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Estimating Magnitude of Standard Heterosis in Mid-altitude Maize (*Zea mays* L.) Hybrids for Grain Yield and Yield Related Traits at Haro Sabu, West Oromia, Ethiopia

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Abstract

Heterosis is the groundwork for developing a good economically viable hybrid maize variety. Evaluation of Maize test crosses was carried out during the 2019 main cropping season at research field of Haro Sabu Agricultural Research Center West Oromia, Ethiopia. The main objective of the study was to identify direction and magnitude of standard heterosis in mid-land maize hybrids for grain yield and yield attributing agronomic traits. Seventy-two maize hybrids and three standard checks were tested using 5x15 alpha-lattice (0, 1) design with two replications. The analysis of variance exhibited a highly significant ($p<0.01$) genotypic differences for all observed agronomic traits with exception to shelling %, stand count at harvesting and common leaf rust. The study identified elite and high grain yielding test crosses possessing positive and significant standard heterosis over the best check hybrid (BH547)as in case of L3xL1, L5xL1, L5xT2, L6xT4, L8xT1, L8xT2, L8xT4, L9xT2, L10xT2, L11xT3, L12xT1, L13xT2, L16xT2, L18xT1. These crosses could be used in maize breeding program after further confirmation of the stability of present results across years and locations.

Keywords: Heterosis, Hybrids, Maize

1. Introduction

Maize (*Zea mays* L.) belonging to the tribe Maydeae of grass family Poaceae, which is diploid with a basic set of ten (n=10) chromosomes (Paliwal, 2000b) [11]. Maize has a wider environmental plasticity, and occupies the unique place as queen of cereals because of its immense potential. Nowadays, Maize has been recognized as industrial crops due to its diversified products (Pavan *et al.*, 2011) [13]. Ethiopia is the fourth largest maize producing country in Africa, and first in east African region (FAO, 2019) [21]. In Ethiopia, research system has developed and released/recommended a number of improved Maize varieties with their agronomic practices and plant protection technologies for maize growing agro-ecologies; mid-altitude sub-humid, highland, low moisture stress and lowland sub-humid (Banti *et al.*, 1993).

Maize ranks first and followed by teff, sorghum, wheat, barley and millet in production and productivity. From the total volume of maize production; 95% was produced by small holder and remainder 5% by commercial farms, most of which used for seed. Maize has significant values for Ethiopia where rapidly increasing population has already outstripped the available food supplies. The increasing Maize production and alternative utilization in food channels can reduce the pressure on wheat, rice, and its import. Productivity of maize was estimated to 4.179 (Ethiopia), 4.292 (oromia), 4.574 (West Wollega) and 4.571 (Kellem Wollega) tone per one hectare of land (CSA, 2020/21) [4]. The progress observed could be resulted from maize productivity improvement through utilization of appropriate inputs and crop management than area expansion (FAO, 2019) [21]. Hybrid Maize varieties have played a vital role in increasing production and productivity as it has much higher yield potentiality than those of synthetics and composites (Karim *et al.*, 2018) [7]. Heterosis is as prerequisite as combining ability for developing a good economically viable hybrid maize variety. The magnitude of heterosis provides information on extent of genetic diversity of parents in developing superior F1 so as to exploit hybrid vigor and has direct bearing on breeding methodology to be adapted for varietal improvement (Radish *et al.*, 2014).

Therefore, current study was developed with the main objective of estimating direction and magnitude of standard heterosis for grain yield and yield attributing agronomic traits in mid-altitude maize at Haro Sabu Agricultural Research Center, West Oromia, Ethiopia.

2. Materials and Methods

2.1 Description of the study area

Field experiment was executed at Haro Sabu Agricultural Research Center main station in main cropping season of 2019. Experimental area is found at 550 kilometers from Addis Ababa; the capital city of Ethiopia. The research station is found between $8^0$52'51''N (latitude), $35^0$13'18''E (longitude) and 1515 meter above sea level with Nitosol having sandy loam soil textural class. The study area is characterized with unimodal rain fall distribution pattern from April to November. During the experimental execution the area received 1481 mm annual rain fall with 12.65 ºC and 28.93 °C monthly minimum and maximum temperature, respectively.

2.2. Experimental materials

Test Materials: Field experiment was carried out on seventy-two test crosses and three standard checks (BH-543, BH-546 and BH-547) adapted to mid-altitudeagro-ecology of west Ethiopia. Test crosses were developed by crossing 18 inbred lines with 4 single cross testers in line x tester mating design developed by Kempthorne (1957) [8]. The inbred lines were developed at Bako National Maize Research Center (BNMRC) using pedigree method (Table 1).

2.3. Experimental design and field management

Field experiment was conducted in 5x15 alpha-lattice (0,1) design with two replications, where one replication holds 15 blocks each consists of 5 plots following the procedure suggested by Patterson and Williams (1996) [14]. Two row plots with 5.1 m length were used at 75 cm and 30 cm row and plant spacing, respectively. Two seeds were planted per hill and followed by thinning to one plant per hill after seedling establishment to obtain a total plant population of 44,444 per hectare. In organic fertilizer; DAP (18% N and 46% P_2O_5) was applied at the rate of 100 kgha^{-1}, whereas, Urea (46% N) used at the rate of 200 kg ha^{-1} in split form (each 50% at sowing and knee height). All management practices were commenced as uniformly as required.

