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Original Paper

Evaluation of Standard Heterosis for Grain Yield and Yield-Related Traits in Maize (Zea mays L.) Hybrids in West Gojam, Ethiopia

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***Abstract*— maize (Zea mays L.) is one of the most important cereal crops worldwide, leading in total crop yield production. However, the national average grain yield of maize in Ethiopia remains low. Hybrid development is one of the most widely used breeding strategies to improve maize productivity. Selecting promising germplasm with strong heterosis is essential for developing high-yielding maize varieties. Hence, the objective of this study was to evaluate the standard heterosis of the crosses for yield and yield-related traits. A total of thirty crosses, along with a widely used standard hybrid, were evaluated using a randomized complete block design (RCBD) with two replications during the 2018 cropping season at Adet. Analysis of variance showed significant difference among hybrids for all the studied traits except number of kernel per row (NKR) and ear length (EL). Percentages of standard heterosis in each trait were observed from negative to positive values. High amount of standard heterosis in grain yield was recorded in L4 x T2 (40.32%), L4 x T1 (40.30%) and L11 x T2 (24.95%) over the standard check BH 540. Based on standard heterosis L4 x T1, L4 xT2 and L11 x T2 are promising crosses for development of hybrid varieties after additional verification of the results.**

***Keywords*— hybrid, inbred lines, Standard heterosis, Maize (Zea mays L.) and Tester**

I. INTRODUCTION

Maize (Zea mays L., 2n=2x=20) is one of the most important cereal crops worldwide, ranking third after wheat and rice. It serves as a staple food and a crucial source of feed, fuel, and fiber in many part of the world. According to the Food and Agriculture Organization [1], maize was cultivated on approximately 197 million hectares globally, producing 1,134 million tons of grain in the 2017 production season.

Maize is one the major fundamental cereal crops for food security in Ethiopia in general and in Amhara region in particular. According to central statistical agency [2], maize production in Ethiopia reached 96.4 million quintals, cultivated on 2.3 million hectares, while in the Amhara region, it accounted for 22.6 million quintals on 0.53 million hectares. Specifically, in West Gojam, maize covered 40,000 hectares, producing 1.2 million quintals. The national average maize productivity stands at 4.24 tons per hectare, with Amhara region yielding 4.27 tons per hectare and West Gojam at 3.03 tons per hectare [2]. In different countries, the productivity of maize range from 6 to 10 tons per hectare. In contrast, maize productivity in other countries ranges from 6 to 10 tons per hectare, with national averages of 10.7, 9.63, 9.59, 5.70, and 6.32 tons per hectare in the USA, Canada, Germany, Brazil, and China, respectively [1].The lower maize productivity in Ethiopia, compared to these countries, is attributed to several factors, including the lack of high-yielding varieties, biotic and abiotic stresses, and limited adoption of improved agricultural technologies by small-scale farmers [3]. This indicates the need to develop high yielding hybrid maize varieties that perform well under biotic and abiotic stresses conditions. In order to achieve this, potentially suitable parents and superior combinations must be identified. The hybrid development in Ethiopia has been highly effective in increasing maize yields since the commercialization of the hybrids in the country. Increased yields are in part due to improved agronomic practices and increased inputs, but increased yields could not have been realized without genetic improvements [4].

Enhancing of maize production and productivity can be achieved by using of an essential management practices and high performance hybrid maize varieties. Understanding heterosis, or hybrid vigor, is crucial for identifying superior F1 crosses in hybrid development [5]. [6] reported significant standard heterosis over commercial checks for key agronomic traits, including grain yield, plant height, ear height, ear length, ear diameter, number of kernel rows per ear, number of kernels per row, and thousand-kernel weight. Similarly, [7] reported significant heterosis over the standard checks in plant height, ear height, ear girth, number of kernels per row, number of kernel row per ear, thousand grain weight and grain yield per hectare in his study on identification of superior parental combinations based on single cross hybrid performance comprised of hybrids involving 8 parents along with one check in maize. To develop high yielding hybrid variety knowledge on the magnitude of heterosis is very important. However, there is no available information on the magnitudes of standard heterosis of thirty crosses used in this finding. The main objective of the present investigation was to evaluate the extent of standard heterosis for grain yield and yield related traits of maize crosses.

