American Journal of Plant Biology
2022; 7(2): 81-94
http://www.sciencepublishinggroup.com/j/ajpb
doi: 10.11648/j.ajpb.20220702.11
ISSN: 2578-8329 (Print); ISSN: 2578-8337 (Online)

Hybrid Performance and Heterosis for Yield and Agronomic Traits of Quality Protein Maize (*Zea Mays* L.) Inbred Lines Adapted to Mid-altitude Agro-Ecology of Ethiopia

Lemi Yadesa[1, *], Sentayehu Alamerew[2], Berhanu Tadesse[1]

[1]Ethiopian Institute of Agricultural Research, Bako National Maize Research Centre, Addis Ababa, Ethiopia

[2]College of Agriculture and Veterinary Medicine, Jimma University, Jimma, Ethiopia

Email address:
lemikooyadi64@gmail.com (L. Yadesa)
[*]Corresponding author

To cite this article:
Lemi Yadesa, Sentayehu Alamerew, Berhanu Tadesse. Hybrid Performance and Heterosis for Yield and Agronomic Traits of Quality Protein Maize (*Zea Mays* L.) Inbred Lines Adapted to Mid-altitude Agro-Ecology of Ethiopia. *American Journal of Plant Biology*. Vol. 7, No. 2, 2022, pp. 81-94. doi: 10.11648/j.ajpb.20220702.11

Received: February 14, 2022; **Accepted**: March 4, 2022; **Published**: April 14, 2022

Abstract: Maize is a primary crop in most farming systems and staple food of the rural population in abundant of the mid-altitude sub- humid agro-ecologies of Ethiopia. Nearly 88% of maize produced in Ethiopia is consumed as food, both as green and dry grain. Yet, it has low protein content since it is normal maize, with poor protein quality limited by deficiencies in lysine and tryptophan and has an excess of leucine and isoleucine. Suggestions on hybrid performance and heterosis of QPM inbred for grain yield and its components is vital to design suitable breeding strategies for the development of nutritionally enhanced maize varieties. A line x tester analysis involving 36 crosses generated by crossing nine elite maize inbred lines with four testers and four checks were evaluated for yield and yield related traits at Bako and Jimma. The objectives were to evaluate mean performance and the magnitude of heterosis for quality protein maize inbred lines, adapted to mid altitude agroecology of Ethiopia. The genotypes were evaluated in alpha lattice design replicated three times. Analyses of variances showed significant ($p<0.05$ or $p<0.01$) mean squares due to genotypes in each and across locations for most traits studied, indicating the existence of appropriate genetic variability. The crosses, L5xT2, L7xT2, L8xT1, L8xT2, L3xT2, L5xT1, and L1xT1 showed higher grain yield. The estimated mid and better parent heterosis for grain yield across locations for all crosses displayed positive and highly significant variances which ranged from 386.6% to 111.2% and 288.9% to 72.2%, respectively. From this study, about 77.78% of crosses had better potential for grain yield. The results attained in this experiment suggest that the hopeful potentials of the identified inbred lines for further breeding of QPM for the mid-altitude agro-ecology of Ethiopia.

Keywords: Better-Parent, Heterosis, Grain Yield, Mean Performance, Mid-parent, Line x Tester, Standard Heterosis

1. Introduction

Maize has great yield potential and attained the leading position among the cereals based on production as well as productivity [30]. About 88% of maize produced in Ethiopia is consumed as food, both as fresh and dry grain [2]. Although, normal maize has low protein content, about 8% to 11% of the kernel weight with poor protein quality limited by deficiencies in lysine and tryptophan and has an excess of leucine and isoleucine [23], leading to a poor growth in children and pellagra in adult [9]. Quality protein maize is a maize with increased lysine and tryptophan levels and contains higher amount of lysine and tryptophan in the endosperm ensuring higher biological value (80%) and availability of protein to human and animal [20].

Despite the importance of quality protein maize to ease protein deficiency, most of the maize cultivated in Ethiopia is conventional maize. While, to utilize the conceivable nutritional benefits of QPM, research on QPM was started in Ethiopia in 1994 [4] by the introduction and evaluation of open-pollinated varieties and pools introduced from

CIMMYT QPM pools [19]. At following, the National Maize Research program of Ethiopia has released QPM maize varieties adapted to the mid-altitude, low moisture stress and highland agro-ecologies of Ethiopia. However, the market share of these varieties is generally small due to several characteristics that have limited their adoption by farmers, including: - high susceptibility to CLR, especially when grown in rust hot spot; susceptibility to TLB and low seed yield of [4] and many biotic and abiotic constraints still limit maize production and productivity in different maize producing area of Ethiopia [1].

Compared to conventional maize, breeding for QPM varieties is a daunting task due to narrow genetic base of QPM germplasm, complex genetic system, and limited funding. Thus, several research studies have been done over the years to solve these constraints on QPM varieties and still it need a continuous effort and obligatory to know the breeding values of the new inbred lines prior to using the new introduced inbred lines for hybrid formation [10, 3]. To overcome these challenges, the national maize program of Ethiopia introduces new finished and early generation inbred lines from CIMMYT and IITA to use for breeding and hybrid formation. However, most of the studies conducted in Ethiopia were focused on locally developed inbred lines or introduced inbred lines only from CIMMTY. In this study, new inbred lines from both IITA and CIMMYT are newly introduced for hybrid formation. But the mean performances and the magnitude heterosis of these newly introduced QPM inbred lines used in the present study has not been studied before. Hence, this study was conducted to estimate the magnitudes of heterosis for grain yield and its related traits of QPM crosses, and to evaluate the mean performance of inbred lines adapted to mid altitude agro ecology of Ethiopia.

2. Materials and Methods

2.1. Description of Experimental Sites

The experiment was conducted at Bako National Maize Research Center (BNMRC) and Jimma Agricultural Research Center (JARC) during 2019 cropping season. BNMRC is in East Wollega zone of the Oromia Regional State, Western Ethiopia. BNMRC lies between 9°06' north latitude and 37°09' east longitude in the sub-humid agro-ecology, at an altitude of 1650 meters above sea level. The mean minimum and maximum temperatures of the location are 19.7°C and 22.7°C, respectively. The long-term annual rainfall of the site is 1245 mm per year and relative humidity of 63.55%. The soil type at BNMRC is characterized by reddish brown in color and clay and loam in texture with pH of 6.0 and 5.9 [17]. JARC is in Jimma zone, Oromia Regional State, South Western of Ethiopia. The center is located between 7°40'37'N and 36°49'47'E and at an altitude of 1753 m.a.s.l. The average maximum and minimum temperatures are 11.9 and 26.2°C, respectively. It receives an average annual rainfall of 1532 mm. The long-term annual rain fall of the site is 1572 mm per year with RH of 67%. The soil type at JARC is characterized by reddish brown with pH of 5.20 [22].

2.2. Experimental Materials

The experiment consisted of 36 F_1 hybrids, four standard checks (BH540, BHQPY545, BH546 and BH547) and 13 parental lines. The 36 F1 hybrids were generated by using design-II in 2018/2019 cropping season at Bako National Maize Research Center from 13 parental lines (9 as females and 4 as males) (Table 1) introduced from CIMMYT and IITA for QPM germplasm development.

Table 1. *Code and inbred lines, testers and checks used in the experiment.*

Line's code	Genotype name	genotype origin	Tester's code	Genotype name	Genotype origin
L1	CML511	CIMMYT-Zimbabwe	T1	CML144	CIMMYT-Zimbabwe
L2	CZLQ2	CIMMYT-Zimbabwe	T2	CZLQ1	CIMMYT-Zimbabwe
L3	CZLQ3	CIMMYT-Zimbabwe	T3	CZLQ5	CIMMYT-Zimbabwe
L4	TZMI818	IITA-Nigeria	T4	TZMI809	IITA-Nigeria
L5	TZMI819	IITA-Nigeria	Checks	Check's name	Origin of checks
L6	TZMI820	IITA-Nigeria	1	BH540 (SC 22/124-b (113))	BNMRC
L7	TZMI825	IITA-Nigeria	2	BHQPY545 (CML161/CML165)	BNMRC
L8	TZMI829	IITA-Nigeria	3	BH546 (CML395/CML202//BKL001)	BNMRC
L9	TZMI833	IITA-Nigeria	4	BH547 (BKL002/CML312//BKL003)	BNMRC

2.3. Experimental Design and Field Managements

Two trials (a hybrid and inbred trial) were conducted during the main cropping season of 2018/2019. The hybrid trial which is consisted of 36F1 experimental crosses and four standard checks were planted using 5x8 alpha lattices experimental design with three replications. Each entry was planted on one row plot of 5m long with spacing of 0.75 m between rows and 0.25 m between plants. The hybrid and parental trials were planted adjacent to each other in the same field to avoid the shading effect of hybrids on inbred lines when included in the same trial. For both trials, two seeds were planted per hill to ensure uniform germination and enough plant stand which later thinned to one seedling per station to attain a final plant density of 53,333 plants per hectare. NPS and urea fertilizers were applied at the rate of 150 kg/ha and 250 kg/ha, respectively. The others agronomic practices were carried out as per the recommendation for the areas.