Table 1: Description of maize inbred lines and testers parents used in cross formation

Code	Pedigree	Source
L1	BLWBAMNM SYN 2006F3-35-2-1-1-1	BNMRC
L2	BLWBAMNM SYN 2006F3-35-2-2-2-1	BNMRC
L3	BLWBAMNM SYN 2006F3-35-2-2-3-1	BNMRC
L4	BLWBAMNM SYN 2006F3-61-2-1-1-1	NMRC
L5	BLWBAMNM SYN 2006F3-149-1-1-2-1	BNMRC
L6	NM Composite 2008-10-3-2-2-1-1	BNMRC
L7	NM Composite 2008-10-3-2-2-1-2	BNMRC
L8	NM Composite 2008-42-2-1-1-1-1	BNMRC
L9	NM Composite 2008-42-2-1-1-2-1	BNMRC
L10	NM Composite 2008-45-1-2-1-1-1	BNMRC
L11	(SC-22 x Z605C2F2428-3-B-B-B-B-B-# X SC-22)F2 x SC-22(F2)-13-2-2-1-1-1	BNMRC
L12	(SC-22x DRA-F2-141-2-1-1-10-B-B-#XSC-22)F2 x SC-22(F2)-9-1-1-2-1-1	BNMRC
L13	CML-197 x 142-1-e(F2) 17-1-1-1-1-1-1	BNMRC
L14	CML-197 x 142-1-e(F2) 60-1-1-1-1-1-1	BNMRC
L15	CML-197 x 142-1-e(F2) 60-1-1-2-1-1-1	BNMRC
L16	CML-197 x 142-1-e(F2) 197-1-1-1-1-1-1	BNMRC
L17	35B-190-O-S10-2-1-2-2-1-3-1-1	BNMRC
L18	35B-190-O-S10-2-1-2-3-1-1-1-1	BNMRC
T1	PO'00E-3-2-1-2-1/CML312	BNMRC
T2	CML202/ILO'00E-1-9-1-1-1-1-1	BNMRC
T3	CML312/CML442	CIMMYT
T4	CML395/CML202	CIMMYT
BH-543	Released Variety	BNMRC
BH-546	Released Variety	BNMRC
BH-547	Released Variety	BNMRC

Key: BNMRC= Bako National maize research centre, CIMMTY= International Maize and Wheat Improvement Centre, L= inbred lines, T=Testers

2.4. Data analysis

Field data were collected on grain yield and yield attributing agronomic traits including number of ear per plant, number of kernels row per ear, number of kernels per row, weight of thousand kernel (gram), ear height (cm), plant height (cm), harvesting index (ton ha^{-}1), shelling percentage (%), number of days to anthesis, number of days to anthesis silking interval, number of days to silking, number of days to maturity, and disease reaction; gray leaf spot and tarcicum leaf blight on the base of 1-9 score using the procedures developed in Maize descriptor. The collected data were subjected to SAS statistical package (SAS, 2006 version 9.1.3) [16] for further analysis. Mean separation was carried out by deploying Duncan's New Multiple Range Test (DNMRT), the procedure suggested by Gomez and Gomez (1984) [6].

2.5. Standard Heterosis

Estimation of standard heterosis (SH%) was commenced by following the method developed by Falconer and Mackay (1996) [5].

$$\text{Standard Heterosis } (\%) = \left[\frac{F1 - STV}{STV}\right] x\ 100$$

Where, SH= standard heterosis, F_1= mean value of the cross, STV=mean value of standard check.

The difference in the magnitude of heterosis was tested following the procedure of Panse Sukhatme (1961) [12]. Standard error and critical difference were computed as;

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

$$CD = SE(d)xt$$

Where, SE (d) is standard error of the difference, MSe=error mean square from analysis of variance, r= number of replications, CD=critical difference and 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 suggested by Snedecor and Cochran (1967) as follows:

$$\text{Heterosis't'} = \frac{\text{MeanofF1p} - \text{StandardCheck}}{\frac{\sqrt{2\text{MSe}}}{\text{r}}}$$

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

3. Results and Discussions

3.1 Analysis of variance (ANOVA)

Analysis of variance revealed significant ($p<0.01$) variation of genotypes for all observed traits except for shelling percentage (SP), stand count at harvesting (SCH) and common leaf rust (CLR) as shown in table 2. The presence of significant genotypic difference indicates existence of inherent genetic variation which could be exploited and makes selection possible for further maize breeding program. The depicted genetic variation among the tested genotypes for character of interest pave the way for breeder to carryout careful selection of the most desirable crosses and these finding is in agreement with Kumar *et al*. (2021) [9]; Yadesa (2022) [18].