II. Materials and Methods

A. Description of Experimental Site

The field experiment was carried out at Adet Agricultural Research Center (AARC) experimental farm of Amhara Regional Agricultural Research Institute (ARARI) and the center is situated in the woynadega (mid-altitude) agro ecological zone. Geographically, AARC is situated from 37° 28' 38" to 37° 29' 50" E longitude and from 11° 16' 19" to 11° 17' 28" N latitude and an altitude of 2240 meters above sea level (m.a.s.l.). It is positioned 450 km northwest of Addis Ababa, along the route to Bahir Dar via Mota town, and 42 km from Bahir Dar. The center has moderate and favorable climate with temperature ranging from 10.81°C to 25.55°C and annual rainfall of 1432 mm in 2018 cropping season. The soil type at the experimental site is nitisol, characterized by a pH of 5.43.

B. Experimental Materials

A total of thirty three-way crosses and one standard hybrid check (BH 540) were evaluated in this study during the 2018 main cropping season (Table I). Fifteen inbred lines were crossed with two single-cross testers, CML395/CML202 (T1) and CML442/CML312 (T2), using a Line × Tester mating design to develop the thirty three-way crosses during the 2017 main cropping season. The inbred lines used were at the S4 generation and were developed through selfing from improved maize varieties by the Adet Agricultural Research Center (AARC). The testers, developed by the International Maize and Wheat Improvement Center (CIMMYT), are widely utilized in maize breeding programs across Africa to assess the performance of inbred lines.

TABLE I. PEDIGREE OF GENOTYPES AND DESIGNATION

Entry No.	Pedigree	Designation
1	CML161/CML165-3-1-1-2//CML395/CML202	L1 x T1
2	CML161/CML165-3-1-1-2// CML442/CML312	L1 x T2
3	CML395/CML202//142-1e-4-2-1-1/// CML395/CML202	L2 x T1
4	CML395/CML202//142-1e-4-2-1-1/// CML442/CML312	L2 x T2
5	CML161/CML165-3-1-1-4// CML395/CML202	L3 x T1
6	CML161/CML165-3-1-1-4// CML442/CML312	L3 x T2
7	JJ/PA4-3-1-2-3// CML395/CML202	L4 x T1
8	JJ/PA4-3-1-2-3// CML442/CML312	L4 x T2
9	CML161/CML165-4-1-1-3// CML395/CML202	L5 x T1
10	CML161/CML165-4-1-1-3// CML442/CML312	L5 x T2
11	CML161/CML165-3-3-2-2// CML395/CML202	L6 x T1
12	CML161/CML165-3-3-2-2// CML442/CML312	L6 x T2
13	CML161/CML165-3-3-2-1// CML395/CML202	L7 x T1
14	CML161/CML165-3-3-2-1// CML442/CML312	L7 x T2
15	CML161/CML165-3-1-1-3// CML395/CML202	L8 x T1
16	CML161/CML165-3-1-1-3// CML442/CML312	L8 x T2
17	KULENI- 5-3-2-1// CML395/CML202	L9 x T1
18	KULENI- 5-3-2-1// CML442/CML312	L9 x T2
19	MTB/99-7-3-2-1// CML395/CML202	L10 x T1
20	MTB/99-7-3-2-1// CML442/CML312	L10 x T2
21	KULENI- 5-3-2-3// CML395/CML202	L11 x T1
22	KULENI- 5-3-2-3// CML442/CML312	L11 x T2
23	KULENI-5-6-1-3// CML395/CML202	L12 x T1
24	KULENI-5-6-1-3// CML442/CML312	L12 x T2
25	HORA-4-1-2-1// CML395/CML202	L13 x T1
26	HORA-4-1-2-1// CML442/CML312	L13 x T2
27	GUTO- 6-2-1-3// CML395/CML202	L14 x T1
28	GUTO- 6-2-1-3// CML442/CML312	L14 x T2
29	CML161/CML165-4-1-1-1// CML395/CML202	L15 x T1
30	CML161/CML165-4-1-1-1// CML442/CML312	L15 x T2
31	BH-540	Check