2.4. Data Collected

Data on grain yield and other important agronomic traits were collected on a plot and sampled plants bases. Data collected on a plot basis include days to 50% silking (DS), number of ears per plant (EPP), field weight (FW) (kg/plot), plant aspects (PA), ear aspects (EA) and bad husk cover (HC); while data recorded on sampled plants basis were ear height (EH) (cm) and plant height (PH) (cm), number of rows per ear (NRPE), number of kernels per row (NKPR), ear diameter (ED), ear length (EL), thousand kernels weight (TKW), root lodging (RL), stock lodging (SL) and major diseases such as gray leaf spot (GLS), turcicum leaf blight (TLB) and common leaf rust (CLR).

2.5. Data Analysis

2.5.1. Analysis of Variance (ANOVA)

Analyses of variance (ANOVA) was computed for grain yield and other agronomic traits for individual location. Prior to combined data analysis across locations, Bartlett's test for grain yield and related traits were conducted to test homogeneity of error variances [18]. As a result, combined analysis over the two locations was carried out for these traits by using PROC MIXED in SAS [26]. Least significant difference (LSD) was used for mean comparisons for both hybrid and inbred lines genotypes. For traits that displayed significant differences among crosses, line by tester analysis was performed to further partition the variances due to crosses into lines, tester and line by tester effects using SAS program [26].

2.5.2. Heterosis Estimation

Better parent heterosis (BPH), mid parent heterosis (MPH) and standard heterosis (SH) or economic heterosis in percent were calculated for those characters showed statistically significant differences among genotypes as suggested by Falconer and Mackay [26]. These were computed as percentage increase or decrease of the cross performances over the mid parent, best parent and best standard check as follows. Four best standard checks BH540, BHQPY545, BH546 and BH547 were used to estimate of standard heterosis. This was calculated as percentage increase or decrease of the cross performances over the standard checks. The standard checks selected are well adapted to mid altitude agroecology and popular among the farming community for high yielding potential.

$$MPH = \frac{(F1-MP)}{MP} * 100,\ BPH\ (\%) = \frac{(F1-BP)}{BP} * 100,\ STH\ (\%) = \frac{(F1-SV)}{SV} * 100$$

Where: F1 = mean value of a cross, MP = mean value of the two parents, BP = mean value of the better parent and SV = mean value of standard check variety.

Significance for heterosis tested using the t-test. The standard errors of the difference for heterosis were calculated follows:

$$SE\ (d)\ \text{for BPH and SH} = \pm\sqrt{2mse/r},\ \text{SE of mid parent heterosis} = \pm\sqrt{3mse/2r}$$

Where, SE (d) is standard error of the difference, MSe is error mean square and r is number of replications. Significance of heterosis was tested using the t-test against the critical difference (CD). The CD for testing the significance of mid parent (MP), better parent (BP) and standard heterosis (SH) was calculated according to Singh and Chaudhary, (31) as follows:

1) Critical difference (CD) for heterosis over MP: CD for MP = $\pm(\sqrt{3mse}/2r)$*t

$$SE\ (d)\ \text{for MP} = \pm(\sqrt{3mse}/2r),\ t\ (\text{mid- parent}) = \frac{(F1-MP)}{SE(d)}$$

2) Critical difference for heterosis over better parent or SH.

CD for BP/SH = $\pm(\sqrt{2mse}/r)$*t, SE (d) for BP/SH = $\pm(\sqrt{2mse}/r)$*t

t (better parent) $= \frac{F1-BP}{SE(d)}$, t (standard hybrid) $= \frac{F1-SV}{SE(d)}$

Where's, SE (d) is standard error of the difference, MSe is the error mean square, r is the number of replication and F1, MP, BP and SV are mean values of the hybrids, mid-parent, better parent, and standard check varieties, respectively. The computed t values were tested against the t value at the error degrees of freedom for table value at 5% and 1% probability levels.

3. Results and Discussion

3.1. Analysis of Variance

Mean squares of the studied traits from analysis of variance (ANOVA) and for genotype mean square at individual locations and combined over the two locations are presented in Table 2.

After pooled analysis, most of the traits showed significant differences due to genotypes and highly significant differences ($p<0.01$) were observed among the genotypes for grain yield, days to anthesis, days to silking, plant height, ear height, ear position, number of kernels per row, ear diameter, thousand kernels weights, ear per plant, plant aspect, ear aspect, turcicum leaf blight and common leaf rust (Table 2). Traits such as grain yield, ear diameter and turcicum leaf blight showed significant differences for genotype by location (G x L) interactions whereas highly significant differences ($p<0.01$) and significant differences due to genotypes were observed for common leaf rust and number of kernels per row, indicating that genotypes performed differently across locations, this means the relative performances of the genotypes were affected by the variable environmental conditions.

Majority of traits such as days to anthesis, days to silking, days to maturity, plant height, ear height, ear position, thousand kernel weights, ears per plant, plant aspect, ear aspect, gray leaf spot, phaeosphaeria leaf spot, maize strike virus and root lodging showed non-significant differences for genotype by location (G x L) interactions, implying the similar performance of the genotypes for these specific traits across the test locations. The non-significant of G x L interaction for most of yield related traits in a genotype is desirable as it displays the opportunity of developing steady genotypes with respect to these parameters (Table 2). Tilahun *et al.* [32] reported that combined analysis of mean square was significant at p<0.05 and highly significance at p<0.01 among locations, genotypes, and crosses in all studied traits except ear position, indicating the presence of genetic variability among crosses. And, he observed that mean squares due to crosses × locations interaction for all studied traits, except anthesis silking interval and gray leaf spot exhibited non-significant variation. Generally, the similar finding for significant genotype of grain yield and other traits such as number of kernels per row, ear diameter, number of rows per ear and ear length due to mean square of genotypes showing significant differences were previously reported based on studies at various time and location [12, 21, 7, 24, 10, 6, 33, 13].

Table 2. *Analysis of variance for grain yield and agronomic traits of line by tester crosses involving nine lines and four testers at Bako and Jimma in 2019 main cropping season.*