Table 2: Analysis of variance due to mean square of maize genotypes evaluated for grain yield and yield attributing traits at HaroSabu Agricultural Research Center, West Ethiopia

Traits	Error (df=46)	Rep (df=1)	Rep (block) (df=28)	Entry (df=74)
Grain yield (GY)	0.22	0.5	0.24	3.92**
Number of ear per plant (EPP)	0.01	0.03	0.02	0.08**
Kernels row per ear (KRPE)	0.63	0.03	0.62	2.57**
Kernels per row (KPR)	9.26	11.54	15.33	33.13**
Thousand kernel weight (TKW)	166.28	1.48	84.95	753.48**
Shelling percentage (SP)	4.48	14.15	4.44	5.07
Plant height (PH)	81.92	1845.98**	86.19	336.74**
Ear height (EH)	50.69	315.26	34.16	274.55**
Stand count at harvesting (SCH)	1.94	12.91	1.21	3.12
Harvesting index (HI)	18.95	57.81	37.45	82.73**
Days to anthesis (DA)	0.34	0.01	0.38	4.10**
Days to silking (DS)	0.45	0.11	0.47	6.18**
Anthesis-silking interval (ASI)	0.18	0.11	0.24	0.65**
Days to maturity (DM)	0.78	0.81	0.85	12.45**
Gray leaf spot (GLS)	0.26	0.88	0.26	0.77**
Tarcicum leaf blight (TLB)	0.16	0.28	0.14	0.46**
Common leaf rust (CLR)	0.14	0.03	0.13	0.24

Whereas, HSARC= Haro Sabu Agricultural Research Centre, Rep= replication, Rep(block)= block within replication, **= significant difference at 0.01 probability level *= significant difference at 0.05 probability level and values with no asterisk are non-significant

3.2 Mean Performance of Maize Genotypes

The mean grain yield (GY) varied from 6.46 ton ha^{-1} for L17xT4 to 12.39 ton $ha^{-1}$for L3xT1 with an overall mean of 8.22 ton ha^{-1}. 24 crosses exhibited higher mean GY than BH547. L3xT1 and L5xT1 increased grain yield over BH547 by 24%. Most crosses involve L5, L8, T1 and T2 as parents and such performance most likely could be resulted from using inbred lines from diverse germplasm source or belonging to testers to different heterotic groups. The higher grain yield of crosses over BH547 shows the high possibility of selecting a better commercial variety. This finding is in correspondence with Woldu *et al.* (2020) [20] and Yadesa (2022) [18] who reported significant mean of grain yield and related traits than the best hybrid check.

For EPP; the minimum and maximum value 0.90 and 1.75 was recorded from L2xT3 and L6xT4 crosses with an overall mean of 1.39, respectively. The mean of 18 crosses were significantly higher than the mean of BH547. Number of kernels row per ear (KRPE) ranged from 11.45 for L4xT2 to 17.33 for L5xT2 with the average 14.46. L5xT1, L5xT2, L3xT1 and L10xT2 showed significantly higher KRPE than BH547 (14.45), while L5xT1 and L5xT2 had significantly higher mean than BH543. Similarly, the mean for number of kernels per row (KPR) varied from 30.23 for L1xT3 to 48.15 for L11xT1 with average mean of 40.48. No cross had significantly higher mean than BH547 for KPR; however, numerically higher mean was recorded from twenty eight crosses (Results were not displayed). Mean of thousand kernel weight (TKW) ranged from 287.45 giram for L10xT4 to 382.52 giram for L3xT2 with average mean of 335.73 giram. Despite no crosses with higher and significant mean of TKW than BH543, significantly higher mean of TKW was retained from L11xT3 over BH547. This result is in agreement with Woldu *et al.* (2020) [20]; Yadesa (2022) [18] for GY and yield attributing traits; KRPE, KPR and TKW.

For plant height (PH); the shortest (227.80 cm) and the tallest

(292.60cm) mean was retained from L17xT3 and L13xT1 with an overall mean of 262.17 cm, respectively. Though no cross had significantly taller PH than BH547; L13xT1, L8xT4, L8xT3, L13xT3 and L3xT1 were significantly taller than BH543 and increased PH by 5-7% than BH547. 15 crosses explained significantly shorter PH than BH547. The shortest ear height (EH) was exhibited by L1xT3 (98.54cm) while the tallest EH displayed by L13xT2 (153.23cm) with average mean of 133.48cm (Results were not displayed). The significantly lower ear height (EH) was displayed by 22 crosses compared to BH547 and the existence of inherent genetic variability for plant statue reveals the opportunity to improve these genotypes for different farming system. With this, the cross identified for shorter plant statue are desirable to develop lodging resistant varieties and for easy field management. Extremely dwarf varieties have the problem of crowded canopy, aeration and transmission of sun light to the lower parts resulting in drastic reduction in yield. Unlikely, the cross with higher plant statue contribute a gene responsible for high biomass yield which might be used in animal feeding, fencing and fuel in rural areas are susceptible to lodging. Hence, attention should be given during inclusion of the selected cross in maize breeding. Woldu *et al.* (2020) [20]; Kumar *et al.* (2021) [9] reported the increasing and decreasing plant statue over the standard checks in their separate study.

For harvest index (HI), L2xT3 displayed the lowest mean (33.05 t ha^{-1}) while L10xT2 showed the highest mean (58.99 t ha^{-1}) with average mean of 46.86 t ha^{-1}. The mean of 52.57, 48.79 and 42.49 t ha^{-1} HI were recorded from BH543, BH547 and BH546 standard check, respectively. The mean of 22 and 26 crosses were higher than BH543 and BH547, respectively for HI. Conversely, some crosses attained significantly lower mean HI than BH543. This result can be justified through further evaluation of these genotypes across years and over locations.