T = Tester, L= Line

C. Experimental Design and Managements

Thirty three way cross and one standard check were planted in Randomized Complete Block Design (RCBD) with two replications. Each entry was sown in two rows, each measuring 5.1 meters in length, with a spacing of 0.75 meters between rows and 0.30 meters between plants. Recommended fertilizers were applied in the form of Nitrogen-Phosphorus-Sulfur (NPS) and urea at rates of 69.16 kg P_2O_5 and 119.22 kg N per hectare. At planting, the entire recommended dose of P_2O_5 and one-third of the nitrogen was applied, while the remaining two-thirds of nitrogen was applied at the knee-height stage. All other standard agronomic practices were carried out as required throughout the growing season.

D. Data Collection and Analysis

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E. *Standard heterosis*

Standard heterosis (SH) of the crosses in percent was evaluated for the parameters that show significant difference among them following the procedure recommended by [9].

$$SH(\%) = \frac{(F1-STV)}{STV} \; x \; 100 \quad (1)$$

Where
F1= Mean value of the crosses
STV = value of standard variety
SH = Standard heterosis

Significance of heterosis was tested using the t-test. The standard errors of the difference for heterosis and t-value were calculated as follows [10].

$$t(Standard\ cross) = \frac{(F1-STV)}{SE(D)} \; x \; 100 \quad (2)$$

$$SE(D) = \left(\frac{2ME}{R}\right)^{1/2} \quad (3)$$

Where,
SE (D) = standard error of the difference
ME = mean square of error
R = number of replication

The calculated t value was evaluated against the t-value at error degree of freedom.

III. Results and Discussion

A. *Analysis of Variance*

The analysis of variance revealed highly significant differences among the genotypes for most of the studied traits. However, the number of kernels per row and ear length did not show significant variation (Table II). Significant differences indicates the presence of genetic variability among the genotypes for further improvement of the traits and hence, selection is essential for identifying the most promising crosses. In agreement with this result, significant mean square due to genotypes for yield and yield related traits have been reported by [7] for days to anthesis, days to silking, days to maturity, plant height, ear height, thousand kernel weight, ear per plant, ear length, ear diameter and grain yield.

The mean performance of the crosses showed that L2 × T2 (91.5 days), L5 × T2 (91.5 days), and L7 × T2 (91.5 days) were the earliest in terms of days to anthesis, while L7 × T2 (93.0 days) was the earliest in days to silking. However, some crosses exhibited delayed anthesis and silking compared to the standard check, BH 540 (Table V). Crosses that exhibited longer days to flowering compared to the checks can be classified as late-maturing types, while those with shorter days to flowering can be considered early-maturing types. However, this classification is not always absolute, as some genotypes may have an extended grain-filling period after flowering, leading to delayed maturity. Nowadays, earliness is a desirable attribute for maize production in view of recurrent droughts as early varieties can escape moisture stresses [7]. Additionally, early-maturing varieties allow for earlier harvesting, enabling the land to be used for cultivating other crops within the same season, facilitating a double-cropping system. Conversely, late-maturing crosses are valuable in breeding programs for developing high-yielding hybrids, particularly in regions with sufficient rainfall [7]. Three-way cross L4 x T2 produced the highest grain yield (12682.2kg ha-1) followed by L4 x T1 (12680.7kgha-1) with overall mean of 9788.73 kgha-1. These three way crosses had better performance in grain yield compared to BH 540 (9038.2 kg ha-1) whereas lower yield was recorded in L5 x T2 (8227.3 kg ha-1) (Table IV).

TABLE II. Mean Squares Due To Genotypes and Error For Grain Yield and Related Traits Evaluated at Adet Agricultural Research Center 2018.

