ha and 118kg/ha, respectively. Urea was applied in 2 equal splits. The first half application was done at sowing along with NPS fertilizer and the second was applied at the knee high stage of the crop. More over all other necessary field management practices were carried out as per the recommendation for the study area and the crop.

Data Collection

Data on grain yield and other important agronomic traits were collected on plot and individual plant basis. Characters were recorded on plant basis by taking five random plants. The average was taken as the mean of the treatment.

Data collected on the plot basis

Days to anthesis (DA): The number of days from planting up to the date when 50% of the plants started pollen shedding.

Days to silking (DS): The number of days from planting to the date when 50% of the plants produced about 2-3cm long.

Anthesis-silking interval (ASI): This was calculated as the difference between number of days to anthesis and number of days to silking (ASI = DA – DS).

Plant aspect (PA): It was recorded based on a scale of 1 to 5 where, 1 = best genotype (consider ear size, uniformity, disease infestation, husk cover) and 5 = poor genotype within each plot.

Days to physiological maturity (DM): It was recorded as the number of days after sowing to when 50% of the plants in the plot form a black layer at the point of attachment of the kernel with the cob.

Stand count at harvest (SH): It was recorded as the total number of plants at harvest from each experimental unit.

Husk cover (HC): It was recorded as on a scale of 1 to 5; where 1 = tightly covered husk extending beyond the ear tip and 5 = ear tips exposed.

Number of ears harvested (NEH): was recorded as the total number of ears harvested from each experimental unit.

Ear aspect (EA): Was recorded based on a scale of 1 to 5, where 1 = clean, uniform, large, and well filled ears and 5 = ears with undesirable features at time of harvesting from each plot.

Thousand kernel weight (TKW): After shelling, random kernels from the bulk of shelled grain in each experimental unit were taken and a thousand kernels were counted using seed counter and weighted in grams and then adjust to 12.5% grain moisture.

Grain moisture: moisture content (%) present in the grain measured at harvesting by taking a sample of ears and shelling separately for each plot using portable digital moisture tester.

Above ground biomass yield (AGB): Plants from the experimental unit were harvested at physiological maturity and weighed in kg after sun drying and converted to hectare basis.

Grain yield/plot (GY): Grain yield per plot adjusted to 12.5% moisture were recorded in kg/plot using the formula below.

Adjusted grain yield (kg plot^{-1}):

$$\frac{\text{Field of weight (kg/plot)} \times (100\text{-MC}) \times \text{shelling\%}}{(100\text{-}12.5) \times \text{Area harvested (plot size)}}$$

Grain yield/ha (GY): This was obtained by converting grain yield per plot into a hectare basis.

Harvest index (HI): The harvest index was calculated by dividing grain yield (kg/ha) by aboveground biomass yield (kg/ha) and expressed in percentage (Donald, 1962).

Data collected on plant basis

Ear height (EH): The height was measured from the ground level to the uppermost useful ear- bearing node of five randomly taken plants.

Plant height (PH): The height was measured from the soil surface to the tassel starts branching of five randomly taken plants.

Ear length (EL): Length of ears from the base to the tip of ear was measured in centimeters.

Ear diameter (ED): This was measured at the midsection along the ear length, as the average diameter of five randomly taken ears using a caliper.

Number of kernel rows per ear (NKRE): This was recorded as the average number of kernels row per ear from the five randomly taken ears.

Number of kernels per row (NKR): Number of kernels per row was counted and the average recorded from five randomly taken ears.

Method of Data Analysis

For the statistical analysis of variance (ANOVA) parameters like ear rot and husk covers were transformed using square root transformation, $X' = \sqrt{x+0.5}$, as most of the plots had zero values (Gomez and Gomez, 1984). Data obtained for twenty one traits from field measurements were subjected to analysis of variance using PROC GLM procedure of SAS, version 9.0 (SAS, 2002).

Estimation of standard heterosis

Economic/ standard heterosis, the superiority of the F_1 hybrid over the standard commercial hybrid variety, expressed as a percentage. The magnitude of heterosis was estimated in relation to standard checks for traits that showed significant differences among crosses following the method suggested by Falconer and Mackay (1996):

$$\mathbf{SH\ (\%) = \left(\frac{F1-SV}{SV}\right)\times 100}$$

Where;

SH= standard heterosis, and
S_V=standard variety,
F_1=mean performance of F_1

The differences in the magnitude of heterosis tested following the procedure of (Panse Sukhatme, 1961). Standard error and critical difference were also computed as:

$$\mathbf{SE\ (d) = \frac{\sqrt{2MSe}}{r}}$$
$$\mathbf{CD = SE\ (d) \times t}$$

Where;

SE (d) is standard error of the difference.
MSe = error mean square from analysis of variance
r = the number of replication
CD =Critical difference
t= value of t at error degree of freedom.

The test of significance of heterosis in relation to standard check was done by't' test as suggested by Snedecor and Cochran (1967) as follows:

$$\mathbf{Heterosis\ 't' = \frac{Mean\ of\ F1 - standard\ check}{\sqrt{\frac{2mse}{r}}}}$$

The computed t-value was compared with the t-value at error degree of freedom corresponding to 5 or 1% level of significance.

RESULT AND DISCUSSION

Analysis of Variance (ANOVA)

The Analysis of variance (ANOVA) due to mean square of genotypes (entries) that comprise twenty eight F_1 hybrids along with two standard checks showed significant difference for yield and yield related traits as well as disease reaction (Table 2). This indicated the presence of variability among the genotypes evaluated. Therefore, this genetic variability provides an opportunity for breeders to select promising genotypes for specific traits. As a result, it could be utilized for the future improvement of in maize.

Mean square of genotypes for grain yield and yield related traits revealed highly significant ($p<0.01$) for the traits studied such as grain yield, biomass yield, days to anthesis, days to silking, plant and ear height, husk cover, ear rot, plant aspect, ear aspect, common rust (*Puccinia sorghi*), days to maturity, thousand kernel weight, kernels per row, and *Turccicum* leaf blight (TLB). The existence of highly significant differences indicates the presence of inherent (genetic) variation among the materials evaluated, which makes selection possible for further breeding program (Dan *et al*., 2018). On the other hand ear length, ear diameter, kernel rows per ear, anthesis silking interval and harvest index, which showed significant difference ($P<0.05$) (Table-2). Therefore, this result highlights the presence of sufficient genetic variability among the genotypes. The presence of variability among the genotypes for character of interest enables the breeder to conduct appropriate selection of the most desirable crosses combination. This is in line with Bullo and Dagne, 2016, Matin *et al.,* 2017 who evaluate maize F_1 crosses for the same purpose.