The minimum mean number of days to anthesis (61.5days) was exhibited by L14xT1 while the maximum (68.5 days) was recorded from L6xT3, L8xT4 and L8xT3 with average mean of 64.17. L6xT3, L8xT4 and L8xT3 increased DA by 2.92% than the latest hybrid check, BH547 (65.5 days). The minimum and maximum value of 61.5 and 71 were recorded from L17xT2 and L6xT3, respectively for days to silking (DS) with average mean of 65.79 days. L6xT3, L6xT4, L8xT3, L8xT4 and L13xT2 were significantly later in DA, DS and ASI compared to BH547. The shortest (0 day) anthesis silking was displayed by L15xT1, L15xT2, L18xT4, L17xT2 and L17xT4 while the longest ASI (2.5 days) was retained by L9xT1, L13xT2, L11xT3, L6xT4, L6xT3, L8xT4 and L8xT3 with average mean of 1.6. As ASI is the most desirable trait in determining drought tolerance, the cross identified for shorter mean indicates short gaps between days to DA and DS, which are desirable for good seed setting and drought tolerance. Away from this; the longer ASI, the variability of pollen would be reduced and abnormal fertilization might take place or not totally happen, which may in turn leads to yield lose and these finding was comparable with Kumar *et al.* (2021) [9]; Xiao *et al.* (2021) [19] reports.

For DA and DS, 20 and 19 crosses were significantly earlier than BH547, respectively. L2xT2 and L14xT4 retained significantly earlier DA while L17xT4, L18xT4, L15xT2 and L15xT1 displayed significantly longer DS than BH543. For days to maturity (DM), the earliest was 136.5 days (L4xT3) and the latest was 151.5 days (L6xT3) with an overall mean of 144.13 days. L6xT3, L6xT4, L16xT2, L13xT2 and L8xT4 were significantly later in maturity and increased DM by 1.68-3.63% over BH547. 31 crosses were significantly earlier maturing than BH547 while 7 crosses displayed significantly earlier DM than BH543, illustrating their importance to develop earlier varieties for moisture stress areas since earliness are desirable to increase water use efficiency (Results were not displayed). The cross attaining the higher mean for DA, ASI, DS and DM could be used as a source of gene governing late phonological traits. Conversely, those crosses attained shorter mean for these traits may contribute a gene responsible for earliness. The earlier maturing crosses are suitable in agro-ecologies receiving shorter rainy season thereby to escape moisture stress encountered during grain filling period. Woldu *et al.* (2020) [20] also reported the earliest and fastest maturing hybrid over the standard checks so far.

Gray leaf spot (GLS) severity score ranged from 1.50 (L3xT1 and L6xT2) to 3.75 (L1xT3, L2xT2, L15xT3, L1xT4, L11xT1, L9xT4, L4xT4 and L14xT4) with average mean of 2.52. The desirable lower mean (1.25) severity score was displayed by L2x T1, L8 xT2, L11xT1, L13xT2, L13xT4 and L17xT1 for Turcicum leaf blight (TLB) where the higher and undesirable severity score 3.25 was retained from L7xT4 and L14xT4 with an overall mean of 1.92. 35 and 44 crosses attained the lower mean severity score than BH-547 for GLS and TLB, respectively (Results were not displayed). For TLB the result of present study was not consistent with Gudeta *et al.* (2015) who reported non-significant difference of maize genotypes in the study of heterosis and combining ability in QPM version of early generation high land maize inbred line in Ethiopia. None consistency of the result might be attributed by the use of inbred lines from diverse sources of germplasm in generation of the crosses, which was in correspondence with Woldu *et al.* (2020) [20]; Annor *et al.* (2020) [1]; Xiao *et al.* (2021) [19].

3.3 Standard Heterosis

Among the 3 standard checks used in this study; BH543, BH546 and BH547, standard heterosis (SH) was considered for BH547 due to its better mean performance for grain yield and most of yield attributing traits considered in this study. Standard heterosis was further estimated for agronomic traits attaining significant ($p<0.01$ or $p<0.5$) difference in analysis of variance (Table 2). The magnitude and direction of standard heterosis varied for a trait from cross to cross or among different traits, indicating the existence of considerable amount of standard heterosis for improvement of grain yield and yield attributing traits including foliar disease reaction. These results are in correspondence with Annor *et al.* (2020) [1]; Yadesa (2022) [18]. Desirable positive and significant standard heterosis (SH) was estimated for grain yield, ear per plant and kernels row per ear. Conversely, the desirable negative and significant SH was computed for days to anthesis and maturity (Table 3). The standard heterosis for grain yield (GY), varied from 31.04% for L17xT4 to 32.37% for L3xT1 over the high yielding hybrid check, BH547. 14 crosses exhibited positive and significant ($p<0.01$ or $p<0.5$) standard heterosis than BH547 for GY consistently. In line with this, Malkamu *et al.* (2018); Yadesa (2022) [18] reported different magnitude of standard heterosis for grain yield.

For ear per plant (EPP), 23 crosses revealed the desirable significant and positive standard heterosis (SH) which varied from -31.82% for L2xT3 to 32.20% for L6xt4 over BH547 (Table 3).These cross combination is highly prolific than the standard check and could be used to improve grain yield. Complimentary result was found by Anor *et al.* (2020); Kumar *et al.* (2021) [9] who reported the increasing SH effect for number of ear per plant. On the contrary, three crosses showed undesirable significant and negative SH for EPP (Table 3).