Traits	Hybrids						Parents					
	Loc (DF=1)	Genotype (DF=39)	GxL (DF=39)	Rep (L) (DF=4)	Bloc (R) (DF=21)	Error (DF=156)	Genotype (DF=12)	Location (DF=1)	GxL (DF=12)	Rep (L) (DF=4)	Bloc (R) (DF=6)	Error (DF=48)
GY	711.04**	8.86**	2.37*	5.2*	1.5*	1.018	3.91**	2.27*	0.26	0.2	0.03	0.41
DA	319.7**	21.8**	1.06	2.67	15.2*	5.78	8.01*	1115.7**	6.43*	1.05	0.21	2.87
DS	75.93*	27.9**	0.5	4.9	15.8*	5.86	6.54*	886.78**	5.06	1.28	1.24	2.95
ASI	0.27**	0.006*	0.008*	0.005	0.004	0.004	0.006	0.0012	0.003	0.011*	0.012*	0.0033
DM	68.27*	34.8*	19.49	167**	54.8**	16.94	27.25	9.35	11.76	11.03	8.76	19.72
PH	0.13067	1287**	10.22	611.5*	276.1*	164.9	2232.2**	237.83	327.78*	238.83	453.6*	97.71
EH	0.937	620.9**	0.518	448**	262**	73.13	946.91**	11.69	52.71	19.91	16.6	78.42
EPO	0.00004	0.007**	0.00004	0.005*	0.004**	0.001	0.018*	0.0004	0.002	0.004	0.004	0.011
NRE	8.36*	2.24**	2.24**	0.57	1.60*	0.64	3.29*	12.80*	3.71*	0.5	0.114	1.19
NKR	6512.5**	34.15**	20.14**	15.44	28.51*	11.85	36.47*	125.65*	16.06	33.13	27.99	12.02
EL	873.64**	3.98*	3.86*	10.42*	4.84*	2.26	14.87**	1.71	1.13	2.21	2.31	1.24
ED	33.10**	0.22**	0.11*	0.51**	0.17*	0.065	0.56*	0.54	0.33*	3.61**	4.07**	0.16
TKW	0.24**	0.006**	0.002	0.004	0.0021	0.002	0.02**	0.001	0.001	0.002*	0.0001	0.0007
EPP	28.26**	0.26**	0.22	0.19	0.11	0.092	3.48	20*	2.86	3.07	2.036	2.73
PA	11.70**	1.15**	0.18	0.071	0.42*	0.154	1.96**	6.51**	0.32*	0.09	0.086	0.15
EA	0.55	1.07**	0.22	1.37*	0.39	0.24	1.53**	0.39	0.096	0.32	0.099	0.21
GLS	4.96**	0.169*	0.104	0.08	0.11	0.08	0.45*	0.16	0.053	0.35	0.003	0.2
TLB	4.13**	0.26**	0.14*	0.12	0.20*	0.073	2.62**	20**	1.77**	0.56*	0.09	0.19
CLR	5.61**	0.52**	0.36**	0.49*	0.33*	0.13	1.72*	0.12	2.04**	1.11	1.28	0.47
PLS	0.46	0.37**	0.078	0.66*	0.24*	0.17	3.46**	0.32	0.14	0.022	0.009	0.29
MSV	2.71**	0.173	0.073	0.08	0.14	0.16	0.53*	0.32	0.92*	0.013	0.0001	0.26
SL	12.29**	0.16*	0.18*	0.03	0.084	0.074	2.37*	52.5**	1.49	0.67	0.14	0.86
RL	9.20**	0.14*	0.054	0.41**	0.13*	0.062	1.03	23.71**	0.68	0.36	0.054	0.8
ER	21.24	0.23*	0.174*	0.12	0.16	0.11	15.62**	76.01**	10.29*	0.68	0.023	3.28
HC	9.64**	0.44**	0.43**	0.60*	0.23*	0.12	1.44	52.51**	2.35*	2.59*	0.44*	0.88

*=Significance level at 0.05, **=Significance level at 0.01 no asterisk of */**=non-significance at 0.05 and 0.01 levels, GY=grain yield, DA=days of anthesis, DS=days of silking, ASI=anthesis silking interval days, DM=days of maturity, PH=plant height, EH=ear height, EPO=ear position, NRPE=numbers of rows per ear, NKPR=numbers of kernels per row, EL=ear length, ED=ear diameter, thousand kernel weight, EPP=ear per plant, PA=plant aspect, EA=ear aspect GLS=gray leaf spot, TLB= turcicum leaf blight, CLR=common leaf rusts, PLS= phaeosphaeria leaf spot, MSV=maize streak virus, SL=stock lodging, RL=root lodging, ER=ear rot, HC=husk cover.

3.2. Mean Performance of Hybrids

The combined mean performances of hybrids for across locations are presented in Table 3.

Across locations, overall mean grain yield of the genotypes was 7.23 t/ha ranging from 5 t/ha to 9.8 t/ha. Cross L5xT2 (8.8t/ha), followed by crosses L7xT2 (8.7 t/ha), L8xT1 (8.7 t/ha) and L8xT2 (8.7 t/ha), had higher grain yields while crosses L9 x T3 (5 ton/ha) and L7xT4 (5.4ton/ha) showed lower grain yield. In combined analysis across locations, the maximum grain yield obtained from standard check BH546 (9.81t/ha) whereas the lowest grain yield was recorded from L9xT3 (5t/ha). In another way, 63.9% and 19.4% of crosses showed greater grain yield than the standard checks BH545 and BH540, respectively while 22.2% of crosses showed lower grain yields than the standard check BH545. These results imply that 77.78% of crosses showed good performance and the probability to obtain good hybrids of quality protein maize at both studied areas. In combined analysis across locations, the longest duration of days to anthesis and days to silking among the crosses was recorded by L2xT4 (86 days) and L5xT3 (86 days) whereas the shortest duration was recorded by L5xT3 (78 days) and L5xT3 (77days), respectively with general mean values of 82 and 81 days as its arrangement. In other definition, above 77.8% and 69.4% of crosses were taken greater than 80 and less than 86 days to anthesis and days to silking, respectively. Most of crosses displayed longer number of days to anthesis and silking. Hence, crosses displaying longer number of days to anthesis and silking show to belong to late maturing type. Across locations, with related to plant height and ear height, the tallest plant height and ear height were obtained from BH546 (263.63cm) and BH547 (112.3cm) and the shortest was from the crosses of L6xT4 (104.3cm) and L5xT3 (78cm). These results revealed that the morphological arrangement was moderately grouped into the same range since there is no more variation among crosses at both studied locations.

Across locations, the ratio of ear height to plant height or ear position ranged from 0.38 to 0.50, conversely 97.22% of crosses ranged between 0.40 to 0.50 whereas only 2.78% of crosses was out of the majority domain of 0.40 to 0.5 (Table 4). As many crosses showed ear placement near to the mid part of the plant, indicating desirable character for lodging tolerance [17]. Crosses which have shorter plant and ear height are anticipated for lodging tolerance and to apply indispensable management practices, whereas taller crosses are important to harvest high biomass yield that can be used as animal feed and source of fuel for poor farmers [7, 17]. Previous reports suggested that plant and ear height could be used as essential agronomic parameters for maize selection breeding [25, 5]. Shorter plant height and medium ear placement are desirable for lodging resistance and mechanized agriculture.

In combined analysis across locations, the maximum and minimum number of kernels per row were obtained from the crosses of L3xT3 (40.07) and L6xT4 (30.77), whereas the longest and widest ear length and ear diameter and shortest and slightest (narrowest) ear length and ear diameter were recorded from the crosses of L7xT3 (17.53cm) & BH547 (4.93cm) and L3xT2 (13.17cm) and L3xT2 (4.10cm), respectively. Across locations, the number of ears per plant ranged from 0.68 to 1.46 with grand mean values of 1.05 by means of the maximum number scored from the check BH545 (1.46) and the minimum from L9xT3 (0.68). For general explanations, nearly 61.1% of crosses contributes ≥1 ear per plant. Compared with standard checks, 94.44% of crosses was better contributors than the check of BH547 (0.76), similarly 36.11% of crosses was greater than the standard check BH540. Indicating thereby these were prolific crosses as they showed higher number of ears per plant.

Across locations, the maximum and the minimum thousand grains weight were attained from the check BH540 (355g) and cross L3xT2 (192g), respectively, whereas almost 50% of crosses showed greater than or equal (≥) to the standard check BH545 and 27.78% of crosses had greater than the standard check BH546. In combined analysis across locations, major diseases plague under natural invasion mean values for TLB and CLR scored 1.3 to 2.3 and 1.7 to 2.8 for disease reactions respectively. With other assessment 94.44% and 83.33% of crosses was more resistant to TLB than the standard checks BH547 and BH540 whereas 80.56% of crosses was more resistant than the standard checks BH546 and BH545. The most top resistant crosses to TLB under natural infestation were L3xT1, L4xT1 and L6xT2 since they were scored less than 1.5 (Table 3).