Source of var.	**DF**	**Mean Squares**					
		DA	**DS**	**DM**	**PH**	**EH**	**TKWT**
Genotype	32	11.96**	11.65**	17.62**	584.06**	493.00**	3878.46**
Error	28	1.68	1.26	3.43	94.68	57.17	921.04
Cv (%)		1.37	1.17	1.06	3.59	5.14	7.22

TABLE III. Continued Table II

Source of var.	**DF**	**Mean Squares**					
		DA	**DS**	**DM**	**PH**	**EH**	**TKWT**
Genotype	32	0.06**	2.53**	3.95^{ns}	2.01^{ns}	0.059**	2115051.05**
Error	28	0.02	0.59	4.69	1.20	0.02	537732.00
Cv (%)		9.69	5.39	6.15	5.65	2.50	7.48

*=significant at 0.05 probability level

**=significant at 0.01 probability level

DF = degree of freedom, DA = days to anthesis (days), DS = days to silking (days), DM = maturity of date, PH = plant height (cm), EH = ear height (cm), TKWT = thousand kernel weight (gram), EPP = ear per plant (number), KRE = number of kernel row per ear (number), NKR = number of kernel per row (number), EL = ear length (cm), ED = ear diameter (cm) and grain yield (kg/ha)

TABLE IV. Mean Performance Of Thirty One Genotypes (30 Three Way Cross And 1 Hybrid Checks) For Fifteen Traits.

Entry	**DA**	**DS**	**DM**	**PH (cm)**	**EH (cm)**	**TKWT (g)**	**EPP**	**KRE**	**NKR**	**EL(cm)**	**ED (cm)**	**GY (kg/ha)**
L1 x T1	95.0^{a-g}	97.0^{b-g}	175.5^{def}	282.8^{b-f}	150.6^{c-h}	370.19fg	1.24cde	14.5a-e	38.22a	19.7a	5.24abc	9696.6b-f
L1 x T2	92.5^{e-h}	94.0^{gh}	172.5^{f}	274.5^{b-h}	130.8^{g-j}	399.94b-g	1.33a-e	15.9ab	33.58a	18.9a	5.17a-d	10085.7b-f
L2 x	92.0^{fgh}	94.5^{fgh}	172.0^{f}	252.0^{f-i}	148.3^{c-i}	472.61a-e	1.33a-e	13.9b-e	33.35a	17.6a	5.23a-d	10023.7b-f