Table 3: Percentage of standard heterosis for grain yield and some yield components in maize genotypes evaluated at HSARC, West Ethiopia

Code	GY	EPP	KRPE	KPR	TKW	EH	PH	HI
L$_1$ x T$_1$	-15.54**	-8.71	0.73	-14.48	-5.43	-3.95	1.67	-21.46*
L1x T2	-16.24**	-17.05	1.25	-20.74**	-9.33*	-12.33*	-5.51**	-17.38
L1 x T3	-20.51**	-17.05	-4.08	-27.80**	-11.03**	-32.50**	-9.79**	-27.83**
L1 x T4	-19.12**	-1.52	-7.89	-9.75	-8.07*	-18.76**	-8.78**	-9.88
L2x T1	1.34	13.64	1.31	-6.64	-5.57	-0.45	-2.14	-6.91
L2 x T2	-18.70**	6.44	-0.69	-22.17**	-8.31*	-14.45**	-6.78**	-22.53*
L2 xT3	-11.75*	-31.82**	1.94	-22.69**	-3.22	-19.22**	-7.45**	-32.26**
L2 x T4	-20.09**	-7.95	-13.15*	1.55	-2.31	-9.65	-6.02**	-27.01**
L3 x T1	32.37**	29.17**	16.12**	7.01	1.29	-0.66	5.84**	15.78
L3 x T2	9.67	20.83*	10.07	12.47	9.43*	-5.11	2.36	15.37
L3 x T3	-10.26*	-16.67	2.8	-12.59	-2.53	-24.05**	-9.75**	-24.53**
L3 x T4	-21.21**	15.15	-6.78	11.17	-5.54	-7.65	-9.69**	-10.31
L4 x T1	-16.93**	-0.38	2.77	5.1	-2.97	-4.53	-1.99	-6.17
L4 x T2	0.85	20.83*	-20.76**	-1.98	-10.01**	-6.89	-4.65**	-2.42
L4 x T3	-24.47**	-16.67	-4.98	-9.15	-4.81	-17.85**	-7.00**	-29.56**
L4 x T4	-12.18*	28.41**	-14.98**	0.36	-13.05**	-9.71	-6.33**	-3.14
L5 x T1	31.94**	29.17**	16.26**	11.16	0.43	-0.04	1.06	15.31
L5 x T2	30.13**	29.17**	22.70**	9.53	1.28	4.41	2.77	18.32*
L5x T3	-10.74*	-24.24**	5.47	-11.61	4.91	-17.93**	-8.22**	-12.11
L5 x T4	-17.31**	23.48*	-2.01	10.01	2.71	-7.29	-6.98**	-5.96
L6 x T1	7.32	12.5	4.29	-4.16	1.34	-4.91	1.51	-2.89
L6 x T2	1.66	22.73*	3.53	-9.05	-7.54*	-2.73	-0.04	-13.04
L6 x T3	9.4	28.41**	11.87*	-7.96	0.45	-2.75	1.31	11.6
L6x T4	12.23*	32.2**	12.08*	3.01	1.98	-4.15	-2.42	16.93
L7 x T1	-5.02	0.76	-7.54	-4.35	-5.86	-3.11	2.08	4.39
L7 x T2	-13.57**	1.89	3.25	-4.35	-3.21	-6.12	-2.4	-18.96*
L7 xT3	-9.03	-16.29	8.62	4.93	-2.55	-18.78**	-9.32**	-2.66
L7 x T4	-15.65**	7.2	-18.20**	-13.55	-9.07*	-23.75**	-9.50**	3.94

Whereas; EH= ear height, EPP = ear per plant, GY= grain yield, HSARC= Haro Sabu Agricultural Research Centre, HI= harvesting index, KPR= kernels per row, KRPE= kernels row per ear, PH=plant height, TKW= thousand kernel weight, **= significant difference at 0.01 probability level *= significant difference at 0.05 probability level and values with no asterisk are non-significant

The finding of this study was in contrary with Berhanu (2009) [3] who reported the undesirable negative SH over the best check for EPP, indicating presence of increasing and decreasing SH effect in maize crosses for EPP. For kernel row per ear (KRPE), 8 crosses including L3xT1, L5xT1, L5xT2, L6xT4, L10xT2, L11xT1 and L11xT3exhibited the desirable significant ($p<0.01$ or $p<0.5$) and positive SH which was found in the range of -20.76 for L4xT2 and 22.70 for L5xT2. Conversely, L4xT2, L4xT4, L7xT4, L10xT4 and L13xT1 showed undesirable negative and significant ($p<0.01$ or $p<0.5$) SH over BH547 for KRPE consistently (Table 3). This result was not comparable with the finding of Woldu *et al*. (2020) [20]; Yadesa (2022) [18] who reported none of the hybrids exhibited positive and significant economic heterosis for kernel row per ear.

For kernel per row (KPR), the lowest SH of -27.80% was detected from L1xT3 while the highest value of 15.01% from L11xT1 over BH547. Most of the crosses had non-significant ($p>0.05$) SH for KRPE and KPR compared to the check (Table 3). Karim *et al.* (2018) [7]; Kumar *et al.* (2021) [9] reported significant heterosis for grain yield and yield attributing traits which was in accordance with this study.