Table 3. *Mean values of yield and agronomic attributes of 36 test cross hybrids and four standard checks of maize genotypes evaluated at Bako and Jimma in 2019 main cropping season.*

Entries	GY (t/ha)	DA (days)	DS (days)	ASI (Days)	PH (cm)	EPO (ratio)	DM (days)	EH (cm)	TLB (scale)	CLR (scale)	ER (%)	HC (%)
L1 xT1	8.4^{b-f}	85^{a}	83.7^{ab}	0^{a-c}	247.1^{b-f}	0.43^{bc}	155^{a-f}	112.5^{b-d}	2.0^{c-e}	1.8^{ij}	1^{d-g}	0.67^{h}
L1 xT2	8.3^{b-f}	82.0^{c-i}	81.7^{e-i}	-0.5^{a-e}	237.7^{d-l}	0.47^{ab}	151^{f-i}	107.0^{d-j}	1.9^{c-e}	2.3^{c-h}	2^{a-d}	0.83^{hg}
L1 xT3	6.6^{i-n}	80.5^{f-l}	79.8^{h-m}	-1^{d-f}	224.0^{l-o}	0.40^{dc}	155^{a-f}	90.7^{m-p}	1.75^{d-g}	2.2^{d-h}	1.17^{c-g}	0.83^{hg}
L1 xT4	5.7^{n-q}	82.2^{c-h}	82.8^{b-g}	-0.17^{a-c}	230.7^{i-o}	0.43^{bc}	154^{b-h}	101.3^{f-k}	1.8^{c-f}	1.8^{h-j}	1.5^{b-g}	0.83^{hg}
L2xT1	7.0^{g-l}	84.3^{a-c}	84.5^{a-d}	0.17^{a-c}	233.3^{e-m}	0.43^{bc}	155^{a-f}	101.0^{g-l}	1.7^{e-h}	2.1^{e-i}	0.5^{g}	1^{f-h}
L2xT2	7.9^{b-g}	82.6^{c-j}	82.3^{e-i}	0^{a-c}	233.7^{e-l}	0.45^{a}	156^{a-f}	109.7^{b-g}	1.7^{e-h}	2.5^{c-g}	1.7^{b-f}	1.33^{e-h}
L2xT3	5.9^{l-q}	82.3^{b-h}	83.8^{a-e}	0.33^{a}	232.7^{f-n}	0.47^{ab}	158^{ab}	109.3^{b-g}	1.8^{c-f}	2.3^{b-f}	0.5^{g}	1.66^{d-h}
L2xT4	8.0^{b-g}	85.7^{a}	84.8^{a-c}	-1.5^{f}	234.7^{e-l}	0.50^{a}	155^{a-f}	115.7^{a-d}	1.7^{e-h}	1.8^{ij}	1^{d-g}	1^{f-h}
L3xT1	7.4^{e-j}	82.5^{b-g}	82.7^{c-g}	-0.33^{a-e}	249.8^{a-d}	0.43^{bc}	155^{a-f}	111.0^{b-f}	1.3^{ij}	1.9^{g-j}	0.8^{e-g}	1^{f-h}
L3xT2	8.6^{b-e}	78.8^{k-m}	78.3^{j-m}	-0.33^{a-e}	219^{m-q}	0.47^{ab}	152^{e-h}	100^{g-m}	1.5^{g-j}	2.5^{a-d}	2^{a-d}	0.83^{hg}
L3xT3	7.5^{pq}	80.8^{j-m}	80.2^{j-m}	-1.17^{f}	235.5^{qr}	0.43^{bc}	154^{a-g}	104.3^{l-p}	1.75^{d-g}	2.6^{a-d}	1.3^{c-g}	1.66^{d-h}
L3xT4	8.2^{b-f}	80.0^{g-m}	79.2^{i-m}	-1^{d-f}	204.4^{qr}	0.50^{a}	151^{e-i}	95.3^{k-p}	1.9^{c-e}	1.9^{g-j}	1.8^{a-e}	4.16^{a}
L4xT1	7.6^{d-j}	80.7^{e-l}	80.2^{g-l}	-0.33^{a-e}	228.0^{j-p}	0.40^{dc}	156^{a-e}	99.3^{h-n}	1.4^{h-j}	1.9^{g-j}	0.66^{fg}	3^{a-c}
L4xT2	7.7^{c-i}	79.0^{k-m}	78.7^{j-m}	-0.5^{a-e}	242.3^{d-j}	0.43^{bc}	152^{c-h}	108.3^{c-i}	1.8^{c-f}	2.4^{b-e}	1.17^{c-g}	1.5^{d-h}
L4xT3	5.9^{l-q}	83.7^{a-d}	83.7^{a-e}	-0.5^{a-e}	226.0^{k-p}	0.40^{dc}	150^{g-i}	92.7^{k-p}	2.1^{a-c}	2.2^{d-h}	1.33^{b-g}	1.5^{d-h}
L4xT4	5.8^{m-q}	80.7^{e-l}	81.0^{g-k}	-0.5^{a-e}	230.3^{o-r}	0.40^{dc}	150^{g-i}	107.2^{l-p}	2.3^{a}	2^{f-j}	1.17^{c-g}	1^{f-h}
L5xT1	8.5^{b-f}	82.0^{c-i}	81.8^{d-i}	-0.5^{a-e}	234.0^{e-i}	0.40^{dc}	156^{a-e}	98.0^{j-o}	1.8^{d-g}	2^{f-j}	2.83^{a}	0.83^{gh}
L5xT2	8.8^{a-c}	78.5^{k-m}	78.0^{k-m}	-0.67^{b-f}	244.7^{c-h}	0.40^{dc}	152^{c-h}	106.0^{d-j}	1.6^{f-h}	2.3^{b-f}	1.7^{b-f}	1.16^{e-h}
L5xT3	6.2^{l-p}	77.7^{m}	77.2^{m}	-1.17^{f}	205.0^{q-r}	0.40^{dc}	152^{d-h}	78.0^{q}	2.0^{b-d}	2.8^{a}	1.33^{b-g}	1.33^{e-h}
L5xT4	7.4^{f-k}	79.0^{k-m}	78.2^{j-m}	-1^{d-f}	214.7^{p-r}	0.40^{dc}	150^{e-i}	89.7^{n-p}	1.8^{c-f}	1.9^{g-j}	1^{d-g}	1.66^{d-h}
L6xT1	6.6^{i-o}	85.7^{a}	85.8^{a}	0.33^{a}	228.7^{j-p}	0.40^{dc}	156^{a-e}	94.7^{k-p}	1.6^{f-g}	1.8^{h-j}	1.17^{c-g}	1^{f-h}
L6xT2	6.8^{i-m}	81.8^{c-j}	80.8^{g-j}	-0.67^{b-f}	218.7^{n-r}	0.40^{dc}	155^{a-f}	90.7^{m-p}	1.3^{j}	1.75^{ij}	1.7^{b-f}	1^{f-h}
L6xT3	6.7^{i-n}	78.2^{lm}	77.3^{m}	-0.83^{c-f}	235.3^{d-l}	0.38^{d}	152^{c-h}	91.3^{l-p}	1.9^{c-e}	2.5^{a-d}	1^{d-g}	0.83^{hg}
L6xT4	6.1^{l-q}	82.7^{b-g}	82.2^{c-h}	-0.5^{a-e}	204.3^{r}	0.40^{dc}	151^{e-f}	86.7^{pq}	1.8^{d-g}	1.9^{g-j}	1.7^{b-f}	0.83^{hg}
L7xT1	7.5^{e-j}	83.0^{a-f}	82.8^{b-g}	-0.5^{a-e}	258.3^{a-c}	0.40^{cd}	153^{c-h}	119^{ab}	1.8^{d-g}	2.5^{a-d}	1.5^{b-g}	0.66^{h}
L7xT2	8.7^{b-d}	81.2^{d-k}	80.8^{f-j}	0^{a-c}	239.0^{d-k}	0.43^{bc}	154^{b-h}	102.3^{f-k}	1.6^{f-i}	2.0^{f-j}	1.17^{c-g}	$1.16e^{-h}$
L7xT3	5.6^{n-q}	84.5^{a-c}	84.2^{a-e}	-0.33^{a-e}	239.7^{d-k}	0.40^{dc}	154^{b-h}	99.0^{i-n}	1.9^{c-e}	2.2^{d-h}	1.5^{b-g}	2.16^{b-f}
L7xT4	5.4^{o-q}	82.3^{b-h}	82.5^{c-h}	-0.33^{a-e}	229.0^{j-o}	0.40^{dc}	152^{e-h}	100^{g-m}	1.8^{c-f}	1.9^{g-j}	1^{d-g}	3.3^{ab}
L8xT1	8.7^{a-d}	82.0^{c-i}	81.5^{e-i}	0^{a-c}	260.0^{ab}	0.43^{bc}	159^{a}	117.5^{a-c}	1.7^{f-h}	1.7^{j}	1.83^{a-e}	1.33^{e-h}
L8xT2	8.7^{a-d}	79.3^{i-m}	78.5^{j-m}	-0.83^{c-f}	247.0^{b-f}	0.47^{ab}	156^{a-d}	111.7^{b-e}	1.6^{f-i}	2.1^{f-i}	1.67^{b-f}	1.33^{e-h}
L8xT3	7.0^{g-l}	78.2^{lm}	77.7^{lm}	-0.83^{c-f}	230.0^{i-o}	0.40^{dc}	155^{a-e}	95^{k-p}	1.9^{c-e}	2.3^{b-f}	1.83^{a-e}	1.33^{e-h}

