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Hybrid Performance and Standard Heterosis of Maize (*Zea mays* L.) for Grain Yield and Yield Related Trait in Eastern Ethiopia

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Abstract: Determination of standard heterosis in maize hybrids is required for their commercial exploitation and thereby enhancing their productivity. Therefore, the research designed to determine the performance of hybrid and their economic heterosis to enhance the production and productivity of maize. The experimental material, comprised twenty-eight F_1 hybrids along with the standard check (BHQPY-545), were evaluated using Alpha-Lattice Design with three replications during 2018 and 2019 cropping season at Haramaya University Research Site (Raare). Analysis of variance due to mean square of genotype exhibit significant difference for grain yield, ear diameter, anthesis-silking interval, days to maturity, number of kernels per row, number of kernel rows per ear and 1000-kernel weight. The mean value of the six crosses L1×L3, L1×L8, L3×L5, L4×L8, L6×L8 and L2×L4 had higher grain yield than the standard check BHQPY-545. The highest percentage of standard heterosis for grain yield was obtained from the crosses L1×L3 (11.05%), L1×L8 (10.89%), L3×L5 (6.97%), L4×L8 (5.61%) over BHQPY-545, indicating these hybrids had superior potential for commercial cultivation. The highest significant positive standard heterosis for 1000-kernel weight, number of kernels per row, ear length and ear diameter was manifested by the crosses L3×L5 (37.64%), L1×L3 (15.66%) L5×L6 (11.32%), and L2×L8 (15.21%), over BHQPY-545. The observed highest heterosis for grain yield and yield related traits indicates the potential of F_1 hybrids; therefore, such promising hybrids could be recommended for further use in breeding program and/or commercial use, after verifying the results by repeating the research across locations.

Keywords: Crosses, Genotype, Hybrid, Standard Check

1. Introduction

Maize (*Zea mays* L.) is one of the highest value crops, with a wider range of uses as food for human being, feed for animals and raw materials for industrial uses. Maize is the global leading cereal crop in terms of production, which is produced not only in temperate regions but also in tropical and sub-tropical agro-ecologies. In sub-Saharan Africa, Maize is the primary source of calories (466.5 kcal/capita/day) and also the second most important source of protein (12 g/capita/day) after wheat [5]. Maize, along with rice and wheat make-up three-fourths of the world grain production and dominate human diets [9]. Every part of the maize plant has economic value; for example, the grain, leaves, stalk, tassel, and ear can all be used to produce a large variety of food and non-food products. Therefore, due to this versatile use, maize gaining popularity and increase the growing demand among farmers. In view of its high demand for food grains and high yield per unit area, maize has been among the leading food grains selected to achieve food self-sufficiency in Ethiopia [1].

Maize is the most important grain crop in Ethiopia next to teff and is widely cultivated throughout the country under diverse environments. According to CSA [4] report Ethiopia by 2020/21 cropping season the total grain crop area, 81.19% (10,538,341.91 hectares) was under cereals of which maize share as large area as 19.46% (about 2,526,212.36 hectares) after teff 22.56% (about 2,928,206.26 hectares). Regarding total annual production, cereals contributed 88.36% (about 302,054,260.58 quintals) in which maize constitutes 30.88%

(105,570,935.92 quintals), followed by teff and sorghum [4]. Approximately 88% of maize produced in Ethiopia is consumed as food, both as green and dry grain [17]. This showed the potential of maize crop for food security associated with increased human population. The national average maize yield in Ethiopia during 2020/21 cropping season was about 4.18 t ha^{-1} [4], which is the highest in east African countries, but lower than world average yield about 5.93 ton ha^{-1} [18]. The reason behind these wide gaps in the yield is attributed to an array of abiotic and biotic stresses, old varieties dominating the seed system in the country and inadequate quantity and quality of foundation seed for the major food staples [17]. Therefore, greater efforts should be taken to improve the productivity of maize crop through breeding as high national priority issue.