Standard heterosis for thousand seed weight (TKW) ranged from -17.77% for L10xT4 to9.43%for L3xT2 than BH547. Positive and significant SH of TKW was computed from L3xT2 and L8xT3 over BH-547. This finding was in agreement with Malkamu *et al.* (2018); Yadesa (2022) [18] who reported the positive and significant SH for GY and yield related traits such as KRPE, KPR and TKW than BH547. Standard heterosis (SH) for harvesting index (HI) varied from -32.26% for L2xT3 to 20.91% for L10xT2 compared with BH547. L5xT2, L10xT2 and L12xT1 cross showed desirable positive and significant SH over the check consistently (Table 3).

Table 3: Continued…

Code	GY	EPP	KRPE	KPR	TKW	EH	PH	HI
L8 x T1	30.13**	22.73*	5.26	-3.15	-2.77	-0.36	3.77*	11.79
L8 x T2	22.33**	21.21*	0.21	-1.77	-7.14	-3.16	1.77	10.53
L8 xT3	1.12	-17.05	7.72	-1.79	8.80*	1.38	6.09**	-11.99
L8 x T4	20.03**	30.68**	6.89	7.08	6.15	-0.18	6.62**	16.68
L9 x T1	-29.11**	6.44	0.07	-3.08	-2.44	-3.34	-0.56	-9.04
L9 x T2	15.12**	30.30**	-2.6	1.67	-2.34	-1.66	1.2	12.71
L9 x T3	-19.71**	-15.15	1.25	-10.19	0.09	-18.07**	-6.41**	-19.06*
L9 x T4	-7.1	15.15	2.94	-9.25	-10.65**	-7.9	-4.20*	9.41
L10 xT1	-13.35*	22.73*	9.34	2.22	-5.49	1.19	-0.1	-8.01
L10 x T2	21.53**	30.30**	16.12**	-8.16	-9.51*	2.23	4.15*	20.91*
L10 xT3	-20.67**	-24.24**	3.53	-8.86	-11.35**	-11.93*	-2.18	-8.01
L10 x T4	-15.06**	21.21*	-18.37**	9.39	-17.77**	-4.02	-2.36	10.56
L11 xT1	-3.1	14.77	12.04*	15.03*	-1.61	-5.44	3.22	-3.91

L11 xT2	0.11	-1.89	0.8	6.95	-1.48	-1.71	-5.37**	-0.61
L11 x T3	23.45**	30.68**	11.59*	12.24	6.83	-11.04*	-3.24*	13.83
L11 x T4	-3.26	1.52	-4.71	11.44	-3.16	-15.07**	-8.90**	8.94
L12 x T1	19.76**	20.45*	9.34	7.12	-6.58	-2.73	-1.4	18.55*
L12 xT2	-2.88	-2.27	-2.56	-3	-6.4	1.73	-1.3	-9.96
L12 x T3	-11.86*	-17.42	-4.71	-6.98	0.45	1.86	1.65	-2.66
L12 x T4	-27.46**	-0.76	-4.98	-8	2.38	-0.6	-0.19	-14.04
L13 xT1	-17.95**	6.44	-11.7*	5.61	-2.57	-4.36	7.72**	-17.01
L13 x T2	11.81*	22.73*	3.39	-1.72	3.61	4.96	1.02	12.2
L13 x T3	8.81	23.86**	1.8	-1.77	0.38	-1.13	5.86**	12.5
L13x T4	-16.03**	-1.14	-9.83	5.21	-1.07	1.2	2.36	8.61
L14 x T1	-18.11**	-0.38	-6.51	0.84	-2.61	-1.55	-0.19	-17.01
L14 x T2	-6.62	7.2	-5.16	-7.6	-12.77**	-8.49	-4.80**	1.11
L14 x T3	-27.51**	-14.77	2.94	-1.74	-12.91**	-27.10**	-14.18**	-22.24*
L14 x T4	-5.82	13.64	-6.57	0.57	-9.89*	-19.82**	-12.61**	9.4

For ear height (EH), the lowest and highest SH of -32.5% and 4.96% was estimated from L1xT3and L13xT2, respectively over the standard check, BH547. 25 crosses revealed the desirable significant and negative SH for ear height (Table 3).The standard heterosis for plant height ranged from -16.13% for L17xT3 to -7.72% for L13xT1 than BH547. Most of the crosses attained the negative and significant (P<0.01 or P<0.05) SH for PH compared with the best hybrid (BH547).