T1											
L2 x T2	91.5^{gh}	94.0^{gh}	176.0^{d-g}	245.0^{hi}	124.2^{ij}	477.95abc	1.03e	14.2b-e	33.32a	19.4a	5.20a-d	9723.9b-f
L3 x T1	98.0^{abc}	99.0^{a-d}	171.0^{f}	273.2^{b-h}	156.6^{b-f}	394.79b-g	1.44a-e	14.7a-e	34.78a	18.6a	5.07a-f	8500.1def
L3 x T2	95.0^{a-g}	97.0^{b-g}	171.5^{f}	279.0^{b-g}	148.8^{c-i}	392.81b-g	1.14de	14.8a-e	35.76a	19.6a	5.38a	8561.6def
L4 x T1	94.5^{b-g}	96.0^{d-h}	175.0^{def}	282.5^{b-f}	157.9^{b-e}	384.06c-g	1.74a	13.2c-f	36.16a	17.9a	4.98a-f	12680.7a
L4 x T2	93.0^{d-g}	94.5^{fgh}	175.0^{def}	290.0^{b-e}	158.4^{b-e}	509.46a	1.51a-d	14.3a-e	36.38a	19.3a	5.26ab	12682.2a
L5 x T1	93.0^{d-g}	96.0^{d-h}	173.0^{f}	271.9^{b-h}	129.0^{g-j}	414.05a-g	1.48a-d	13.3c-f	33.92a	18.9a	5.07a-f	9117.7b-f
L5 x T2	91.5^{gh}	94.5^{fgh}	172.5^{f}	236.5^{i}	117.3^{j}	372.60fg	1.36a-e	14.3a-e	32.82a	17.8a	4.93b-f	8227.3f
L6 x T1	94.5^{b-g}	96.0^{d-h}	179.5^{a-e}	283.7^{b-f}	163.0^{bcd}	413.34a-g	1.25cde	14.0b-e	35.77a	20.6a	5.03a-f	10754.8a-e
L6 x T2	92.5^{e-h}	94.0^{gh}	173.5^{ef}	269.0^{b-h}	146.4^{c-i}	449.58a-f	1.14de	13.6b-f	37.92a	20.5a	5.05a-f	8873.4b-f
L7 x T1	94.0^{c-g}	94.5^{fgh}	180.5^{a-d}	267.8^{b-i}	146.5^{c-i}	423.51a-f	1.69ab	13.5b-f	36.68a	19.3a	4.82c-f	11062.0abc
L7 x T2	91.5^{gh}	93.0^{hi}	175.5^{def}	258.8^{d-i}	132.6^{f-j}	451.89a-f	1.25cde	13.5b-f	34.38a	21.2a	4.97a-f	9018.3b-f
L8 x T1	95.5^{a-g}	95.5^{d-h}	171.0^{f}	279.0^{b-g}	165.5^{bc}	380.04c-g	1.49a-d	13.5b-f	36.24a	18.9a	4.83c-f	9597.2b-f
L8 x T2	94.0^{c-g}	95.0^{e-h}	177.0^{b-f}	274.8^{b-h}	153.8^{c-g}	404.81b-g	1.21cde	15.1a-e	36.70a	20.9a	5.01a-f	9677.1b-f
L9 x T1	96.0^{a-f}	97.5^{a-g}	172.0^{f}	272.8^{b-h}	140.7^{c-j}	380.64c-g	1.27b-e	15.0a-e	33.38a	17.3a	5.12a-e	9061.6b-f
L9 x T2	92.0^{gh}	95.0^{e-h}	174.0^{ef}	258.0^{e-i}	126.2^{hij}	469.57a-f	1.02e	14.9a-e	34.90a	21.2a	5.21a-d	8343.3ef
L10 x T1	97.0^{a-d}	98.5^{a-e}	174.5^{def}	263.5^{b-i}	136.2^{e-j}	423.32a-f	1.43a-e	14.3a-e	34.24a	18.3a	5.19a-d	10876.5a-d
L10 x T2	96.0^{a-f}	98.5^{a-e}	175.0^{def}	263.0^{b-i}	135.5^{e-j}	384.41c-g	1.32a-e	15.9ab	36.26a	20.1a	5.02a-f	9387.6b-f
L11 x T1	97.5^{abc}	100.0^{abc}	174.5^{def}	291.5^{bc}	179.7^{ab}	376.03d-g	1.35a-e	14.9a-e	35.38a	18.8a	5.17a-d	9311.4b-f
L11 x T2	94.5^{b-g}	96.0^{d-h}	175.0^{def}	275.5^{b-h}	138.3^{d-j}	424.74a-f	1.37a-e	14.5a-e	35.82a	20.4a	5.17a-d	11293.5ab
L12 x T1	95.5^{a-g}	98.0^{a-f}	181.5^{abc}	269.5^{b-h}	141.5^{c-j}	389.81c-g	1.36a-e	16.8a	36.86a	19.0a	5.11a-e	9583.6b-f
L12 x T2	96.5^{a-e}	98.0^{a-f}	182.0^{ab}	273.0^{b-h}	149.2^{c-h}	447.68a-f	1.14de	15.7abc	34.74a	19.9a	5.03a-f	10854.1a-d
L13 x T1	98.5^{ab}	100.5^{ab}	176.0^{c-f}	290.4^{bcd}	161.7^{bcd}	390.69c-g	1.60abc	13.6b-f	35.78a	19.2a	4.85b-f	9101.0b-f
L13 x T2	96.0^{a-f}	100.0^{abc}	172.5^{f}	295.0^{b}	163.6^{bc}	418.52a-f	1.33a-e	13.9b-e	34.42a	20.1a	4.81def	9573.9b-f
L14 x T1	96.0^{a-f}	97.0^{b-g}	175.0^{def}	253.7^{f-i}	151.3^{c-g}	318.46g	1.49a-d	14.9a-e	36.82a	18.4a	5.00a-f	9680.6b-f
L14 x T2	93.0^{d-g}	94.0^{gh}	174.0^{ef}	252.5^{f-i}	133.1^{f-j}	388.28c-g	1.23cde	15.4a-d	35.38a	19.7a	5.26ab	9748.5b-f
L15 x T1	95.0^{a-g}	97.5^{a-g}	171.0^{f}	258.5^{d-i}	151.7^{c-g}	400.54b-g	1.74a	12.9def	32.16a	19.1a	4.84b-f	8827.5c-f
L15 x T2	95.5^{a-g}	96.5^{c-h}	176.5^{b-f}	247.5^{ghi}	129.8^{g-j}	463.06a-f	1.57a-d	14.1b-e	35.92a	19.2a	5.12a-e	10487.1a-f
BH 540	96.5^{a-e}	97.0^{b-g}	176.5^{b-f}	277.5^{b-g}	160.2^{b-e}	476.38a-d	1.32a-e	13.0def	32.16a	18.4a	4.74f	9038.2b-f
Mean	94.63	96.40	174.87	269.75	146.08	414.96	1.36	14.39	35.17	19.30	5.06	9788.73
CV	1.36	1.17	1.07	3.71	5.37	6.96	9.80	5.31	5.90	5.71	2.40	7.71
R^2	0.88	0.91	0.87	0.86	0.89	0.85	0.84	0.79	0.64	0.68	0.83	0.87
F. Test	**	**	**	**	**	**	**	**	Ns	Ns	**	**