Entries	GY (t/ha)	DA (days)	DS (days)	ASI (Days)	PH (cm)	EPO (ratio)	DM (days)	EH (cm)	TLB (scale)	CLR (scale)	ER (%)	HC (%)
L8xT4	6.4^{k-o}	84.0^{a-c}	83.3^{a-f}	-1^{d-f}	240.0^{d-j}	0.47^{ab}	156a-f	109.7^{b-g}	1.75^{d-g}	1.9^{g-j}	2.17^{a-c}	0.67^{h}
L9xT1	8.3^{b-f}	83.2^{a-f}	82.8^{b-g}	-0.33^{a-e}	245.3^{c-g}	0.50^{a}	154^{b-h}	115.3^{a-d}	1.8^{c-f}	2.3^{b-f}	2^{a-d}	2^{c-g}
L9xT2	6.3^{k-p}	81.8^{d-j}	82.2^{c-h}	0.17^{ab}	237.7^{d-l}	0.47^{ab}	157^{a-c}	106.7^{d-j}	1.9^{c-e}	2.4^{b-e}	1.67^{b-f}	2.33^{b-e}
L9xT3	5.0^{q}	79.7^{h-m}	79.3^{i-m}	-0.5^{a-e}	217.3^{o-r}	0.40^{dc}	147^{i}	88.7^{op}	2.1^{a-c}	2.6^{a-c}	1.33^{b-g}	3^{a-c}
L9xT4	7.0^{g-l}	81.2^{d-j}	79.8^{h-m}	-1.17^{ef}	232.0^{g-n}	0.47^{ab}	154^{b-h}	109^{c-h}	2.0^{b-d}	2.1^{e-i}	1.33^{b-g}	1^{f-h}
BH540	8.3^{b-f}	82.2^{c-h}	81.8^{e-i}	-0.33^{a-e}	247.7^{b-c}	0.43^{bc}	153^{c-h}	112.7^{b-d}	2.0^{b-d}	1.8^{h-j}	1.17^{c-g}	1.33^{e-h}
BHQPY545	6.6^{i-n}	83.3^{a-e}	82.8^{b-g}	-0.5^{a-e}	240.3^{d-k}	0.40^{cd}	149^{hi}	102^{e-k}	1.75^{d-g}	2.67^{ab}	2.83^{a}	1.5^{d-h}
BH546	9.81^{a}	82.3^{b-h}	82.2^{c-h}	-0.83^{c-f}	263.67^{a}	0.43^{bc}	157^{a-c}	117.3^{a-c}	1.83^{c-f}	2.67^{ab}	1.33^{b-g}	1.33^{e-h}
BH547	8.95^{ab}	81.8^{c-j}	81.5^{e-i}	-0.33^{a-e}	243.7^{d-i}	0.50^{a}	154^{b-h}	123^{a}	2.25^{ab}	1.75^{ij}	1^{d-g}	0.67^{h}
Entry Mean	7.23	81.6	81.28	0.33	233.1	0.43	159	102.5	1.79	2.14	2.83	4.16
Cross Mean	7.09	81.5	81.18	0.33	231.33	0.43	159	101.25	1.78	2.13	2.83	4.16
CV (%)	14.2	3	3	5.47	5.89	8.57	2.67	9.55	15.48	53.11	67.38	0.39
LSD (0.05)	1.15	2.74	2.76	0.07	14.66	0.04	4.7	9.76	0.31	0.41	1.07	25.34
F-test	*	**	**	ns	**	**	*	**	**	**	*	**
Maximum	9.81	85.7	85.8	0.33	263.6	0.5	159	123	2.3	2.8	2.83	4.16
Minimum	5	77.7	77.2	-1.5	204.3	0.38	147	78	1.3	1.7	0.5	0.66

*=0.05 and **= 0.01 significant probability level. GY= grain yield per hectare, DA= days to anthesis, DS= days to silking, EH= ear height, PH= plant height, RPE=Number of rows per ear, TKW=thousand kernel weight, EPP=ear per plant, EL=ear length, ED=ear diameter, LSD = least significant difference, CV = co-efficient of variation.