Table 2: Mean Square of Genotypes for Grain Yield and Related Traits Evaluated at Haramaya, Eastern Ethiopia.

Source of variation	df	Mean squares										
		GY (t/ha)	DT (day)	DS (day)	ASI (day)	PS (scale)	ET (scale)	PA (scale)	PH (cm)	EH (cm)	EA (scale)	HC (#)
Rep	2	5.03	3.34	4.57	0.28*	0.09	0.03	0.03	112.83	198.28	0.01	1.14**
Blk/(Rep)	10	1.26	0.87	1.69	0.05	0.04	0.04	0.08	141.15	37.1	0.05	0.47*

Table 2. Continues

Genotypes	29	6.80**	9.55**	8.40**	0.15*	0.11**	0.13**	0.17**	1212.08**	401.90**	0.73**	2.08**
Error	48	1.75	1.08	1.19	0.08	0.03	0.06	0.05	192.26	65.18	0.08	0.18

		EPP (#)	DM (day)	EL (cm)	ED (cm)	NKR (#)	NKRE (#)	TKW (gm)	BY (t/ha)	ER (#)	HI (%)
Rep	2	0.02	1.42	1.41	0.09	3.83	2.44	1277.02	39.63	1.28**	25.54
Blk(Rep)	10	0.01	0.77	5.66	0.19	3.54	4.03	3644.99	7.45	0.19	14.62
Genotypes	29	0.18**	97.97**	9.38*	0.77*	30.04**	8.33*	10491.39**	48.58**	0.53**	39.56*
Error	48	0.02	0.69	5.29	0.45	4.17	4.63	4056.71	17.09	0.23	20.93

** = Significant at P<0.01 level of probability , * = Significant at P<0.05 Level of probability, GY= grain yield, BM=biomass yield, DA = number of days to anthesis, ED = ear diameter, EH = ear height, EL = ear length, EPP =number of ear per plant , NKR = number of kernels per row, PH = plant height, NKRE = Number of kernel rows per ear, DS = number of days to silking, TKW = thousand kernels weight, MD=maturity date, PA=plant aspect and EA=ear aspect, HC=husk cover, ASI= anthesis silking interval, HI=harvest index, ER=ear rot, ET=*Turccicum*leafblight and PS=*Pucciniasorgh*i(rust).

Mean Performance of Genotypes

The mean performances of all the crosses along with the two standard checks BHQPY-545 and MH-138 for all of the studied traits are presented in Table 3.

The mean of grain yield for crosses tested under this experiment ranged from the lowest 3.97 ton ha^{-1} for L1×L5 to the highest 11.19 ton ha^{-1} for L3×L6 with the average value of 7.96 ton ha^{-1}. The top four high yielding crosses L3×L6 (11.19 ton ha^{-1}), L3×L8 (9.99 ton ha^{-1}), L2×L5 (9.33 ton ha^{-1}), and L6×L8 (9.31 ton ha^{-1}) exhibited higher mean value of grain yield relative to one of the best checks BHQPY-545 (hybrid check with mean value of GY 9.28 ton ha^{-1}). On the other hand, the mean value of twenty crosses showed higher grain yields than the total average grain yield (7.96 ton ha^{-1}) and out-yielded the grand mean of the second check MH-138 (hybrid check with the mean value of GY of 7.50 ton ha^{-1}) (Table 3). As a result, these crosses that illustrated better mean performance than the standard checks indicate the possibility of obtaining a good hybrid, with many desirable traits to enhance grain yield. These results agreed with those reported by Shushay (2014) and Girma *et al.* (2015) who reported significant mean performance of GY and yield related traits over the best hybrid check (BHQPY-545) in the study of combining ability of maize inbred lines for grain yield and yield related traits. The same author Berhanu (2009) found the highest grain yield of 14.07 t/ha and the lowest grain yield of 4.90 t/ha in test crosses of maize inbred lines evaluated at Bako, Hawassa and Jimma Research Centers.

Concerning the biomass yield, the highest mean value was 27.77 ton ha^{-1} obtained from the cross L3×L6 and the lowest biomass yield was 11.0 ton ha^{-1} obtained from the cross L1×L5 with the mean value of 19.97 for biomass yield. Similarly, the mean value of thousand kernel weight ranged from the highest 472.42gm for L3×L6 to the lowest 226.00gm in L1×L5 with the average value of 360.4gm for thousand kernel weight. On the other hand the mean value of harvest index ranged from 47.26 for L2×L8 to 33.84 for L3×L4 with the mean value of 40.44 for harvest index.

Concerning the days to maturity ranged from the highest 170.33days for L6×L8 and L3×L5 to the lowest 141.67days for L4×L6 with the mean value of 164.34 days for maturity date. Early maturing crosses could be promoted for the development of early maturing varieties for moisture stress environments since earliness are desirable to increase water and land use efficiency.

Table 3: Mean performance of maize hybrids for grain yield and yield related traits obtained from 8×8 diallel cross at Haramaya Eastern Ethiopia in 2018 main cropping season