Table 3: Continued…

Code	GY	EPP	KRPE	KPR	TKW	EH	PH	HI
L15 x T1	-21.96**	-8.71	-2.42	-4.85	-14.00**	-19.86**	-12.24**	-27.16**
L15 x T2	-19.39**	-1.89	-3.56	-13.33	-9.53*	-22.07**	-11.15**	-22.26*
L15 x T3	-12.71*	-0.38	1.9	-16.15*	-8.54*	-26.68**	-12.93**	-6.9
L15 x T4	-8.87	22.73*	-9.13	-13.38	-14.82**	-31.21**	-11.97**	-4.71
L16 x T1	-15.71**	-7.58	-1.45	4.95	-4.72	-16.73**	-7.40**	-11.07
L16 x T2	12.61*	7.2	2.84	4.25	5.75	-2.97	-1.75	10.66
L16 xT3	-25.16**	-16.67	1.56	-1.7	-0.31	-4.79	-3.12	-9.72
L16 x T4	-12.23*	-8.33	0.35	9.51	-2.41	-3.23	-1.14	-3.59
L17 x T1	9.83	14.77	-2.98	-3.42	-4.17	-10.80*	-5.51**	7.58
L17 x T2	-15.49**	-16.29	-2.63	-13.38	-10.16**	-14.69**	-7.38**	-7.79
L17 x T3	-20.35**	-8.71	-6.3	-18.16*	-8.30*	-22.84**	-16.13**	-21.91*
L17 xT4	-31.04**	0	-8.2	-20.93**	-9.53*	-4	-3.50*	-14.86
L18 x T1	14.16**	28.41**	2.91	9.72	-0.5	1.79	-2.77	12.52
L18 xT2	-9.51	0	0.21	-12.45	-14.48**	-3.7	-4.30*	-14.22
L18 x T3	-11.22*	14.39	-2.91	-12.66	-11.31**	-21.51**	-9.35**	-7.54
L18 x T4	-22.65**	16.29	-7.58	-7.38	0.53	-7.58	-5.77**	-9.74
Minimum	-31.04	-31.82	-20.76	-27.8	-17.77	-32.5	-16.13	-32.26
Maximum	32.37	32.2	22.7	15.03	9.43	4.41	7.72	20.91
CDα0.05	0.94	0.23	1.6	6.13	25.96	14.33	18.22	8.76
CDα0.01	1.26	0.31	2.14	8.18	34.65	19.13	24.32	11.7

The minimum value of SH was estimated from L17xT2 and L14xT1 while the maximum value estimated from L6xT3, L8xT3 and L8xT4 compared to BH547 for DA. Standard heterosisof days to silking (DS) varied from -7.52% for L17xT2 to 6.77% for L6xT3 and L8xT4 than BH547. For days to maturity (DM), L4xT3 showed the lowest value of SH while L6xT3 and L6xT4 exhibited the highest values over the late matured check (BH547). Therefore, as maturity related traits *viz*; DA, DS and DM concerned; the desirable negative and significant SH was observed for many cross combinations over high yielding hybrid check BH547 (Table 4). Such genotypes identified for their earlier maturity could be used in multiple cropping systems and to increase efficient land and water use. Significant heterosis for phonological traits have been said by way of a variety of people including Kumar *et al.* (2021) [9]; Yadesa (2022) [18]; Xiao *et al.* (2021) [19].

Table 4: Percentage of standard heterosis for phonological traits and some foliar disease in maize genotypes evaluated at HSARC, West Ethiopia

Code	**DS**	**DA**	**DM**	**GLS**	**TLB**	**Code**	**DS**	**DA**	**DM**	**GLS**	**TLB**
L_1 x T_1	0	0	-2.40**	10	0	L8 x T1	0.75	1.55	-0.34	0	-25
L_1x T_2	-2.26*	-1.55	-2.40**	0	-12.5	L8 x T2	3.01**	3.10**	1.03	-30	-37.5
L1 x T3	-2.26*	-1.55	-1.71**	50.00*	12.5	L8 xT3	6.02**	6.20**	1.03	-20	-25
L1 x T4	-1.5	-1.55	-2.40**	50.00*	50.00*	L8 x T4	6.77**	6.20**	1.71**	-30	-12.5
L2x T1	-1.5	-1.55	-0.34	-30	-37.5	L9 x T1	-0.75	-1.55	-1.03	0	-12.5
L2 x T2	-4.51**	-3.88**	-2.40**	50.00*	0	L9 x T2	0	0	0.68	-10	-25
L2 xT3	-3.76**	-2.33*	-1.71**	40	0	L9 x T3	-0.75	0	-1.03	10	-12.5
L2 x T4	-2.26*	-1.55	-1.03	20	50.00*	L9 x T4	-1.5	-1.55	-2.4.00**	50.00*	-25
L3 x T1	0	0	-1.37*	-40	-12.5	L10 xT1	-3.76**	-3.10**	-2.4.00**	30	-12.5
L3 x T2	0.75	0.78	-1.03	-30	-12.5	L10 x T2	-1.5	-1.55	-1.03	-30	-12.5
L3 x T3	0	0	-1.03	-20	0	L10 xT3	-1.5	-1.55	-1.03	-10	-12.5