*=significant at 0.05 probability level

**=significant at 0.01 probability level

DF = degree of freedom, DA = days to anthesis (days), DS = days to silking (days), DM = maturity of date, PH = plant height (cm), EH = ear height (cm), TKWT = thousand kernel weight (gram), EPP = ear per plant (number), KRE = number of kernel row per ear (number), NKR = number of kernel per row (number), EL = ear length (cm), ED = ear diameter (cm) and grain yield (kg/ha).

B. Standard Heterosis

The standard heterosis over the standard check i.e.BH 540 was calculated for grain yield and yield related traits that expressed significant differences among genotypes (Table V). The magnitude of standard heterosis over the check varied from -5.18 % (L2 x T2, L5 x T2, and L7 x T2) to 2.07 % (L13 x T1). Three crosses, L2 x T2, L5 x T2 and L7 x T2, exhibited high negative significant standard heterosis over the check (Table 4). This result agree with [11, 12] who reported significant heterosis for days to anthesis. For days to silking, negative standard heterosis is desirable, and it ranged from -4.12% (L7 × T2) to 3.61% (L13 × T1). Five hybrids, L1 x T2, L2 x T2, L6 x T2, L7 x T2 and L14 x T2, were relatively expressed high negative significant standard heterosis over the standard check and three crosses, L11 x T1, L13 x T1, and L13 x T2, also expressed positive significant standard heterosis over the check (Table V). This finding is in matching with [11, 12] who reported positive and negative significant standard heterosis for days to silking over the standard check. For days to maturity, the magnitude of standard heterosis over the check varied from -3.12 % (L3 x T1, L8 x T1 and L15 x T1) to 3.12 % (L12 x T2). Three crosses, L3 x T1, L8 x T1 and L15 x T1, were relatively showed high negative significant heterosis over the standard check. Cross L7 x T1, L12 x T1 and L12 x T2 displayed positive significant heterosis over the check BH 540 (Table V). This result agree with [11, 12] who reported positive and negative significant standard heterosis for days to maturity over the check.

The standard heterosis of plant height over the check ranging from -14.77 % (L5 x T2) to 6.31 % (L13 x T2). High negative value indicated that crosses were shorter than check while high positive value also indicated that crosses were taller than the check. Five crosses, L2 x T1, L2 x T2, L5 x T2, L14 x T1, L14 x T2 and L15 x T2 displayed negative significant heterosis over the check (Table V). This result agree with [12, 13] who reported negative significant level of heterosis on plant height. Regarding to ear height, the standard heterosis over the check ranging from -26.78 % (L5 x T2) to 12.17% (L11 x T1). Thirteen crosses ranging from -26.78 % (L5 x T2) to -11.67 % (L12 x T1) exhibited negative significant standard heterosis over BH 540 and one cross (L11 x T1) showed positive significant heterosis over BH 540 (Table V). This finding agreed with [12, 14] who reported positive and negative significant heterosis on ear height. The standard heterosis of thousand kernel weight over check ranging from -33.15% (L14 x T1) to 6.94 % (L4 x T2). Cross L14 x T1 exhibited highest significant negative standard heterosis over BH 540 with the value of -33.15% and followed by L1 x T1 with the value of -22.29% (Table V). This results are matching with the earlier findings by [15]. The magnitude standard hetreosis for ear per plant over the check ranging from -22.81 % (L9 x T2) to 31.94 % (L4 x T1 and L15 x T1). Four crosses, L4 x T1, L7 x T1, L13 x T1 and L15 x T1 displayed positive significant standard heterosis over the check (Table V). In line with the current finding positive and significant heterosis was also reported by [12, 16] on ear per plant.