Crosses	GY (t/ha)	BM (t/ha)	HI (%)	DT (day)	DS (day)	ASI (day)	EL (cm)	ED (cm)	NKR (#)	NKRE (#)	TKW (gm)
L1×L2	5.91	13.39	44.14	79.00	82.00	3.00	17.32	4.24	40.87	11.89	309.70
L1×L3	6.29	17.62	39.54	80.00	83.00	3.00	14.65	3.98	37.00	11.61	330.32
L1×L4	9.18	20.72	44.48	77.33	80.67	3.33	19.50	4.86	44.07	14.98	448.42
L1×L5	3.97	11.00	36.60	82.33	85.33	3.00	15.26	3.88	36.00	12.41	226.00
L1×L6	8.74	19.51	45.08	77.67	80.67	3.00	17.69	4.31	41.20	14.13	326.50
L1×L7	7.75	21.47	36.84	78.00	81.00	3.00	15.30	3.97	41.47	11.36	306.53
L1×L8	7.24	15.52	46.63	79.33	82.33	3.00	19.03	5.20	42.53	16.23	321.48
L2×L3	8.47	18.80	45.07	82.00	85.00	3.00	19.21	4.59	38.73	12.90	384.20
L2×L4	7.97	19.38	41.20	78.67	81.67	3.00	16.55	4.64	41.13	14.29	346.77
L2×L5	9.33	22.65	41.22	80.00	83.00	3.00	19.94	4.83	37.67	13.39	417.22
L2×L6	7.29	18.10	40.18	80.33	83.33	3.00	18.10	3.77	40.87	12.94	380.29
L2×L7	8.07	18.01	45.22	78.33	81.33	3.00	18.63	4.58	41.07	13.09	332.90
L2×L8	8.02	17.00	47.26	80.00	83.67	3.67	19.21	4.92	41.27	14.69	382.11
L3×L4	9.12	27.11	33.84	77.67	80.67	3.00	14.49	3.42	41.27	9.59	421.20
L3×L5	7.95	18.16	44.07	78.00	81.00	3.00	18.65	4.89	41.73	13.17	365.97
L3×L6	11.19	27.77	40.35	77.00	80.67	3.67	17.49	4.35	39.93	11.20	472.42
L3×L7	6.60	18.91	38.61	81.00	84.00	3.00	14.43	3.84	40.13	11.05	293.85
L3×L8	9.99	25.58	39.18	78.00	81.00	3.00	19.97	5.39	42.13	16.02	393.84
L4×L5	4.86	12.07	39.73	82.33	85.33	3.00	19.16	4.83	34.53	13.84	234.84
L4×L6	9.15	23.23	39.24	76.33	79.67	3.33	16.74	4.16	37.53	12.34	359.37
L4×L7	7.80	20.77	37.51	78.67	81.67	3.00	18.05	4.43	42.20	11.70	325.38
L4×L8	6.08	15.74	38.72	78.33	81.33	3.00	16.03	4.10	41.50	11.85	284.59
L5×L6	7.69	20.73	37.14	77.67	80.67	3.00	17.59	4.09	42.47	11.15	400.91
L5×L7	7.41	20.80	35.82	79.67	82.67	3.00	18.80	4.63	43.20	13.03	381.44
L5×L8	8.80	23.45	37.26	77.33	80.67	3.33	18.56	4.63	38.93	12.39	451.34
L6×L7	8.95	23.96	37.37	78.33	81.33	3.00	18.13	4.72	38.40	13.14	370.82
L6×L8	9.31	26.22	35.60	83.33	86.67	3.33	16.29	4.51	28.47	12.32	403.03
L7×L8	8.75	22.72	38.51	80.33	83.33	3.00	14.47	3.67	38.53	11.27	319.92
BHQPY	9.28	20.15	46.19	78.67	83.00	3.67	19.74	5.67	37.70	17.04	375.67
MH138	7.50	18.65	40.53	78.00	81.00	3.00	16.11	4.24	37.67	13.42	305.20
CV	16.60	20.70	11.31	1.26	1.25	9.02	13.14	15.07	5.16	16.62	17.67
LSD	2.17	6.79	7.51	1.64	1.69	0.46	3.77	1.10	3.35	3.53	104.00
Max	11.19	27.77	47.26	83.33	86.67	3.67	19.97	5.67	44.07	17.04	472.42
Mean	7.96	19.97	40.44	79.12	82.26	3.11	17.50	4.44	39.67	12.95	360.40
Min	3.97	11.00	33.84	76.33	79.67	3.00	14.43	3.42	28.47	9.59	226.00

** = Significant at P<0.01 level of probability, * = Significant at P<0.05 Level of probability, GY= grain yield, BM=biomass yield, DA = number of days to anthesis, ED = ear diameter, EL = ear length, NKR = number of kernels per row, NKRE = Number of kernel rows per ear, DS = number of days to silking, TKW = thousand kernels weight , ASI= anthesis silking interval, HI=harvest index,

Table 3. Continued

Crosses	PS (scale)	ET (scale)	PA (scale)	PH (cm)	EH (cm)	EA (scale)	ER (#)	MD (day)	HC (#)	EPP (#)
L1×L2	1.50	2.00	1.67	198.33	93.33	2.17	1.74	161.67	1.05	1.03
L1×L3	1.50	1.83	2.00	170.00	70.00	2.33	1.43	160.33	1.05	1.02
L1×L4	1.00	1.33	1.33	211.67	101.67	1.17	1.10	167.67	0.71	1.53
L1×L5	1.50	1.50	2.00	185.00	83.33	2.50	1.56	161.00	0.88	1.10
L1×L6	1.33	1.50	1.33	203.33	90.00	1.50	1.00	168.33	0.71	1.50
L1×L7	1.50	1.50	1.83	198.33	93.33	1.33	1.17	156.00	1.84	1.03
L1×L8	1.50	1.50	1.50	196.67	96.67	1.83	1.56	160.00	1.05	1.05
L2×L3	1.50	1.50	1.50	180.00	83.33	1.50	1.00	165.33	0.88	1.28
L2×L4	1.67	1.67	1.67	200.00	90.00	2.17	2.18	163.00	3.68	1.16
L2×L5	1.33	1.33	1.67	211.67	105.00	1.50	1.39	168.00	3.15	1.15
L2×L6	1.67	1.67	1.50	195.00	96.67	1.50	1.95	160.33	1.77	1.05
L2×L7	1.50	1.50	1.50	203.33	101.67	1.17	1.44	160.67	1.76	1.02
L2×L8	1.50	1.67	1.50	190.00	96.67	1.33	1.55	160.67	1.00	1.02
L3×L4	1.50	1.50	1.83	178.33	88.33	1.17	1.10	168.33	1.00	1.14
L3×L5	1.17	1.33	1.50	190.00	100.00	1.67	1.65	170.33	0.88	1.28
L3×L6	1.00	1.50	1.50	215.00	98.33	2.17	2.41	170.00	4.04	1.82
L3×L7	1.50	1.50	1.50	201.67	103.33	1.33	1.17	168.33	0.71	1.12
L3×L8	1.17	1.17	1.17	221.67	115.00	1.33	1.87	169.67	2.41	1.42
L4×L5	1.50	1.50	1.83	183.33	80.00	3.00	1.72	163.67	1.34	1.00
L4×L6	1.33	1.33	1.50	210.00	98.33	1.50	1.17	141.67	1.00	1.23
L4×L7	1.50	1.67	1.50	196.67	95.00	1.83	1.44	167.67	1.18	1.11
L4×L8	1.50	1.50	1.50	218.33	108.33	2.33	2.08	164.67	1.43	1.11
L5×L6	1.50	1.83	1.50	206.67	101.67	1.83	1.57	164.33	1.44	1.07
L5×L7	1.50	1.50	1.50	191.67	95.00	1.50	1.10	168.33	1.10	1.01
L5×L8	1.17	1.17	1.50	200.00	108.33	1.50	1.00	164.67	0.71	1.55
L6×L7	1.33	1.67	1.67	198.33	100.00	1.50	1.64	169.33	1.68	1.35
L6×L8	1.83	1.83	2.33	125.00	60.00	3.00	1.60	170.33	0.71	1.01
L7×L8	1.67	2.00	1.50	151.67	85.00	1.50	1.00	163.67	0.71	1.63
BHQPY	1.17	1.33	1.34	203.33	101.67	1.33	1.00	169.00	1.68	1.79
MH138	1.50	1.67	1.49	160.00	78.33	1.67	1.01	163.33	0.71	1.36
CV	12.47	15.38	13.41	7.18	8.59	16.65	33.28	0.51	30.13	12.48
LSD	0.29	0.39	0.35	22.76	13.25	0.48	0.78	0.78	0.18	0.25
Max	1.83	2.00	2.33	221.67	115.00	3.00	2.41	170.33	4.04	1.82
Mean	1.43	1.55	1.59	193.17	93.94	1.74	1.45	164.34	1.41	1.23
Min	1.00	1.17	1.17	125.00	60.00	1.17	1.00	141.67	0.71	1.00