The production and productivity of maize enhance by using improved hybrid maize varieties accompanied with appropriate agronomic practices. As a result, gene action and hybrid vigor/heterosis can be used more effectively in breeding programs for the identification of advanced F_1 hybrids and thereby enhance the productivity of the crop. Heterosis breeding has received more attention than any other branches of plant breeding in several crop plants, and thus maize is one such cross fertilized crop in which an array of hybrids have been realized over decades. The term heterosis was coined by Shull [14], which can be used as one important consideration for identification novel hybrid and selecting parent genotype which produce superior F_1 hybrid. 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 (better parent) performance of their genetically distinct homozygous parents in measurable characters [12]. Similarly, heterosis is a phenomenon in which an F_1 hybrid of two genetically dissimilar parents shows superiority over the standard commercial check variety, which is so called economic heterosis or superiority over check. Hence, determination of heterosis in reference to standard check (standard heterosis) is important for commercial utilization of maize hybrids. Indeed, new maize hybrid must be superior to preexisting commercial cultivars for grain yield and other economic traits to be used as a commercial variety. As a result, superior single cross hybrid operates through the phenomenon of heterosis are the important needs to modern agriculture [19]. Keeping this in view, an attempt was made to determine the performance of single cross maize hybrids and their standard heterosis to enhance the production and productivity of maize yield in eastern Ethiopia.

2. Materials and Methods

2.1. Description of Study Area

The experiment was conducted on research farm of Haramaya University (Raare) for two years (2018 and 2019 cropping season). The study area is located at an altitude of 2020 m.a.s.l. and lies at 9° 26' N latitude and 42°3' E longitude. The area received average annual rainfall during 2018 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).

2.2. Experimental Design and Field Management

The experiment was comprised of eight maize inbred lines, which were crossed in 8×8 half diallel mating design. The resulting 28 F_1 hybrids along with the standard check (BHQPY-545) were evaluated using alpha-lattice designs with three replications at Haramaya University Research Station (Raare) during 2018 and 2019 cropping seasons. Each plot consisted of two rows each of 5.1 meter length with spacing of 0.75m between rows and 0.3m within rows. 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. During plantation Urea and NPS fertilizers were applied at the rates of 140kg/ha and 118kg/ha, respectively. Urea was applied in two equal splits. The first half application was done at the time of planting along with NPS fertilizer while the remaining half was applied at the knee high stage of the crop. Moreover, all other necessary field management practices were carried out as per the recommendation for the study area and the crop.

2.3. Data Collection

Data on grain yield and yield related 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.

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

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

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

Days to maturity (DM): the number of days from planting to the stage at which 75% of the plants had reached physiological maturity, which is the time at which kernels form black layer at the point of attachment of the karnel with the cob.

Plant aspect (PA): was scored 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.

Ear aspect (EA): was score 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.

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

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

Thousand kernel weight (TKW): thousands of kernels from each plot were counted by automatic seed counter and were weighed using a sensitive balance after adjusting the moisture content to 12.5%.

Grain moisture: moisture content (%) present in the grain was 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% of moisture content was recorded for each plot in kg/plot using the formula below.

$$\text{Adjusted grain yield (kg plot}^{-1}) = \frac{\text{Field of weight (kg/plot)} \times (100-\text{MC}) \times \text{shelling\%}}{(100-12.5) \times \text{Area harvested (plot size)}}$$

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

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

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

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

Ear diameter (ED): 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): was recorded as the average number of kernels row per ear from five randomly taken ears.

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

2.4. Data Analysis

Before data analysis, anthesis-silking interval (ASI) was normalized using $\ln\sqrt{(ASI+10)}$ as suggested by Bolaños and Edmeades [3]. Analysis of variance for grain yield and yield related traits was computed with the PROC GLM procedure in SAS versions 9.0 [13]. Mean separation was done by using Least Significant Difference test (LSD).

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 [7]:

$$\text{SH}(\%) = \frac{\text{F1}-\text{SV}}{\text{SV}} \times 100$$

Where;

SH= standard heterosis, and

SV=standard variety,

F_1=mean performance of F_1

The differences in the magnitude of heterosis tested following the procedure of [11]. Standard error and critical difference were also computed as:

$$\text{SE (d)} = \sqrt{\frac{2\text{MSE}}{\text{r}}}$$

Where;

SE (d) is standard error of the difference.