L3 x T4	-1.5	0	-0.34	-30	-25	L10 x T4	-1.5	-0.78	-1.03	50.00*	-12.5
L4 x T1	0.75	0.78	-0.34	-20	0	L11 xT1	-0.75	0	-1.71**	-30	-37.5
L4 x T2	0.75	0.78	0	-20	-12.5	L11 xT2	-0.75	0	-1.03	-20	-12.5
L4 x T3	-5.26**	-3.88**	-6.51**	10	12.5	L11 x T3	2.26*	1.55	0.34	-20	-25
L4 x T4	-2.26*	-3.10**	-1.37*	50.00*	37.5	L11 x T4	-0.75	-0.78	-1.71**	20	-12.5
L5 x T1	0	0	-1.03	-30	-25	L12 x T1	-0.75	0	-0.34	-10	-25
L5 x T2	1.5	1.55	-1.03	-30	-25	L12 xT2	-1.5	0	-2.05**	0	0
L5x T3	0	0.78	-1.71**	-30	-12.5	L12 x T3	-0.75	-0.78	-0.34	-30	-12.5
L5 x T4	0.75	0.78	-0.34	0	-25	L12 x T4	-2.26*	-2.33*	-1.71**	10	-25
L6 x T1	0.75	1.55	-1.37*	-10	-25	L13 xT1	2.26*	2.33*	-0.34	-10	-12.5
L6 x T2	3.01**	3.10**	0.34	-40	-12.5	L13 x T2	4.51**	3.88**	2.40**	-30	-37.5
L6 x T3	6.77**	6.20**	3.77**	-30	0	L13 x T3	0.75	0.78	0.34	-10	-25
L6x T4	5.26**	4.65**	3.77**	-30	0	L13x T4	-0.75	-0.78	0.34	10	-37.5
L7 x T1	-3.76**	-2.33*	-2.4**	-10	0	L14 x T1	-5.26**	-4.65**	-2.40**	-30	0
L7 x T2	-3.76**	-3.10**	-1.71**	20	37.5	L14 x T2	-3.76**	-2.33*	-2.05**	-10	-12.5
L7 xT3	-3.76**	-3.10**	-1.03	40	25	L14 x T3	-3.01**	-3.10**	-1.71**	20	-25
L7 x T4	-1.5	-1.55	-1.37*	30	62.50**	L14 x T4	-3.76**	-3.88**	-2.05**	50.00*	62.50**

Whereas, ASI= anthesis-silking interval, DA= days to anthesis, DM= days to maturity, DS= days to silking, GLS= gray leaf spot, HSARC= Haro Sabu Agricultural Research Centre TLB, = tarcicum leaf blight, **= significant difference at 0.01 probability level *= significant difference at 0.05 probability level and values with no asterisk are non-significant

Minimum value of -50.00% for L3XT1 and L6XT2, and the maximum value of 50.00% standard heterosis were estimated from 8 crosses for GLS compared to BH547. The lowest magnitude of -37.50% standard heterosis was estimated from 7 crosses whereas the highest magnitude 62.50% computed from L7xT4 and L14xT4 cross combination over BH547 for TLB. Most of the crosses revealed non-significant SH for GLS and TLB compared to the check (Table 4).

Table 4: Continued…

Code	DS	DA	DM	GLS	TLB
L15 x T1	-6.02**	-3.10**	-2.40**	20	50.00*
L15 x T2	-6.02**	-3.10**	-5.48**	30	25
L15 x T3	-3.01**	-1.55	-2.40**	50.00*	50.00*
L15 x T4	-2.26*	-0.78	-3.08**	10	50.00*
L16 x T1	0.75	1.55	-0.34	10	-25
L16 x T2	2.26*	2.33*	3.08**	0	-12.5
L16 xT3	0	0.78	-0.34	10	-12.5
L16 x T4	-0.75	-0.78	-1.37*	-20	-25
L17 x T1	-2.26*	-1.55	-1.71**	-10	-37.5
L17 x T2	-7.52**	-4.65**	-6.16**	-10	0
L17 x T3	-4.51**	-3.10**	-4.45**	0	12.5
L17 xT4	-5.26**	-2.33*	-3.77**	0	50.00*
L18 x T1	-0.75	0	0.34	0	-25
L18 xT2	-1.5	-0.78	-3.77**	30	12.5
L18 x T3	-3.01**	-1.55	-2.40**	10	0
L18 x T4	-5.26**	-2.33*	-4.11**	0	-25
Minimum	-7.52	-4.65	-6.51	-40	-37.5
Maximum	6.77	6.2	3.77	50	62.5
CDα0.05	1.35	1.18	1.77	1.02	0.8
CDα0.01	1.8	1.57	2.37	1.36	1.06

In general, the difference in percentages of SH can be attributed to the stage of inbreeding of used materials, the environmental conditions in which the materials were evaluated and the performance of the parental inbred lines. Hence, the identified crosses could be promising for commercial variety development after evaluating its performance and stability across years and locations. The result of present study was in accordance with (Yadesa, 2022; Xiao *et al.* (2021) [18, 19].

4. Conclusions

Cross combination displayed the desirable higher mean, positive and significant standard heterosis for grain yield, number of ear per plant, number of kernel row per ear, number of kernel per row, thousand kernel weight and harvesting index were identified in this study. Correspondently, some other F1 hybrids attained the desirable lower mean, negative and significant standard heterosis for days to anthesis, days to silking, anthesis silking interval, days to maturity, plant height, ear height, and gray leaf spot and tarcicium leaf blight. This indicates, predominance of non-fixable inter allelic interaction for respective traits. The desirable significant and positive heterotic response of grain yield was retained in particularly selected cross combinations like L3xL1, L5xL1, L5xT2, L6xT4, L8xT1, L8xT2, L8xT4, L9xT2, L10xT2, L11xT3, L12xT1, L13xT2, L16xT2 and L18xT1 consistently. These cross combination could be promising for commercial variety development after evaluating their performance and stability across years and locations.

5. Conflict of interests

The authors have not declared any conflict of interests.

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