For number of kernel rows per ear, the standard hetreosis over the check ranging from -0.77 % (L15 x T1) to 29.23 % (L12 x T1). Significant positive standard heterosis over BH 540 was found in 12 crosses that means as compared to the standard check these crosses expresses high number of rows per ear. Three crosses, L1 x T2, L10 x T2 and L12 x T1 expressed the highest positive significant standard heterosis over check (Table V). [15, 16] also report similar standard heterosis effect on the number of kernel rows per ear in their finding on combining ability and heterosis on yield and component characters in maize. For ear diameter, the magnitude of heterosis over the check ranging from 1.48 % (L13 x T2) to 13.50 % (L3 x T2). Out of thirty crosses, 22 hybrids showed positive significant standard heterosis over the check. Three hybrids, L3 x T2, L4 x T2 and L14 x T2, expressed highest positive significant heterosis over BH 540 (Table V). Similarly [15, 17, 18] found significant positive heterosis on ear diameter. The magnitude of standard heterosis in positive direction is important for Grain yield. Standard heterosis over the check varied from -8.97 % (L5 x T2) to 40.32 % (L4 x T2). From the hybrids, seven hybrids ranging from 18.99 % (L6 x T1) to 40.32 % (L4 x T2) exhibited positive significant heterosis over BH 540. The maximum positive significant heterosis was recorded by L4 x T2 (40.32 %), L4 x T1 (40.30 %) and L11 x T2 (24.95%) over BH 540 for grain yield (Table V). This result is in line with the previous investigators by [19, 20, 16, 11] who found high percent of heterosis over the standard check for grain yield.

TABLE V. STANDARD HETEROSIS OF MAIZE HYBRID OVER THE BH 540 FOR GRAIN YIELD AND RELATED TRAITS.

Crosses	DA	DS	DM	PH	EH	TKWT	EPP	KRE	ED	GY
L1 x T1	-1.55	0.00	-0.57	1.91	-5.99	-22.29*	-5.70	11.54	10.55**	7.28
L1 x T2	-4.15**	-3.09*	-2.27*	-1.08	-18.35**	-16.05*	0.76	22.31**	9.07**	11.59
L2 x T1	-4.66**	-2.58*	-2.55*	-9.19*	-7.43	-0.79	0.76	6.92	10.34**	10.90
L2 x T2	-5.18**	-3.09*	-0.28	-11.71**	-22.47**	0.33	-21.67*	9.23	9.70**	7.59
L3 x T1	1.55	2.06	-3.12**	-1.55	-2.25	-17.13*	9.51	13.08*	6.96*	-5.95
L3 x T2	-1.55	0.00	-2.83*	0.54	-7.12	-17.54*	-13.69	13.85*	13.50**	-5.27
L4 x T1	-2.07	-1.03	-0.85	1.80	-1.44	-19.38**	31.94**	1.54	5.06	40.30**
L4 x T2	-3.63*	-2.58*	-0.85	4.50	-1.12	6.94	14.83	10.00	10.97**	40.32**
L5 x T1	-3.63*	-1.03	-1.98	-2.02	-19.48**	-13.08*	12.17	2.31	6.96*	0.88
L5 x T2	-5.18**	-2.58*	-2.27*	-14.77**	-26.78**	-21.79**	3.04	10.00	4.01	-8.97
L6 x T1	-2.07	-1.03	1.70	2.23	1.75	-13.23*	-4.94	7.69	6.12*	18.99*
L6 x T2	-4.15**	-3.09*	-1.70	-3.06	-8.61	-5.63	-13.69	4.62	6.54*	-1.82
L7 x T1	-2.59	-2.58*	2.27*	-3.50	-8.55	-11.10	28.52**	3.85	1.69	22.39*
L7 x T2	-5.18**	-4.12**	-0.57	-6.74	-17.23**	-5.14	-4.94	3.85	4.85	-0.22
L8 x T1	-1.04	-1.55	-3.12**	0.54	3.31	-20.22**	12.93	3.85	1.90	6.18
L8 x T2	-2.59	-2.06	0.28	-0.97	-4.00	-15.02*	-8.37	16.15**	5.70*	7.07
L9 x T1	-0.52	0.52	-2.55*	-1.69	-12.17*	-20.10**	-3.42	15.38*	8.02**	0.26