MSE = error mean square from analysis of variance

r = the number of replication

The test of significance of heterosis in relation to standard check was done by‘t’ test as suggested by Snedecor and Cochran [15] as follows:

$$\text{Heterosis 't'} = \frac{\text{Mean of F1}-\text{standard check}}{\text{SE(d)}}$$

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

3. Result and Discussion

3.1. Analysis of Variance (ANOVA)

Table 1. *Analysis of variance due to mean square of genotypes evaluated at Haramaya, Eastern Ethiopia, during the 2018 and 2019 cropping season.*

Mean squares				
Trait	Rep (df=2)	Blk (Entry) (df=56)	Genotypes (df=28)	Error (df=85)
GY	7.06	11.894**	15.682**	3.717
DA	14.822	113.501	7.994	80.803
DS	11.372	122.220	9.955	83.250
ASI	0.338	0.501	0.407**	0.120
PS	0.0004	0.049	0.047	0.034
ET	0.041	0.154**	0.031	0.086
PA	0.017	0.270**	0.148	0.137
PH	176.798	961.723	434.641	659.789
EH	111.175	596.689	132.857	423.127
EA	0.019	0.262*	0.196	0.162
DM	0.994	2.774**	138.247**	1.314
EL	0.903	3.874**	2.844	2.018
ED	0.030	0.096	0.670**	0.09
NKR	1.672	4.898	42.251**	4.105
NKRE	0.329	0.182	5.057**	0.155
TKW	1618.579	2471.691**	1853.840*	1040.349

Note: a GY = grain yield; DA = days to anthesis; DS = days to silking; ASI = anthesis silking interval; ED = ear diameter; PH = plant height; EH = ear height; EL = ear length; NKR = number of kernels per row; NKRE = number of kernel rows per ear; TKW = thousand kernels weight; DM = days to maturity; PA = plant aspect; EA = ear aspect; ET = *Turccicum* leaf blight and PS = *Puccinia* sorghi (rust).** = Significant at P<0.01 level of probability and * = Significant at P<0.05 level of probability.

Analysis of variance due to mean square of genotype exhibit significant difference for grain yield, days to maturity, anthesis-silking interval, ear diameter, 1000 kernel weight, number of kernels per row and number of kernel row per ear (Table 1). The presence of significant differences among the evaluated hybrids indicating the presence of genetic variability, which can be exploited in future breeding scheme. Therefore, the existence of sufficient genetic variability among crosses for the trait of interest enables the breeder to conduct appropriate selection of the most desirable cross combinations. The results were comparable with the earlier view of Woldu [20] and Tefera *et al*. [16] in their combining ability and heterosis studies on maize.

3.2. Mean Performance of Genotypes

The mean performances of the F_1 maize hybrids along with the standard cheek BHQPY-545 are illustrated in Table 2. Among the entire cross L1×L3 (10.88ton/ha) exhibited superior performance for grain yield, while the cross L4×L5 (5.03ton/ha) was the lowest performing hybrid for grain yield with an average value of grain yield 8.90g. The mean value of the six crosses namely L1×L3, L1×L8, L3×L5, L4×L8, L6×L8 and L2×L4 exhibited higher grain yield than the total average grain yield, and out-yielded the grand mean of the standard check BHQPY-545. Therefore, these high performing crosses than the standard check indicates the possibility of obtaining better commercial variety and thereby enhance the production and productivity of maize. These results were comparable with the earlier reports of Berhanu [2] and Woldu [20]. The highest mean value of 1000-kernel weight was retained from the cross L3×L5 (416.17g), while the lowest value of thousand kernel weight recorded from the standard check BHQPY-545 (302.37g) with an average value of thousand kernel weight 362.10g.

Table 2. *Mean performance of maize genotypes evaluated at Haramaya, Eastern Ethiopia, during the 2018 and 2019 cropping season.*