Table 3. *Continued.*

Entries	PA (scale)	EA (scale)	RPE (#)	KPR (#)	TKW (kg)	GLS (Scale)	EL (cm)	ED (cm)	EPP (#)	PLS (Scale)	SL (%)	RL (%)
L1xT1	2.3^{i-m}	2.5^{l-n}	15.03c-j	37.07^{a-g}	0.275^{b-i}	1.4^{b-e}	14.7^{d-j}	4.49^{b-f}	1.14^{a-j}	1.5^{g}	0.67^{b-f}	0.50^{d-g}
L1xT2	2.6^{f-j}	3.0^{f-l}	14.7^{f-l}	32.8^{h-k}	0.243^{g-k}	1.3^{c-f}	14.2^{ij}	4.29^{d-i}	1.3^{a-d}	1.83^{e-g}	0.67^{b-f}	0.67^{c-f}
L1xT3	2.6^{f-j}	2.3^{n}	14.26^{j-m}	37.9^{a-d}	0.302^{b-e}	1.25^{d-f}	16.9^{a}	4.59^{bc}	1.1^{b-k}	2.08^{b-f}	0.17^{ef}	1.33^{ab}
L1xT4	3.0^{b-f}	3.2^{d-j}	15.43^{a-g}	31.03^{l}	0.265^{c-j}	1.7^{ab}	14.07^{ij}	4.52^{b-e}	0.8^{kl}	1.83^{e-g}	1.17^{a-c}	0.50^{d-g}
L2xT1	2.25^{i-m}	3.5^{a-f}	14.93^{c-l}	32.7^{h-l}	0.288^{b-g}	1.08^{f}	14.95^{c-i}	4.75^{ab}	1.3^{a-d}	1.67^{fg}	1.17^{a-c}	0.50^{d-g}
L2xT2	2.3^{h-l}	3.25^{c-i}	14.76^{f-m}	36.5^{a-h}	0.27^{c-j}	1.3^{c-f}	15.9^{a-e}	4.38^{c-i}	1.4^{a-d}	1.912^{d-g}	0.83^{a-e}	0.17^{fg}
L2xT3	2.25^{i-m}	2.75^{i-n}	15.36^{c-h}	34.2^{d-l}	0.32^{ab}	1.17^{ef}	16.08^{a-f}	4.76^{ab}	1.05^{c-k}	2.17^{a-d}	0.33^{d-f}	0.33^{d-f}
L2xT4	2.2^{j-m}	2.4^{nm}	14.56^{g-n}	33.13^{h-l}	0.30^{b-e}	1.3^{c-f}	16.6^{a-c}	4.77^{ab}	1.0^{d-l}	1.912^{d-g}	0.33^{d-f}	0.50^{d-g}
L3xT1	1.9^{lm}	2.9^{g-m}	14.9^{c-l}	34.07^{d-l}	0.257^{d-k}	1.17^{ef}	14.77^{d-j}	4.42^{c-g}	0.94^{e-l}	2^{c-f}	1^{a-d}	0.17^{fg}
L3xT2	2.5^{g-k}	3.9^{a}	14.73^{f-l}	32.17^{i-l}	0.192^{l}	1.25^{d-f}	13.17^{j}	4.1^{i}	1.37^{a-c}	2^{c-f}	1^{a-d}	0.83^{b-e}
L3xT3	2.6^{e-i}	3.0^{f-l}	14.13^{k-n}	40.07^{a}	0.27^{c-j}	1.7^{ab}	16.3^{a-d}	4.42^{c-g}	0.92^{f-l}	1.912^{d-g}	1.33^{a-c}	0.17^{fg}
L3xT4	2.8^{d-h}	3.3^{b-h}	15.8^{a-c}	32.1^{i-l}	0.273^{b-j}	1.4^{b-e}	14.43^{f-j}	4.3^{d-i}	1.04^{c-k}	2.41^{a-c}	1.58^{ab}	0.67^{c-f}
L4xT1	2.2^{j-m}	3.58^{a-e}	14.4^{i-n}	35.87^{b-i}	0.227^{j-l}	1.58^{a-c}	15.53^{b-i}	4.41^{c-g}	1.09^{b-k}	1.912^{d-g}	1.25^{a-c}	0.83^{b-e}
L4xT2	2.7^{e-i}	3.75^{a-c}	14.56^{g-n}	34.97^{d-k}	0.227^{j-l}	1.25^{d-f}	15.98^{a-g}	4.41^{c-g}	1.2^{a-h}	2.17^{a-e}	1.17^{bc}	0.33^{e-g}
L4xT3	3.17^{a-d}	3.3^{b-h}	14.53^{g-n}	35.9^{b-i}	0.24^{h-k}	1.67^{ab}	15.4^{b-i}	4.12^{hi}	0.9^{g-l}	2^{c-f}	1.17^{bc}	1.67^{a}
L4xT4	3.25^{a-c}	3.8^{ab}	15.36^{a-h}	32.33^{i-l}	0.23^{i-l}	1.5^{a-d}	14.37^{g-j}	4.28^{d-i}	0.85^{i-l}	2.33^{a-c}	1.17^{bc}	1.33^{ab}
L5xT1	2.3^{h-l}	3.08^{e-k}	14.46^{h-n}	36.53^{a-h}	0.255^{e-k}	1.25^{d-f}	15.26^{b-i}	4.4^{c-g}	1.09^{b-k}	1.75^{e-g}	1.08^{c}	1^{b-d}
L5xT2	2.5^{g-k}	3.08e-k	14.4i-n	31.43^{kl}	0.30^{b-e}	1.17^{ef}	15.4^{b-i}	4.39^{c-h}	1.07^{c-k}	1.83^{e-g}	0.83^{a-d}	0.50^{d-g}
L5xT3	3.3^{ab}	2.9^{g-m}	13.73^{on}	33.33^{f-l}	0.26^{e-k}	1.75^{ab}	15.23^{b-i}	4.2^{f-i}	0.69^{l}	2.08^{b-f}	0.5^{c-f}	0.33^{e-g}
L5xT4	2.8^{d-h}	2.8^{h-m}	15.26^{a-i}	33.17^{g-l}	0.298^{b-e}	1.42^{b-e}	16.08^{a-f}	4.54^{b-d}	0.94^{f-l}	2.166^{a-e}	1^{a-c}	1^{b-d}
L6xT1	2.58^{f-j}	2.9^{g-m}	15.5^{a-f}	31.03^{l}	0.217^{kl}	1.33^{d-f}	15^{c-i}	4.23^{e-i}	0.88^{g-l}	1.5^{g}	1.17^{bc}	1^{b-d}
L6xT2	2.75^{d-h}	3.58^{a-e}	13.9^{nm}	33.9^{e-l}	0.273^{b-j}	1.42^{b-e}	14.27^{h-j}	4.17^{g-i}	0.82^{j-l}	1.83^{e-g}	1^{a-c}	0.33^{e-g}
L6xT3	3.08^{a-e}	3.08^{e-i}	15^{c-l}	33.5^{f-l}	0.24^{h-l}	1.67ab	14.63d-j	4.12^{hi}	0.89^{g-l}	1.912^{d-g}	1.33^{ab}	1^{b-d}
L6xT4	3.17^{a-d}	3.7^{a-d}	15.2^{a-i}	30.77l	0.255^{e-k}	1.5^{a-d}	14.8^{d-j}	4.45^{c-g}	0.86^{i-l}	1.912^{d-g}	1.33^{ab}	1.17^{a-c}
L7xT1	1.9^{lm}	2.9^{g-m}	15.66^{a-d}	37.23^{a-f}	0.233^{i-l}	1.33^{d-f}	15.37^{b-i}	4.4^{c-h}	1.12^{a-j}	1.83^{e-g}	1.17^{bc}	0.50^{d-g}
L7xT2	2.3^{h-l}	3.4^{a-g}	14.5^{h-n}	35.97^{b-h}	0.303^{b-d}	1.42^{b-e}	15.77^{b-i}	4.38^{c-i}	1.23^{a-f}	2.166^{a-e}	0.83^{a-d}	0.33^{e-g}
L7xT3	3^{b-f}	2.75i-m	13.76^{on}	39.6^{ab}	0.263^{d-k}	1.42^{b-e}	17.53^{a}	4.31^{c-i}	0.87^{g-l}	1.75^{e-g}	1.17^{bc}	0.833^{b-e}
L7xT4	2.67^{e-i}	3.4^{a-g}	16.06^{a}	37.1^{a-f}	0.29^{b-g}	1.33^{d-f}	15.77^{b-i}	4.49^{b-f}	1.05^{c-j}	2^{c-f}	0.83^{a-d}	0.50^{d-g}
L8xT1	2.3^{h-l}	2.3^{n}	15^{c-l}	37.7^{a-e}	0.27^{b-j}	1.17^{ef}	15.63b-i	4.51^{b-f}	1.18^{a-i}	1.912^{d-g}	0.33^{d-f}	0.33^{e-g}
L8xT2	2.58^{f-i}	2.4^{mn}	14.9^{c-l}	39.63^{ab}	0.27^{b-j}	1.58^{a-c}	16.22^{a-e}	4.53^{b-e}	1.21^{a-g}	1.66^{fg}	0.83^{a-d}	0.17^{fg}
L8xT3	2.75^{d-h}	2.75^{i-m}	13.8^{nm}	39.43^{a-c}	0.295^{b-f}	1.42^{b-e}	16.6^{a-c}	4.27^{d-i}	1.15^{a-i}	2.58^{a}	0^{f}	0.50^{d-g}
L8xT4	2.58^{f-i}	3.08^{e-k}	15.6^{a-f}	34.97^{d-j}	0.29^{b-h}	1.42^{b-e}	16.07^{a-g}	4.37^{c-i}	0.81^{j-l}	2.08^{b-f}	0.33^{d-f}	0.33^{e-g}
L9xT1	2.3^{h-l}	3.08^{e-k}	15.7^{a-d}	35.53^{c-i}	0.23^{k-l}	1.58^{a-c}	14.62^{d-j}	4.73^{ab}	1.42^{ab}	2.41^{a-c}	1^{a-d}	0.50^{d-g}
L9xT2	2.8^{c-g}	3.25^{c-i}	15.67^{a-e}	31.3^{kl}	0.25^{f-k}	1.58^{a-c}	14.47^{f-j}	4.77^{ab}	1.08^{b-k}	1.83^{e-g}	1^{a-d}	0.67^{c-f}
L9xT3	3.5^{a}	3.75^{a-c}	14.8^{d-l}	31.3^{kl}	0.27^{c-j}	1.67^{ab}	14.57^{e-j}	4.36^{c-i}	0.69^{l}	2^{c-f}	0.50^{c-f}	0.50^{d-g}
L9xT4	2.75^{d-h}	3.17^{d-j}	15.9^{ab}	32.5^{i-l}	0.27^{c-j}	1.42^{b-e}	15.07^{c-i}	4.76^{ab}	0.848^{i-l}	1.66^{fg}	0.67^{b-f}	0.67^{c-f}
BH540	2.42^{g-j}	2.67^{j-n}	12.9^{o}	33.6^{f-l}	0.36^{a}	1.5^{a-d}	15.95^{a-h}	4.75^{ab}	1.06^{c-k}	2.5^{ab}	1^{a-d}	0.67^{c-f}
BHQPY545	1.83^{m}	2.9^{g-m}	15^{c-l}	35.33^{d-j}	0.27^{c-j}	1.42^{b-e}	15.93^{a-h}	4.38^{c-i}	1.46^{a}	2.33^{a-d}	0.83^{a-e}	0.33^{e-g}
BH546	2.08^{k-m}	3^{f-l}	14.7^{e-l}	35.73^{b-i}	0.28^{b-i}	1.25^{d-f}	15.6^{b-i}	4.56^{b-d}	1.458^{a}	1.92^{d-g}	0.67^{b-f}	0^{g}
BH547	1.25^{n}	2.58^{k-n}	15.13^{b-j}	33.33^{f-l}	0.312^{a-c}	1.5^{a-d}	14.50^{f-j}	4.93^{a}	0.763^{kl}	2.08^{b-f}	1.5^{a}	0.33^{e-g}
Entry Mean	2.55	3.08	16.06	34.67	0.27	1.75	15.34	4.45	1.05	2.58	1.58	1.67
Cross Mean	2.63	3.11	16.06	34.69	0.26	1.75	15.33	4.43	1.03	2.58	1.58	1.67