** = Significant at P<0.01 level of probability, * = Significant at P<0.05 Level of probability, EH = ear height, EL = ear length, EPP =number of ear per plant, PH = plant height,MD=maturity date, PA=plant aspect and EA=ear aspect, HC=husk cover, , ER=ear rot, ET=*Turciccum* leaf blight and PS=*Puccinia*sorgi (rust)

The highest mean value of number of kernel per row was 44.07 that obtained from L1×L4, while the least number of kernels per row was 28.47 for L6×L8 with the average value of 39.67 for number of kernel per row. On the other hand, the higher average performance for number of kernel row per ear was recorded from standard check BHQPY 545(17.04) while the lowest number of kernel row per ear recorded from the cross L3×L4 was 9.59 with the mean value of 12.95 for number of kernel row per ear. Generally the highest kernel per row and kernel row per ear are desirable to enhance grain yield as they are directly correlated.

Concerning number of ear per plant, the highest mean value was recorded 1.82 from L3×L6 and the lowest 1.0 from L4×L5 with the mean value of 1.23 for number of ear per plant. The highest mean values of number of ears per plant were observed from the crosses L3 × L6 (1.82) compared to the highest check BHQPY545 (1.79). This indicated that the cross (L3×L6) were highly prolific as compared to the standard check BHQPY-545, thus which are desirable to enhance grain yield.

The highest mean value for ear length was 19.97cm for L3×L8 and the lowest recorded was 14.43cm for L3×L7 with the mean value17.5cm for ear length. Hybrids with longer ear length indicated that they have inherent genetic potential for longer ear length. Similarly, ear diameter ranged from the highest 5.67cm for (BHQPY 545 (hybrid check)) to the lowest cross of 3.42cm for (L3×L4). Hybrids with wide ear diameter indicated that they have inherent genetic potential for wider ear diameter, which are desirable to enhance grain yield.

The maximum mean value of plant height was recorded 221.67cm from L3×L8 and the minimum value125cm from L6×L8 with average value of 193.17cm for plant height. Similarly, the highest ear height was 115cm for L3×L8 and the lowest record was 60cm obtained from L6×L8 with the mean value of 93.94cm for ear height. The crosses which have shorter plant height and medium ear placement are desirable for lodging resistance and to apply necessary management practices, whereas taller crosses are important to harvest high biomass yield that could be used as animal feed, fencing and source of fuel for resource poor farmers (Girma *et al*., 2015).

The variation for number of days to 50% silking ranged from 86.67days for L6×L8 to 79.67days for L4×L6 with the mean value of crosses 82.26 days for female flowering. Similarly, the number of days to 50% anthesis ranged from 83.33days for L6×L8, to 76.33days for L4×L6 with the mean value of the crosses 79.14 days for male flowering. The crosses which showed longer number of days to anthesis and silking could be considered as late maturing types. Conversely, the crosses which had shorter days to flowering could be regarded as early maturing types. As a result, the crosses which exhibited early anthesis and silking are desirable type of crosses especially in moisture stress environments since early mature crosses are desirable to escape terminal moisture stresses during the growth stages (Banziger *et al*., 2004).

Anthesis-silking interval (ASI) ranged from 3 days for (L1×L2, L1×L3, L1×L5, L1×L6, L1×L7, L1×L8, L2×L3, L2×L4, L2×L5, L2×L6, L3×4, L3×L5) to 3.67days for (L2×L8, L3×L6 and BHQPY-545) with overall mean of 3.11. The anthesis silking interval (ASI) is the most important trait in determining drought tolerance. Moreover, the crosses which exhibited low anthesis-silking interval (ASI) indicates that the cross had short gaps between days to anthesis and silking, which are desirable character for good seed setting and drought tolerance. On the other hand, if the gap between days to anthesis and silking is large, the viability of pollen would be minimized and abnormal fertilization might be taking place or fertilization may not happen consequently, that leads to yield lose.

The ear rot severity score varied from 1.0 in F_1 crosses namely L1×L6, L2×L3, L6×L8, and L7×L8, to 2.4 in L3×L6 with overall mean of 1.45, whereas *Turccicum* leaf blight severity ranged from 1.17 for (L3×L8, L5×L8) to 2.0 for (L1×L2, L7×L8) with overall mean of 1.55. Generally, the TLB severity varies from low to moderate level. In the case of *Puccinia sorghi* (common rust), the lowest severity was observed 1.0 in L1×L4, L3×L6 to the highest 1.83 in L6×L8 with overall mean of 1.43. On the other hand mean values for husk cover ranged from 0.71 for (L1×L6, L1×L4, L3×L7, L5×L8, L6×L8, L7×L8) to 4.04 for (L3×L6) with overall mean of 1.41. As a result, poor husk cover increases the susceptibility of genotypes for ear rot and field infestation of weevil and bird before harvest. On the contrary, materials with good husk cover could be promoted to the next stages of trial evaluation.