Cross	GY (t/ha)	DS (day)	DA (day)	ASI (day)	EL (cm)	ED (cm)	NKPR (#)	NKRE (#)	TKW (gm)	PH (cm)	EH (cm)	DM (day)
L1×L2	9.23	89.00	86.83	3.17	18.20	4.37	40.47	14.35	368.73	222.50	110.00	156.50
L1×L3	10.88	89.50	86.33	3.17	17.67	4.70	43.57	13.42	368.33	219.17	110.83	168.33
L1×L4	6.98	91.67	88.50	3.17	15.62	4.13	34.50	13.02	326.68	205.83	103.33	161.50
L1×L5	8.23	91.83	88.67	3.17	15.87	3.85	36.50	12.02	318.87	195.00	95.00	161.33
L1×L6	7.22	91.83	88.33	3.50	17.05	4.60	39.87	12.13	354.45	214.17	110.00	162.00
L1×L7	9.13	90.00	86.83	3.17	17.03	4.53	42.03	12.28	360.75	210.00	110.00	160.50
L1×L8	10.87	89.00	85.67	3.33	17.50	4.80	39.70	14.10	357.25	221.67	110.00	168.50
L2×L3	9.05	92.00	88.67	3.33	17.60	4.27	37.17	13.40	376.70	219.17	115.83	168.33
L2×L4	10.03	91.50	88.17	3.33	18.07	4.70	40.13	12.82	381.37	228.33	115.00	164.00
L2×L5	9.18	91.33	87.67	3.67	17.82	4.42	40.57	12.33	390.20	221.67	112.50	161.33
L2×L6	7.23	91.33	88.17	3.17	17.13	4.77	39.77	12.70	366.45	205.00	111.67	161.00
L2×L7	8.30	91.17	87.83	3.33	17.33	4.67	40.37	12.42	372.77	219.17	115.00	161.17
L2×L8	9.23	93.17	89.83	3.33	16.55	5.25	37.73	15.87	355.30	205.00	110.00	166.17
L3×L4	9.78	89.33	86.00	3.33	17.47	4.60	39.43	12.22	389.47	225.83	112.50	170.17
L3×L5	10.48	88.33	85.17	3.17	17.88	4.75	40.63	12.22	416.17	225.83	119.17	170.50
L3×L6	7.88	89.83	86.67	3.00	17.78	4.93	40.43	11.73	391.28	189.17	107.50	168.50
L3×L7	8.70	90.83	87.50	3.33	17.73	4.90	40.90	11.75	414.48	216.67	116.67	170.67
L3×L8	7.83	91.83	88.67	3.17	17.68	4.92	39.47	13.20	360.68	214.17	111.67	169.17
L4×L5	5.03	92.33	89.17	3.17	15.92	3.73	33.37	11.32	304.87	201.67	100.00	164.50
L4×L6	8.65	90.67	87.50	3.17	17.40	4.53	41.37	12.10	388.70	216.67	114.17	167.83
L4×L7	8.97	92.33	88.83	3.50	18.53	4.53	40.67	11.20	382.63	225.83	120.83	165.67
L4×L8	10.35	92.17	88.67	3.50	17.25	5.05	36.87	13.75	344.45	218.33	112.50	170.50
L5×L6	9.23	91.67	88.33	3.33	19.02	4.70	42.03	11.70	371.03	217.50	112.50	168.67
L5×L7	9.62	91.17	87.67	3.50	17.10	4.70	41.63	12.13	377.80	215.00	115.83	165.33
L5×L8	8.98	90.17	87.00	3.17	18.00	5.05	38.10	14.28	360.35	215.00	117.50	165.33
L6×L7	9.65	95.33	91.83	3.50	15.08	3.52	27.80	10.30	314.18	175.83	95.00	142.00
L6×L8	10.17	91.00	88.00	3.00	17.57	4.92	37.23	12.78	356.78	215.83	113.33	170.17
L7×L8	7.45	90.83	87.83	3.00	16.05	4.73	37.70	12.68	327.85	195.83	102.50	164.33
BHQPY-545	9.80	89.83	87.33	2.50	17.08	4.56	37.67	15.26	302.37	225.00	119.17	179.83
CV	21.74	10.01	10.23	10.57	8.22	6.51	5.20	3.11	8.86	12.08	18.57	0.70
LSD	2.21	10.48	10.32	0.40	1.63	0.34	2.33	0.45	37.05	29.50	23.63	1.32
Mean	8.90	91.02	88.01	3.28	17.28	4.59	38.89	12.74	362.10	213.13	111.03	165.30
Max	10.88	95.33	91.83	3.67	19.02	5.25	43.57	15.87	416.17	228.33	120.83	179.83
Min	5.03	88.33	85.17	3.00	15.08	3.52	27.80	10.30	302.37	175.83	95.00	142.00

Note: a GY = grain yield; DS = days to silking; DA = days to anthesis; ASI = anthesis silking interval; NKR = number of kernels per row; NKRE = Number of kernel rows per ear; TKW = thousand kernels weight; EL = ear length; EH = ear height; PH = plant height; DM = days to maturity; ED = ear diameter; EL = ear length; ** = Significant at P<0.01 level of probability; * = Significant at P<0.05 level of probability.