Entries	PA (scale)	EA (scale)	RPE (#)	KPR (#)	TKW (kg)	GLS (Scale)	EL (cm)	ED (cm)	EPP (#)	PLS (Scale)	SL (%)	RL (%)
CV (%)	15.57	15.93	5.38	9.64	16.1	19.9	9.7	5.34	21.79	0.47	0.31	0.28
LSD (0.05)	0.45	0.56	0.91	3.93	0.05	0.32	1.71	0.29	0.35	20.75	25.05	25.02
F-test	**	**	**	**	**	*	*	**	**	*	*	*
Maximum	3.5	3.9	16.06	40.07	0.36	1.75	17.53	4.93	1.46	2.58	1.58	1.67
Minimum	1.25	2.3	12.9	30.77	0.19	1	13.17	4.10	0.68	1.5	0	0

*=0.05 and **= 0.01 significant probability level. GY= grain yield per hectare, DA= days to anthesis, DS= days to silking, EH= ear height, PH= plant height, RPE=Number of rows per ear, TKW=thousand kernel weight, EPP=ear per plant, EL=ear length, ED=ear diameter, LSD = least significant difference, CV = co-efficient of variation.

3.3. Mid and Better Parent Heterosis

Concerning standard heterosis of plant height, nine crosses out of 36 crosses displayed negative and significant heterosis over BH540 and seven crosses expressed negative and significant values over the standard checks BH545 and BH547, whereas about 77.78% (28) of crosses articulated negative and significant heterosis over standard check BH546. For ear height, about twelve crosses verbalized negative and significant heterosis over standard check BH540 and only four crosses, expressed negative and significant values over the BH545, whereas half and above half of the crosses were articulated negative and significant heterosis over the standard checks BH546 and BH547, respectively (Table 4). In agreement with the present results, both desirable and undesirable standard heterosis of both traits has been stated by several authors [7, 28, 29, 14, 16]. The negative heterosis for plant and ear height is desirable to enable the selection of effective shorter plants since it indicated a decrease of lodging effect. The estimated standard heterosis for GLS disease traits, only one cross (L5xT3) articulated positive and significant heterosis over the standard check BH546, whereas the others expressed non-significant heterosis over all the standard checks. Regarding TLB disease out of thirty-six, only four crosses expressed negative and significant heterosis over the check BH540 and three crosses exhibited both positive and negative significant heterosis over the standard checks BH545 and BH546, whereas above half of the crosses articulated negative and significant values over the standard check BH547. In others case, for CLR disease, about seven crosses verbalized positive and significant heterosis over a standard check of BH540 and nine crosses expressed positive and significant values over the standard check of BH547, while fifteen crosses and half pronounced negative and significant heterosis over the standard checks of BH545 and BH546, respectively (Table 4). In conformity with the current findings, both positive and negative standard heterosis of traits has been described by [7, 8, 14].

Regarding the expected standard heterosis of number of kernels per row, only one cross (L8xT1) expressed positive and significant heterosis over standard check BH540 and only one cross (L8xT2) displayed positive and significant heterosis over standard check BH547, whereas only one cross (L2xT4) was articulated positive and significant heterosis over standard check BH547 for ear length. Regarding ear per plant, fourteen crosses out of 36 crosses were articulated negative and significant heterosis through vacillated -3.2% to -51.6% over the standard check BH545 and about seven crosses exhibited negative and significant heterosis with vacillated -3.98% to -51.9% over BH546, whereas among crosses about five crosses were expressed positive and significant values with ranged 83.5% to -8.3% over BH547 for this trait (Table 4). Both direction's significant standard heterosis for these traits results and like these findings were described by several researchers, for instance, both negative and positive heterosis for these traits in maize has been reported elsewhere [29, 10, 11, 15, 14] suggested that standard heterosis with negative direction are generally desired for traits like days to anthesis, silking and maturity, anthesis silking interval, plant and ear height, ear position and bad husk cover as negative standard heterosis for these traits directly contributes to earliness, a short number of days between anthesis and silking, short plant stature which is tolerant to lodging and firm husk cover which prevents the ear from rotting and external damage.

Table 4. *Mid and better parent heterosis value for the crosses evaluated across locations, 2019.*

Crosses	GY		DA		DS		PH		EH		GLS		TLB		CRL	
	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
L1xT1	207.7**	147.8**	-7.5**	-8.1**	-7.8**	-8.4**	78.3**	60.5**	96.4**	66.1**	-16.2	-25*	26.2*	19.8	-27**	-30.2**
L1xT2	238.8**	193.3**	-8.7**	-9.9**	-9.2**	-10.5**	90.6**	88.4**	120.3**	113**	-10.7	-17.7	3.5	-5	-4.8	-8
L1xT3	204.1**	190.7**	-11**	-11.5**	-12.3**	-12.6**	86.9**	81.8**	102.3**	93.7**	-10.7	-17.7	-17.1	-32.6*	-8.9	-12
L1xT4	194.6**	175.4**	-9.2**	-9.7**	-9.3**	-9.3**	94.3**	87.3**	101.3**	88.2**	4.6	1.8	-10	-22.7	-28**	-32.6**
L2xT1	114.7**	106.5**	-7.2**	-8.2**	-7.2**	-8.2**	63.1**	51.5**	54.3**	49.2**	-28.6*	-45.0*	10.4	7.6	-8.3	-18.6
L2xT2	145.0**	133.2**	-8.5**	-10.1**	-8.9**	-10.5**	83.6**	79.5**	86.4**	67.5**	16.2	5.3	-5	-15	11.1	0
L2xT3	118.5**	88.5**	-9.4**	-10.4**	-8.3**	-8.9**	87.3**	76.3**	106.2**	73.0**	-0.4	-9.8	-15.3	-32.6*	2.2	-8
L2xT4	224.5**	155.6**	-5.7**	-6.7**	-7.5**	-7.8**	90.6**	77.8**	97.8**	83.2**	-5.5	-22.2	-13	-27	-22.9*	-32.6**
L3xT1	198.4**	118.3**	-9.5**	-10.8**	-9.6**	-10.8**	104**	62.2**	122.8**	63.9**	-35**	-40**	-36**	-49.6**	-33**	-38.3**
L3xT2	290.9**	203.9**	-13**	-14.8**	-13.7**	-15.5**	102**	73.5**	143.2**	98.7**	-13.3	-22.2	-35**	-41.9**	-10.4	-18.8*
L3xT3	290.6**	230.4**	-12**	-12.6**	-12.6**	-13.5**	127**	102**	179.1**	144**	0	-10.2	-31**	-32.6*	-6.8	-15.6
L3xT4	386.6**	355.6**	-13**	-13.5**	-13.9**	-14.6**	99.1**	78.8**	122.3**	77.0**	-16.2	-16.2	-23**	-26.4	-34**	-38.3**