Plant and ear aspects are a visual evaluation of plants and ears before harvesting and at harvesting time respectively, by observing overall performance. Plant aspect was scored on 1-5 scale and the mean values ranged from 1.17 for L3×L8 to 2.3 for L6×L8 with an overall mean of 1.59. Similarly, Ear aspect was also scored on 1-5 scale and the mean values ranged from 1.17 for L3×L4, L2×L7 and L1×L4 to 3.0 for L4×L5 and L6×L8 with overall mean of 1.74. The lower plant and ear aspect scores, indicating that these crosses had desirable characters such as clean, uniform, disease free and well grain filling and could be promoted to the next stage of trial evaluation if they are high yielding and have performed well in other traits. The reverse holds true for higher plant and ear aspect. Generally a number of crosses showed better mean performances for more than one traits as compared to the best hybrid check used in the study. Therefore, crosses that had high grain yield could be used in the breeding program to improve the grain yield and other traits of interest.

Estimation of Standard Heterosis

In the present study the magnitudes and directions of heterosis in F_1 hybrids varied from character to character and cross to cross. Accordingly, the different magnitudes and directions of standard heterosis expressed by the F_1 hybrids for yield and its components for twenty-eight crosses over the two commercial checks namely: BHQPY-545 and MH-138 are presented in Table 4. The estimates of heterosis over the best standard check were computed for grain yield and yield related traits that showed significant differences among genotypes. Thus, positive, negative, significant and non-significant standard heterosis was observed even within a trait for almost all of the observation analyzed compared with the two standard checks (BHQPY-545 and MH-138). This indicates the presence of considerable amount of heterosis for improving grain yield and yield related traits including disease reaction. These result were comparable with the report of (Shushay, 2014; Mahantesh, 2006) observed varying degree of heterosis for grain yield and its related traits in maize.

Number of ear per plant: The estimated heterosis over the two standard checks BHQPY-545 and MH-138 for Number of ear per plant crosses varied from -43.58% to 1.68% and -25.00% to 33.82% respectively. Twenty-six crosses showed significantly lower number of ear per plant than BHQPY-545 while only one of the cross showed higher number of ear per plant than BHQPY-545. Which indicates this crosses is highly prolific than one of the best standard check (BHQPY-545).This crosses is also desirable to enhance grain yield. On the other hand nine hybrids showed significantly lower number of ear per plant than MH-138 while three of the cross showed significantly higher thousand kernel weights than MH-138.

Table 4: Estimates of standard heterosis for yield and yield related trait of maize inbred lines evaluated at Haramaya, eastern Ethiopia.

Cross	GY		EL		NKR		NKRE	
	BHQPY545	MH138	BHQPY545	MH138	BHQPY545	MH138	BHQPY545	MH138
L1×L4	-1.08	22.40*	-1.22	21.04*	16.90**	16.99**	-12.09	11.62
L1×L6	-5.82	16.53*	-10.39	9.81	9.28	9.37*	-17.08	5.29
L1×L7	-16.49*	3.33	-22.49*	-5.03	10.00	10.09*	-33.33**	-15.35
L2×L3	-8.73	12.93	-2.68	19.24	2.73	2.81	-24.30*	-3.87
L2×L4	-14.12*	6.27	-16.16*	2.73	9.10*	9.19*	-16.14	6.48
L2×L5	0.54	24.40*	1.01	23.77*	-0.08	0.00	-21.42*	-0.22
L2×L7	-13.04*	7.60	-5.62	15.64	8.94*	9.03*	-23.18*	-2.46
L2×L8	-13.58*	6.93	-2.68	19.24	9.47*	9.56*	-13.79	9.46
L3×L4	-1.72	21.60*	-26.60**	-10.06	9.47*	9.56*	-43.72**	-28.54*
L3×L5	-14.33*	6.00	-5.52	15.77	10.69*	10.78*	-22.71*	-1.86
L3×L6	20.58**	49.20**	-11.40	8.57	5.92	6.00	-34.27**	-16.54
L3×L8	7.65	33.20**	1.17	23.96*	11.75*	11.84**	-5.99	19.37
L4×L6	-1.40	22.00*	-15.20	3.91	-0.45	-0.37	-27.58*	-8.05
L4XL7	-15.95*	4.00	-8.56	12.04	11.94**	12.03**	-31.34**	-12.82
L5×L6	-17.13*	2.53	-10.89	9.19	12.65**	12.74**	-34.57**	-16.92
L5×L8	-5.17	17.33*	-5.98	15.21	3.26	3.34	-27.29*	-7.68
L6×L7	-3.56	19.33	-8.16	12.54	1.86	1.94	-22.89*	-2.09
L6×L8	0.32	24.13*	-17.48*	1.12	-24.48**	-24.42**	-27.70*	-8.20
L7×L8	-5.71	16.67*	-26.70**	-10.18	2.20	2.28	-33.86**	-16.02
SE(d)	0.71	0.71	1.88	1.88	1.67	1.67	1.76	1.76
CD5%	1.19	1.19	3.16	3.16	2.80	2.80	2.96	2.96
CD1%	1.71	1.71	4.53	4.53	4.03	4.03	4.25	4.25

** = Significant at P<0.01 level of probability, * = Significant at P<0.05 Level of probability, GY= grain yield, EL = ear length, NKR = number of kernels per row, NKRE = Number of kernel rows per ear, CD =critical difference, SE (d) =standard error difference.

Table 4. Continued

Cross	DT		DS		PH		EH	
	BHQPY545	MH138	BHQPY545	MH138	BHQPY545	MH138	BHQPY545	MH138
L1×L4	-1.70	-0.86	-2.81*	-0.41	4.100	32.29**	0.00	29.80**
L1×L6	-1.27	-0.42	-2.81*	-0.41	0.000	27.08**	-11.48*	14.90*
L1×L7	-0.85	0.00	-2.41*	0.00	-2.460	23.96**	-8.20	19.15*
L2×L3	4.23**	5.13**	2.41*	4.94**	-11.47*	12.50*	-18.04**	6.38
L2×L4	0.00	0.86	-1.61	0.82	-1.640	25.00**	-11.48*	14.90*
L2×L5	1.69	2.56*	0.00	2.47**	4.100	32.29**	3.28	34.05**
L2×L7	-0.43	0.42	-2.01	0.41	0.000	27.08**	0.00	29.80**
L2XL8	1.69	2.56**	0.80	3.29	-6.560	18.75**	-4.92	23.41**
L3×L4	-1.27	-0.42	-2.81*	-0.41	-12.30*	11.460	-13.12*	12.77
L3×L5	-0.85	0.00	-2.41*	0.00	-6.560	18.75*	-1.64	27.67**
L3×L6	-2.12	-1.28	-2.81*	-0.41	5.740	34.38**	-3.29	25.53**
L3×L8	-0.85	0.00	-2.41*	0.00	9.020	38.54**	13.11*	46.81**
L4×L6	-2.97**	-2.14	-4.01**	-1.64	3.280	31.25**	-3.29	25.53**
L4×L7	0.00	0.86	-1.61	0.82	-3.280	22.92**	-6.56	21.28**
L5×L6	-1.27	-0.42	-2.81*	-0.41	1.640	29.17**	0.00	29.80**
L5×L8	-1.70	-0.86	-2.81*	-0.41	-1.640	25.00**	6.55	38.30**
L6×L7	-0.43	0.42	-2.01	0.41	-2.460	23.96**	-1.64	27.67**
L6×L8	5.92**	6.83**	4.42**	7.00**	-38.52**	-21.88**	-40.99**	-23.40**
L7×L8	2.11	2.99**	0.40	2.88**	-25.41**	-5.21**	-16.40**	8.52
SE(d)	0.85	0.85	0.89	0.89	11.32	11.32	6.59	6.59
CD5%	1.43	1.43	1.49	1.49	19.01	19.01	11.06	11.06
CD1%	2.05	2.05	2.15	2.15	27.30	27.30	15.90	15.90