Anthesis-silking interval (ASI) is an important trait in determining drought tolerance. For that reason, the crosses which showed low anthesis-silking interval (L3×L6, L16×L8, L7×L8) indicates the tendency of hybrids to be used in drought tolerant variety development, since there were short gaps between days to anthesis and days to silking, and showed desirable characters for good seed composition and drought tolerance. On the other hand, if the anthesis–silking interval is large, the viability of pollen would be reduced and abnormal fertilization might take place or fertilization may not happen consequently, which leads to yield lose. The result was comparable with the earlier report of Bolafios and Edmeades [3] and Woldu *et al*. [21].

The highest mean value of plant height was obtained from the cross L2×L4 (228.33cm), while the lowest mean value of plant height retained from the cross L6×L7 (175.83cm) with an average value of plant height 213.13cm. Likewise, the highest ear height was recorded from the cross L4×L7 (120.83cm), while the lowest record was obtained from L1×L5, L6×L7 (60cm) with the mean value of ear height 111.03cm. Thus, 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 [8].

Among all, the cross L5×L6 (19.02cm) attained the longest ear length, while the shortest ear length obtained from the cross L6×L7 (15.08cm), with the mean value of ear length 17.28cm. Similarly, the highest ear diameter was obtained from the cross L2×L8 (5.25cm), while the lowest ear diameter retained from L6×L7 (3.52cm) with the mean value of ear diameter 4.59cm. Therefore, maize genotypes with longer ear length and wider ear diameter may have inherent genetic potential to enhance grain yield as they are directly correlated with grain yield.

Concerning number of kernels per row, the highest mean value was obtained from the cross L1×L3 (43.57), while the lowest number of kernels per row was retained from the cross L6×L7 (27.80), with an average value of number of kernels per row 38.59. Likewise, the highest number of kernel rows per ear was obtained from the cross L2×L8 (15.87), while the lowest number of kernel rows per ear retained from the cross L6×L7 (10.30) with the mean value number of kernel rows per ear 12.74. The highest number of kernels per row and number of kernel rows per ear are desirable to enhance grain yield of maize as they were directly correlated with grain yield.

Among all, the cross L6×L7 exhibited longer number of days to anthesis and days to silking, which indicates the possibilities to be used as a sources of genes for development of late maturing hybrids. Conversely, the cross L3×L5 had shorter days to anthesis and silking, which could be regarded as early maturing types. Early maturing types of crosses are appropriate in area with short rainy season so as to escape moisture stress encountering during grain filling stage or late in the season.

3.3. Estimation of Standard Heterosis

Information on heterosis of maize germplasm is essential in increasing the efficiency of hybrid development. For that reason, the estimates of heterosis over the best standard check (BHQPY-545) were computed for grain yield and yield related traits in maize. Accordingly, the result exhibited that significant difference among genotypes. However, the magnitude and direction of heterosis in F_1 hybrids varied from character to character, and from cross to cross (Table 3). The overall results indicated that positive and negative significant standard heterosis was observed in most of the crosses compared with the standard check (BHQPY-545). This indicates the presence of considerable amount of heterosis for improving grain yield and yield related traits.

Grain yield: grain yield improvement is the main concern in any plant breeding program. Commercial production of newly developed hybrids cannot be achievable, if it is not performed better than standard commercial check. Positive and significant heterosis is desirable for the grain yield as it indicates increased grain yield potential over the existing standard check. Standard heterosis of crosses for grain yield was ranged from the cross L4×L5 (-48.64%) to L1×L3 (11.05%). Among the crosses, L1×L3 and L1×L8 showed more than 10% yield advantage as compared to the best standard check BHQPY-545, whereas eight crosses had significantly lower grain yield than BHQPY-545. The crosses which exhibited higher grain yield than the standard checks are desirable for the improvement of maize grain yield by exploiting maximum heterosis. The results were comparable with the report of [6].

Number of kernels per row: Standard heterosis of crosses over BHQPY-545 for number of kernels per row ranged from-26.19% (L6×L7) to 15.66% (L1×L3). Among the crosses, eighteen of them exhibited significantly higher number of kernels per row than the standard check BHQPY-545, while only three crosses showed significantly lower number of kernels per row than BHQPY-545. Hence, the highest number of kernels per row are desirable to enhance grain yield as they are directly correlated. The result in line with the finding of Natol *et al*. [10], who reported the presence of positive and significant standard heterosis for number of kernels per row.

Plant height: standard heterosis estimates of crosses over commercial check for plant height ranged from-21.85% (L6×L7) to 1.48% (L2×L4). Among the crosses, L1×L5, L3×L6, L4×L5, L6×L7 and L7× L8 had significantly lower plant height than the cheeck BHQPY-545; which are desirable for the development of short statured hybrids and implied that these hybrids would be lodging resistance and early mature. On the other hand none of the cross had significantly higher plant height than BHQPY-545. This implies that, most of the tested hybrids were short stature compared to the standard check.