L9 x T2	-4.66**	-2.06	-1.42	-7.03	-21.22**	-1.43	-22.81*	14.62*	9.92**	-7.69
L10 x T1	0.52	1.55	-1.13	-5.05	-14.98**	-11.14	8.37	10.00	9.49**	20.34*
L10 x T2	-0.52	1.55	-0.85	-5.23	-15.42**	-19.31**	0.00	22.31**	5.91*	3.87
L11 x T1	1.04	3.09*	-1.13	5.05	12.17*	-21.07**	2.66	14.62*	9.07**	3.02
L11 x T2	-2.07	-1.03	-0.85	-0.72	-13.67**	-10.84	4.18	11.54	9.07**	24.95**
L12 x T1	-1.04	1.03	2.83*	-2.88	-11.67*	-18.17**	3.04	29.23**	7.81**	6.03
L12 x T2	0.00	1.03	3.12**	-1.62	-6.87	-6.02	-13.69	20.77**	6.12*	20.09*
L13 x T1	2.07	3.61**	-0.28	4.65	0.94	-17.99**	21.67*	4.62	2.32	0.69
L13 x T2	-0.52	3.09*	-2.27*	6.31	2.12	-12.15	1.14	6.92	1.48	5.93
L14 x T1	-0.52	0.00	-0.85	-8.58*	-5.56	-33.15**	13.31	14.62*	5.49*	7.11
L14 x T2	-3.63*	-3.09*	-1.42	-9.01*	-16.92**	-18.49**	-6.84	18.46**	10.97**	7.86
L15 x T1	-1.55	0.52	-3.12**	-6.85	-5.31	-15.92*	31.94**	-0.77	2.11	-2.33
L15 x T2	-1.04	-0.52	0.00	-10.81**	-18.98**	-2.80	19.39	8.46	8.02**	16.03
SE(d)	1.29	1.12	1.85	9.73	7.56	30.34	0.13	0.76	0.12	733.30

DA = days to anthesis (days), DS = days to silking (days), DM = days to maturity, PH = plant height (cm), EH = ear height (cm), TKWT = thousand kernel weight (gram), EPP = ear per plant (number), KRE = number of kernel row per ear (number), ED = ear diameter (cm), grain yield (kg/ha) and SE(d) = standard error of difference.

IV. Conclusion And Recommendation

In this study, hybrids L4 × T1 (40.30%), L4 × T2 (40.32%), and L11 × T2 (24.95%) exhibited desirable standard heterosis above the check variety BH 540 for grain yield. So, L4 x T1, L4 x T2 and L11 x T2 could be suggested for future utilization for the development of high yielding varieties. Among all the evaluated crosses, 10 exhibited negative heterosis compared to the check for days to anthesis, while 9 crosses showed negative heterosis for days to silking. This indicates that these hybrids were earlier than the check; hence, maturing earlier in terminal moisture stress area as compared to the standard variety. In this study, maximum standard heterosis for ear per plant and ear diameter was observed from the crosses L4 x L1 (31.94%) and L15 x T1 (31.94%) and L3 x T2 (13.50%), respectively. The presence of genetic variability on grain yield, and yield related traits give desirable information for maize researchers especially who are intend in heterosis breeding. But, this findings will be further evaluated across multiple locations and years to validate the promising results identified in this study. Generally, this finding could be desirable for maize breeders who interested to generate hybrid maize varieties.

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