** = Significant at P<0.01 level of probability, * = Significant at P<0.05 Level of probability, DA = number of days to anthesis, EH = ear height, PH = plant height, DS = number of days to silking, SE (d) =standard error difference and CD = Critical difference.

Table 4. Continued

Cross	TKW		EPP		MD	
	BHQPY545	MH138	BHQPY545	MH138	BHQPY545	MH138
L1×L4	19.37	46.93**	-14.53*	12.50	-0.79*	2.66**
L1×L6	-13.09	6.98	-16.20*	10.29	-0.40	3.06**
L1×L7	-18.40	0.44	-42.46**	-24.26**	-7.69**	-4.49**
L2×L3	2.27	25.88	-28.4**	-5.88	-2.17**	1.22**
L2×L4	-7.69	13.62	-35.20**	-14.71*	-3.55**	-0.20
L2×L5	11.06	36.70*	-35.75**	-15.44*	-0.59	2.86**
L2×L7	-11.38	9.08	-43.02**	-25.00**	-4.93**	-1.63**
L2×L8	1.71	25.20	-43.02**	-25.00**	-4.93**	-1.63**
L3×L4	12.12	38.01*	-36.31**	-16.18*	-0.40	3.06**
L3×L5	-2.58	19.91	-28.49**	-5.88	0.79*	4.29**
L3×L6	25.75**	54.79**	1.68	33.82**	0.59	4.08**
L3×L8	4.84	29.04*	-20.67**	4.41	0.40	3.88**
L4×L6	-4.34	17.75	-31.28**	-9.56	-16.17**	-13.26**
L4XL7	-13.39	6.61	-37.99**	-18.38*	-0.79*	2.66**
L5×L6	6.72	31.36*	-40.22**	-21.32*	-2.76**	0.61
L5×L8	20.14	47.88**	-13.41*	13.97*	-2.56**	0.82*
L6×L7	-1.29	21.50	-24.58**	-0.74	0.20	3.67**
L6×L8	7.28	32.05*	-43.58**	-25.74**	0.79*	4.29**
L7×L8	-14.84	4.82	-8.94	19.85*	-3.15**	0.21
SE(d)	52.00	52.00	0.12	0.12	0.68	0.68
CD5%	87.31	87.31	0.20	0.20	1.14	1.14
CD1%	125.42	125.42	0.29	0.29	1.64	1.64

** = Significant at P<0.01 level of probability, * = Significant at P<0.05 Level of probability, EPP =number of ear per plant, silking, TKW = thousand kernels weight, MD=maturity date, SE (d) =standard error difference and CD = Critical difference.

Days to maturity: The estimated heterosis over the two standard checks BHQPY-545 and MH-138 for days to maturity crosses varied from -16.17% to 0.79 % and -13.26% to 4.29% respectively. Eighteen hybrids revealed significantly earlier than one of the best check (BHQPY-545), which are desirable for days to maturity which helps for adjusting cropping pattern. However, two crosses showed significantly late maturity date than the check hybrid BHQPY-545. On the other hand, nine hybrids revealed significantly lower days to maturity than MH-138 while fifteen hybrids showed significantly higher days to maturity than MH-138. Generally, negative heterosis for days to maturity was desirable for the development of early maturing varieties than the check. As a result early maturing crosses are desirable to escape drought or terminal moister stress and frost.

Plant Height: Hybrid performance with respect to standard heterosis over the two commercial hybrid checks BHQPY-545 and MH-138 for plant height ranged from -38.52% to 9.02 % and -21.88% to 38.54% respectively. Among all six hybrids showed significantly lower plant height than BHQPY-545 while none of the crosses showed significantly higher plant height than

BHQPY-545. On the other hand, two hybrids showed significantly lower plant height than MH-138 while twenty-four hybrids showed significantly higher plant height than MH-138. Generally, negative heterosis for plant height is desirable for breeding short statured hybrids and which implied that these hybrids would resistance to lodging and mature earlier. On the other hand the crosses which showed significantly higher plant height gave higher grain yield, which could be attributed to high photosynthetic products accumulation during long period for grain filling. These results agreed with the finding of (Shushay, 2014; Reddy *et al*., 2015; Natol *et al*., 2017; Matin *et al.,* 2017) who reported both negative and positive values of standard heterosis for plant height.

Ear Height: Hybrid performance with respect to standard heterosis over the two standard checks BHQPY545 and MH138 for ear height ranged from -40.99% to 13.11% and 23.40% to 46.81% respectably. Among all the tested genotypes, nine hybrids exhibited significantly lower ear placement than the check hybrid BHQPY-545 while only one hybrid showed significantly higher ear placement than the hybrid check BHQPY-545. On the other hand, one crosses showed significantly lower ear height than check hybrid MH-138 while twenty-one crosses showed significantly higher ear height than check hybridMH-138 (Table 4). Generally, plant and ear heights are the major concern to plant breeders since plants with increased ear and plant heights are vulnerable to lodging and hence yield reduction. On the contrary, low plant and ear height are desirable to reduce stem lodging problems in maize and for ease of mechanized operations. Therefore, the variability existed in the tested crosses could help in the improvement of these traits.