Ear height: standard heterosis of crosses over the standard check for ear height ranged from-20.28% (L6×L7) to 1.39% (L4×L7). Among all, five crosses (L1×L4, L1×L5, L4×L5, L6×L7 and L7× L8) exhibited significantly lower ear placement than BHQPY-545, while none of the cross exhibited significantly higher ear placement than BHQPY-545. This implies that, most of the tested hybrids were lower ear placement compared to the standard checks, which are desirable to enhance lodging resistance maize varieties and for ease of mechanized operations.

Thousand kernel weight: The estimated heterosis of crosses over the standard check (BHQPY-545) for 1000-

kernel weight varied from -0.83% (L4×L5) to 37.64% (L3×L5). Among all, twenty four crosses exhibited significantly higher 1000-kernel weights than BHQPY-545, while none of the cross had significantly lower 1000-kernel weight than BHQPY-545. The result implies that, most of the crosses showed higher 1000-kernel weight compared to the standard check, which are desirable to enhance grain yield.

Ear length: Heterosis estimates of the crosses over the standard check for ear length ranged from-11.71% (L6×L7) to 11.32% (L5×L6). Among all, four of the crosses exhibited significantly lower ear length than BHQPY-545, while only two cross (L4×L7 and L6×L7) had significantly higher ear length compared to BHQPY-545. Hybrids with Longer ear length are desirable to enhance grain yield. The results were comparable with the finding of Woldu *et al.* [21], who reported the presence of positive and significant standard heterosis for ear length.

Ear diameter: Heterosis estimates of crosses over the standard check for ear diameter ranged from-22.82% (L6×L7) to 15.21% (L2×L8). Among all, five of the crosses exhibited significantly lower ear diameter than BHQPY-545, while eight of the cross exhibited significantly higher ear diameter compared to BHQPY-545. Hybrids with wide ear diameter indicated that they have inherent genetic potential for wider ear diameter, and thus desirable to enhance grain yield.

Table 3. *Estimates of standard heterosis over BHQPY- 545 evaluated at Haramaya, eastern Ethiopia, during 2018 and 2019 cropping season.*