Biomass yield: The estimated heterosis over the two standard checks BHQPY-545 and MH-138 for Biomass yield crosses varied from -45.41% to 37.82% and -41.02% to 48.90% respectively. Among all the tested crosses, three of them showed significantly lower Biomass yield as compared to BHQPY- 545, while three of the cross showed significantly higher Biomass yield than BHQPY-545. Conversely, four crosses showed significantly higher Biomass yield than MH-138 while two of the cross showed significantly lower Biomass yield as compared to MH-138 (Table 4). As a result, high biomass yield are desirable for grain yield improvement, and for farmers who utilize maize Stover for different alternative uses like fire wood, fencing, livestock feed for construction and fuel purpose.

Ear Length: Hybrid performance with respect to standard heterosis over the two standard checks BHQPY-545 and MH-138 for ear length ranged from -26.90% to 1.17% and -10.43% to 23.96% respectively. Among all the tested crosses, nine of them showed significantly lower ear length as compared to BHQPY- 545, while none of the cross showed significantly higher ear length than BHQPY-545. Conversely, three crosses showed significantly higher ear length than MH-138 while none of the cross showed significantly lower ear length as compared to MH-138 (Table 4). As a result, longer ears are desirable and can result in higher grain yield. These results agreed with the finding of Dhoot *et al.* (2017) who reported none of the hybrid exhibited positive significant economic heterosis for ear length in contrast (Natol *et al*., 2017) reported both negative and positive values of standard heterosis for ear length.

Number of Kernels Row per Ear: The estimated heterosis over the two standard checks BHQPY-545 and MH-138 for number of kernels row per ear crosses ranged from -35.15% to -4.75% and -28.54% to 20.94% respectively. Twenty-one of the crosses showed significantly lower number of kernels row per ear than BHQPY545 while none of the crosses showed significantly higher number of kernels row per ear than BHQPY545. Conversely, only one cross showed significantly lower number of kernel row per ear than MH-138 while none of the crosses showed significantly higher number of kernels row per ear than MH-138. These results were comparable with the finding of (Dhoot *et al*., 2017) who reported none of the hybrid exhibited positive significant economic heterosis for kernel row per ear in contrast (Amiruzzaman, 2010) who reported both significant negative and positive values of standard heterosis for kernel row per ear.

Number of Kernels per Row: Hybrid performance with respect to standard heterosis over the two standard checks BHQPY-545 and MH-138 for Number of Kernels per Row ranged from -24.48% to 16.90% and -24.42% to 16.99% respectively. Among all fourteen crosses showed significantly higher number of kernels per row as compared to BHQPY-545 while only two crosses showed significantly lower number of kernels per row than BHQPY-545. On the other hand, sixteen crosses showed significantly higher number of kernel per row as compared to MH-138 while only one cross showed significantly lower number of kernels per row than MH-138. These results agreed with the finding of (Reddy *et al*., 2015; Natol *et al*., 2017) who reported both negative and positive values of standard heterosis for number of kernel per row.

Thousand Kernel Weight: The estimated heterosis over the two standard checks BHQPY-545 and MH-138 for thousand kernel weight crosses varied from -39.84% to

25.75% and -25.95% to 54.79% respectively. Among all two crosses showed significantly lower thousand kernel weight than BHQPY-545 while only one cross showed significantly higher thousand kernel weights than BHQPY-545. On the contrary, eight hybrids showed significantly higher thousand kernel weights than MH-138 while none of the crosses showed significantly lower thousand kernel weights than MH-138 (Table 4). These results agreed with the finding of (Natol *et al*., 2017; Amiruzzaman, 2010; Matin *et al.,* 2017; Reddy *et al*., 2015; Ziggiju *et al*.,2016; Shushay, 2014) who reported both negative and positive values of standard heterosis for thousand kernel weight.

Grain Yield: Hybrid performance with respect to standard heterosis over the two standard checks BHQPY-545 and MH-138 for grain yield ranged from -57.22% to 20.58% and -47.07% to 49.20% respectively. Among all only one crosses showed significantly higher grain yield as compared to BHQPY-545 whereas sixteen hybrids showed significantly lower grain yield than BHQPY-545. On the other hand, ten hybrids exhibited significantly higher grain yield as compared to MH-138 while five crosses showed significantly lower grain yield than MH-138(Table 4). As a result, the crosses which showed higher than the commercial standard check are desirable for the improvement of productivity of maize grain yield by exploiting maximum heterosis. Presence of positive and significant standard heterosis for grain yield was reported by (Berhanu, 2009, Tajwar and Chakraborty, 2013). The same author (Amiruzzaman, 2013; Melkamu, 2013; Shushay, 2014; Girma *et al*., 2015; Reddy *et al*., 2015; Natol *et al*., 2017; Matin *et al.,* 2017) found significant positive and negative values of standard heterosis for grain yield.

Days to tasseling: Hybrid performance with respect to standard heterosis over the two standard checks BHQPY-545 and MH-138 for days to tasseling ranged from -2.97% to 4.65 % and -2.14% to 6.83% respectively. Thirteen hybrids showed significantly lower days to tasseling than one of the best standard check BHQPY-545 while five crosses showed significantly higher days to tasseling than BHQPY-545. On the other hand, seven hybrids revealed non-significant negative value of standard heterosis for days to tasseling over MH-138 while ten hybrids showed significantly higher days to tasseling than MH-138. Consequently, negative and significant standard heterosis for days to tasseling is desirable direction as it indicates earlier tasseling of the crosses than the standard check and the reverse is true for the crosses with positive and significant standard heterosis.

Days to silking: The estimated heterosis over the two standard checks BHQPY-545 and MH-138 for days to silking crosses varied from -4.01% to 4.42 % and -1.64% to 7.0% respectively. Among all ten crosses showed significantly lower days to silking than one of the best check BHQPY-545 while only four crosses showed significantly higher days to silking than BHQPY-545. On the other hand, seven hybrids revealed non significant and negative value of standard heterosis for days to silking over MH-138 while nine hybrids showed significantly higher days to silking than MH-138. As a result, negative and significant standard heterosis for days to silking indicating earlier silking of the hybrids than the commercial hybrid check as directly correlated with early maturity and the reverse is true for the positive heterosis.

SUMMARY AND CONCLUSION

The presence of an appropriate value of heterosis for grain yield and predicting hybrid performance is important in hybrid breeding program. The magnitude of heterosis observed in this study over the best standard check (BHQPY-545) for grain yield were retained from the crosses L3×L6 (20.58%), L3×L8 (7.65%). On the other hand crosses L3×L6(49.20%), L1×L4(22.40%), L1×L6(16.50%), L2×L5(24.40%), L3×L4(21.60%), L3×L8(33.20%), L4×L6(22.0%), L5×L8(17.77%), L6×L8(24.13%), and L7×L8(16.67%) showed maximum standard heterosis over MH-138 for grain yield, indicating the presence of exploitable heterosis essential for this trait to enhance grain yield.