Cross	GY (t/ha)	DT (day)	DS (day)	ASI (day)	DM (day)	EH (cm)	PH (cm)	TKW (gm)	NKRE (#)	NKR (#)	ED (cm)	EL (cm)
L1×L2	-5.79	-0.92	-0.60	26.67	-12.97	-7.69	-1.11	21.95**	-5.95	7.43**	-4.17	6.54
L1×L3	11.05	-0.37	-1.10	26.67	-6.39	-7.00	-2.59	21.81**	-12.07	15.66**	3.14	3.42
L1×L4	-28.74**	2.04	1.34	26.67	-10.19	-13.29*	-8.52	8.04	-14.69	-8.41**	-9.29**	-8.58*
L1×L5	-15.99*	2.23	1.53	26.67	-10.29	-20.28**	-13.33**	5.46	-21.24	-3.10	-15.51**	-7.12*
L1×L6	-26.36**	2.23	1.15	40.00	-9.92	-7.69	-4.81	17.22**	-20.48	5.84*	0.95	-0.19
L1×L7	-6.81	0.19	-0.60	26.67	-10.75	-7.69	-6.67	19.31**	-19.50	11.59**	-0.51	-0.29
L1×L8	10.89	-0.92	-1.90	33.33	-6.30	-7.69	-1.48	18.15**	-7.59	5.40*	5.34*	2.44
L2×L3	-7.65	2.42	1.53	33.33	-6.39	-2.80	-2.59	24.58**	-12.18	-1.33	-6.36*	3.03
L2×L4	2.38	1.86	0.96	33.33	-8.80	-3.50	1.48	26.13**	-16.00	6.55**	3.14	5.76
L2×L5	-6.30	1.67	0.39	46.67	-10.29	-5.60	-1.48	29.05**	-19.17	7.70**	-3.07	4.29
L2×L6	-26.19**	1.67	0.96	26.67	-10.47	-6.29	-8.89	21.19**	-16.77	5.58*	4.61	0.29
L2×L7	-15.31	1.49	0.58	33.33	-10.38	-3.50	-2.59	23.28**	-18.62	7.17**	2.41	1.47
L2×L8	-5.79	3.71	2.87	33.33	-7.60	-7.69	-8.89	17.51**	3.99	0.18	15.21**	-3.12
L3×L4	-0.17	-0.55	-1.50	33.33	-5.38	-5.60	0.37	28.81**	-19.93	4.69*	0.95	2.25
L3×L5	6.97	-1.67	-2.50	26.67	-5.19	0.00	0.37	37.64**	-19.93	7.88**	4.24	4.68
L3×L6	-19.56*	0.00	-0.80	20.00	-6.30	-9.79	-15.92**	29.40**	-23.10	7.34**	8.26**	4.10
L3×L7	-11.22	1.12	0.19	33.33	-5.10	-2.10	-3.70	37.08**	-22.99	8.58**	7.53**	3.81
L3×L8	-20.07*	2.23	1.53	26.67	-5.93	-6.29	-4.81	19.28**	-13.49	4.78*	7.90**	3.51
L4×L5	-48.64**	2.79	2.10	26.67	-8.53	-16.09*	-10.37*	0.83	-25.83	-11.42**	-18.07**	-6.83*
L4×L6	-11.73	0.93	0.19	26.67	-6.67	-4.20	-3.70	28.55**	-20.70	9.82**	-0.51	1.86
L4×L7	-8.50	2.79	1.72	40.00	-7.88	1.39	0.37	26.54**	-26.60	7.97**	-0.51	8.49*
L4×L8	5.61	2.60	1.53	40.00	-5.19	-5.60	-2.96	13.92**	-9.89	-2.12	10.83**	0.98
L5×L6	-5.79	2.04	1.15	33.33	-6.21	-5.60	-3.33	22.71**	-23.32	11.59**	3.14	11.32**
L5×L7	-1.87	1.49	0.39	40.00	-8.06	-2.80	-4.44	24.95**	-20.48	10.53**	3.14	0.10
L5×L8	-8.34	0.38	-0.40	26.67	-8.06	-1.40	-4.44	19.18**	-6.39	1.15	10.83**	5.37
L6×L7	-1.53	6.13	5.16	40.00	-21.04	-20.28**	-21.85**	3.91	-32.50	-26.19**	-22.82**	-11.71**
L6×L8	3.74	1.30	0.77	20.00	-5.38	-4.90	-4.08	17.99**	-16.22	-1.15	7.90**	2.83
L7×L8	-23.98**	1.12	0.58	20.00	-8.62	-13.99*	-12.96**	8.43*	-16.88	0.09	3.88	-6.05
SE(d)	0.91	4.24	4.3	0.16	0.54	9.7	12.11	15.2	0.19	0.96	0.14	0.67

Note: a GY = grain yield; DS = days to silking; DA = days to anthesis; ASI = anthesis silking interval; NKR = number of kernels per row; NKRE = Number of kernel rows per ear; TKW = thousand kernels weight; EH = ear height; EL = ear length; PH = plant height; DM = days to maturity; ED = ear diameter; EL = ear length; ** = Significant at P<0.01 level of probability; * = Significant at P<0.05 level of probability.

4. Conclusion

The phenomenon of heterosis in maize is important for identification and development of promising hybrids in breeding program. Accordingly, in the present study the highest mean value of 1000-kernel weight, grain yield, number of kernel rows per ear, number of kernels per row, ear length and ear diameter were manifested by the cross L1×L3 (10.88), L3×L5 (416.17), L2×L8 (15.87), L1×L3 (43.57), L5×L6 (19.02) and L2×L8 (5.25) respectively. Likewise, high level of heterosis over the best check (BHQPY-545) was observed for grain yield and yield contributing traits. The highest positive and significant standard heterosis for grain yield, 1000-kernel weight, number of kernels per row, ear length and ear diameter was manifested by L3×L5 (37.64%), L1×L3 (11.05), L1×L3 (15.66%), L5×L6 (11.32%) and L2×L8 (15.21%) over BHQPY-545, respectively, which indicated the potential for exploiting hybrid vigour in breeding program and might be used for obtaining high yielding maize hybrids. In conclusion it can be said that those crosses which had superior performance than the standard check exhibited the possibility of obtaining promising hybrid, with many desirable traits. Accordingly, the potential hybrids found in the present study could be recommended for further breeding process and/or commercial use after confirming the result across locations.

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