Maximum standard heterosis was recorded for L3 × L6 (25.75%), L1 × L4 (16.99%) and L3 ×L6 (37.82%) for 1000 kernel weight, number of kernels per row and biomass yield, respectively over BHQPY-545, and L3 × L6 (54.79%), L1 × L4 (16.90%) and L3 ×L6 (48.90%), for 1000 kernel weight, number of kernels per row and biomass yield, respectively over MH-138. Therefore, these high yielding hybrids than the standard checks indicate the possibility of obtaining a good hybrid, with many desirable traits. Accordingly these potential hybrids could be recommended for commercial use, after confirming the result found in the present study over years and across locations.

REFERENCES

Amanullah, S. Jehan, M. Mansoor and M. A. Khan. 2011. Heterosis studies in diallel crosses of maize. *Sarhad Journal of Agriculture*, 27(2): 207-211.

Amiruzzaman M., Islam M.A., Hasan L., Kadir M., Rohman M.M. 2013. Heterosis and combining ability in a diallel among elite inbred lines of maize (*Zea mays* L.). *Emirates Journal of Food and Agriculture*, 25(2): 132-137.

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.

Banziger, M. and Diallo, A.O. 2004. Progress in developing drought and N stress tolerant maize cultivars for eastern and southern Africa. *In*: Friesen, D.K. and Palmer, A.F.E. (Eds.). Integrated Approaches to Higher Maize Productivity in the New Millennium. *Proceedings of the 7th Eastern and Southern Africa Regional Maize Conferenc*e. 5-11 February 2002, CIMMYT/KARI, Nairobi, Kenya. pp. 189- 194.

Berhanu T. 2009. Heterosis and Combining Ability for Yield, Yield Related Parameters and Stover Quality Traits for Food-Feed in maize (*Zea Mays* L.) adapted to the mid-altitude agro-ecology of Ethiopia. M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia, pp 89-152.

Bullo, N.T. and Dagne Wegary. 2016. Combining ability of inbred lines in quality protein maize (QPM) for varietal improvement. *International Journal of Plant Breeding and Crop Science*, 3(1): 079-089.

Dhoot, M., Dubey, R., Ameta, K., Dhoot, R., Kumar, R., &Badaya, V. K. 2017. Estimation of Heterosis for Grain Yield and Architectural Traits in Yellow Seeded Maize (Zea mays L.). *International Journal of Current Microbiology and Applied Sciences. 6*(7): 4536-4542.

Donald, C.M. 1962. In search of yield. *Journal of Australian Institute of Agricultural Sciences*, 28: 171-178.

Falconer, D.S. and T.F.C. Mackay. 1996. *Introduction to quantitative genetics, 4th ed*. Benjamin Cummings, England: 245-247.

Girma C. Hosana, Sentayehu Alamerew, Berhanu Tadesse and 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* 15(4): 2249-4626.

Gomez, A.K. and Gomez, A.A. 1984. *Statistical Procedure for Agricultural Research*, (2nd ed.), John Wiley and sons, New York.

Jiban Shrestha, Dil Bahadur Gurung, Tirtha Raj Rijal. 2018. Standard heterosis for grain yield in maize hybrids. *Fmg. & Mngmt.* 3 (1): 30-36.

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. pp: 103.

Matin, M. Q. I., Rasul, M. G., Islam, A., Mian, M. K., Ivy, N. A., & Ahmed, J. U. 2017. Combining Ability and Heterosis in Maize (Zea mays L.). *American Journal of Biological Science, 4*(6): 84-90.

Melkamu Elmyhum. 2013. Estimation of combining ability and heterosis of quality protein maize inbred lines. *African Journal of Agricultural Research*, 8(48): 6309-6317.

Natol Bakala Hundera, Birahanu Abate and Mandefro Nigussie. 2017. Standard Heterosis of Maize (*Zea mays* L.) Inbred Lines for Grain Yield and Yield Related Traits at Southern Ethiopia, Hawassa. *American-Eurasian Journal of Agriculture and Environmental Sci*ence, 17 (3): 257-264.

Panse V.G. and P.V. Sukhatme.1961. Statistical Methods for Agric. Workers, ICAR Publication, *New Delhi*, pp: 145.

Paschold, A., Marcon, C., Hoecker, N. and Hochholdinger, F. 2010. Molecular dissection of heterosis manifestation during early maize root development. *Theoretical and Applied Genetics*, 120: 383-388.

Reddy V. Ram, Farzana Jabeen and M.R.Sudarshan.2015. Heterosis studies in diallel crosses of maize for yield and yield attributing traits in maize (*Zea mays* L.) over locations. *International Journal of Agriculture, Environment and Biotechnology*, 8(2): 271-283.

SAS Institute, 2002. *Statistical Analysis of system software*, Version 9.0, SAS Institute, Inc., cary, NC, USA.

Shushay welderufael Abrha. 2014. Standard Heterosis of Maize (*Zea mays* L.) Inbred Lines for Grain Yield and Yield Related Traits in Central Rift Valley of Ethiopia. *Journal of Biology, Agriculture and Healthcare*, 4(23): 31-37.

Snedecor, G.W and Cochran, W.G. 1967. *Statistical Methods.* The Iowa State College Press, Ames, Iowa. U.S.A. 160-413.

Tajwar Izhara and M. Chakraborty. 2013. Combining ability and heterosis for grain yield and its components in maize (*Zea mays L.)* inbreds over environments. Department of Plant Breeding and Genetics, Birsa Agricultural University Ranchi-06 (Jharkhand), India.

Thiemann Alexander, Junjie Fu, Felix Seifert, Robert T Grant-Downton, Tobias A Schrag, Heike Pospisil, Matthias Frisch, Albrecht E Melchinger and Stefan Scholten.2014. Genome-wide meta-analysis of maize heterosis reveals the potential role of additive gene expression at pericentromeric loci. *BMC Plant Biology*, 14:88.

Ziggiju Mesenbet, Habtamu Zeleke and Legesse Wolde. 2016. Standard heterosis of pipeline maize (*Zea mays* L.) hybrids for grain yield and yield related traits at Pawe, Northwestern Ethiopia. *International Journal of Plant Breeding and Crop Science,* 3 (2): 6-8.