Crosses	GY		DA		DS		PH		EH		GLS		TLB		CRL	
	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
L4xT1	186.8**	124.2**	-11**	-10.8**	-11.2**	-11.4**	80.6**	48.1**	81.3**	46.7**	6.7	-20	-43**	-59.1**	-37**	-44.4**
L4xT2	224.9**	172.1**	-12**	-12.7**	-12.2**	-13.0**	116**	92.0**	135.0**	115.**	11.6	-2.3	-34**	-47.4**	-19*	-29.8**
L4xT3	182.3**	159.9**	-7.2**	-7.5**	-7.6**	-7.7**	110**	94.0**	119.0**	116**	45.9**	27.8	-31**	-38.6**	-26**	-35.7**
L4xT4	298.9**	287.4**	-9.9**	-10.2**	-10.9**	-11.3**	116.**	102**	124.1**	99.1**	12.4	-10.2	-20**	-32.7**	-38**	-44.4**
L5xT1	143.2**	136.1**	-8.5**	-8.7**	-9.3**	-9.3**	84.9**	51.9**	97.6**	44.7**	-18	-35**	-16.9	-36.4**	-21.3*	-22.5*
L5xT2	173.7**	144.4**	-12**	-12.3**	-12.8**	-13.5**	117.**	93.9**	159.1**	111**	-4	-9.8	-34**	-43.5**	-8	-8
L5xT3	111.2**	72.2**	-13**	-13.5**	-14.6**	-14.9**	90.1**	76.0**	109.9**	82.1**	44.0**	35.3**	-27**	-29.3*	12	12
L5xT4	174.1**	105.6**	-12**	-12.2**	-13.8**	-14.4**	101.**	87.8**	110.2**	66.6**	-1.4	-16.2	-30**	-36.4**	-26.5	-28.8**
L6xT1	185.7**	94.7**	-4.8**	-5.0**	-5.4**	-5.9**	93.7**	48.5**	100.3**	39.9**	-25.7*	-35**	-37**	-55.3**	-43**	-52.0**
L6xT2	235.0**	140.3**	-8.5**	-9.3**	-10.2**	-11.4**	110.**	73.3**	135.1**	80.2**	-1.1	-6.7	-53**	-63.7**	-42**	-52.0**
L6xT3	282.9**	195.2**	-13**	-13.3**	-15.0**	-15.2**	137**	102**	162.1**	113**	20.1	13.3	-39**	-46.9**	-20.	-33.3**
L6xT4	302.6**	238.9**	-8.2**	-8.3**	-9.9**	-10.0**	108**	78.7**	115.0**	61.1**	-5.4	-10.2	-39**	-49.7**	-41**	-49.3**
L7xT1	153.4**	121.2**	-8.6**	-9.6**	-8.9**	-9.7**	91.0**	67.7**	104.4**	75.7**	-25.7*	-35**	-4	-20	7.3	-3.1
L7xT2	224.6**	207.4**	-10**	-11.6**	-10.4**	-11.9**	97.0**	89.4**	106.6**	103**	-1.1	-6.7	-25**	-28.9	-12.7	-20
L7xT3	133.3**	121.3**	-7.0**	-8.0**	-7.7**	-8.2**	106**	106**	116.3**	103.**	-1.1	-6.7	-23**	-28.8	-3.9	-12
L7xT4	149.4**	113.4**	-9.5**	-10.4**	-9.9**	-10.0**	98.4**	96.6**	95.0**	85.8**	-18	-22.2	-21.4*	-22.7	-20	-28.8**
L8xT1	251.5**	156.6**	-9.3**	-9.9**	-10.2**	-10.8**	102**	68.8**	119.5**	73.5**	-27.9*	-40**	2.1	-7.1	-24.4*	-34.1**
L8xT2	296.4**	207.4**	-12**	-12.9**	-12.8**	-14.0**	115**	95.7**	149.2**	122**	20.3	20.3	-16.4	-20	-5	-16
L8xT3	265.5**	208.4**	-14**	-14.1**	-14.6**	-14.9**	109**	97.4**	131.3**	122**	5.3	5.3	-15.6	-28.8	4.1	-8
L8xT4	281.0**	255.6**	-7.2**	-7.7**	-8.8**	-8.8**	120**	110**	135.5**	104**	-6.7	-16.2	-13.5	-22.7	-17.2	-28.8**
L9xT1	257.8**	144.8**	-8.6**	-9.7**	-9.2**	-10.2**	74.7**	59.3**	80.6**	70.3**	-1.5	-20	-10	-28	-9.4	-10.9
L9xT2	208.8**	122.6**	-9.6**	-11.3**	-9.1**	-10.8**	87.9**	87.5**	93.4**	77.8**	24	20.3	-15.6	-24	-4	-4
L9xT3	184.1**	120.3**	-12**	-13.5**	-13.3**	-14.0**	78.6**	71.4**	72.5**	47.8**	31.8*	27.8	-18.8*	-21.3	4	4
L9xT4	359.0**	288.9**	-11**	-11.9**	-13.0**	-13.4**	92.5**	83.0**	91.5**	81.7**	-4.1	-16.2	-17.2*	-20	-18.8	-21.3*
SE(d)	0.71	0.8	1.75	2	1.72	2	9.63	11.1	6.83	7.9	0.2	0.2	0.19	0.2	0.25	0.3
Maximum	386.6	288.9	-4.78	-4.96	-5.37	-5.89	136.9	110	179.1	143.5	45.9	35.3	26.2	19.8	12	12
Minimum	111.2	72.2	-13.5	-14.8	-15	-15.5	63.2	48.1	54.3	39.9	-34.6	-45	-53.4	-63.7	-43.1	-52
CDα=0.01	1.2	1.33	2.8	3.26	2.8	3.22	15.6	17.96	11	12.75	0.3	0.38	0.3	0.36	0.4	0.46
CDα=0.05	1	1.16	2.46	2.84	2.43	2.8	13.55	15.64	9.62	11.1	0.29	0.33	0.27	0.32	0.35	0.4

Crosses	CRL		KPR		EL		EPP		DM		KPE		ED		TKW	
	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
L1xT1	-26.7**	-30.2**	37.45**	26.7**	53.8**	36.3**	5.3	-9.8	3.38	2.87	8.2	2.9	47.6**	36.2**	53.8**	48.1
L1xT2	-4.8	-8	52.17**	47.7**	48.1**	28.8**	9.7	-13.3	0.40	0.13	20.8**	19.8**	48.9**	47.2**	6.7	-4.0
L1xT3	-8.9	-12	40.88**	40.0**	46.5**	25.2*	40.1*	26.4	4.27*	3.47	16.9**	16.5**	52.2**	47.3**	53.8**	50.0
L1xT4	-28.0**	-32.6**	34.18**	33.3**	25.5**	2.2	1.9	-8	3.49	2.80	20**	14.9**	51.7**	40.8**	17.4	3.8
L2xT1	-8.3	-18.6	33.98**	22.8*	27.3**	19.4*	21.5	6.6	0.96	-1.16	16.1**	9.6*	40.5**	33.3**	16.9	3.6
L2XT2	11.1	0	51.86**	48.3**	27.9**	22.5*	15.7	-6.7	-0.20	-1.55	23.4**	23.4**	44.5**	41.9**	1.9	-3.6
L2xT3	2.2	-8	36.29**	34.6**	17.5*	14.7	23.5	8.7	4.59*	2.13	16.2**	15.6**	57.8**	48.4**	36.2**	14.3
L2xT4	-22.9*	-32.6**	55.98**	56.0**	27.6**	23.0**	23.5	8.7	2.51	0.19	20.9**	14.9**	44.4**	37.8**	11.1	7.1
L3xT1	-32.9**	-38.3**	40.44**	24.2**	49.5**	37.2**	-9.5	-26.2	4.31*	4.24*	16.1**	9.6*	42.4**	27.5**	50.3**	20.4
L3xT2	-10.4	-18.8*	70.39**	67.7*	50.7**	35.6**	23.3	-6.7	1.77	0.93	21.8**	21.8**	53.8**	47.2**	5.3	-24.0
L3xT3	-6.8	-15.6	63.16**	55.0**	43.6**	26.8**	63**	55.8*	5.27*	5.06	19.5**	18.9**	64.8**	64.8**	68.8**	42.1
L3xT4	-33.9**	-38.3**	47.56**	41.9**	30.3**	9.4	36.1	29.9	2.26	2.16	24.1**	17.9**	46.6**	32**	38.5*	3.8
L4xT1	-36.7**	-44.4**	45.81**	33.1**	39.7**	35.4**	16.4	-9.8	2.63	2.36	7.9**	5.9	47.4**	27.5**	16.2	6.5
L4xT2	-18.9*	-29.8**	62.64**	59.5**	48.2**	40.7**	10.6	-20	1.84	0.80	16	11.5*	59.7**	47.2**	7.0	-8.0
L4xT3	-25.7**	-35.7**	29.24**	27.1**	26.6**	17.9	31.4	28.6	2.71	2.71	14.6**	10.7*	63.8**	57.5**	29.7	26.3
L4xT4	-37.6**	-44.4**	47.21**	46.6*	22.4**	7.9	16.8	14.3	3.35	3.24	15.5*8	14.2*	58.5**	37.8**	22.7	3.8
L5xT1	-21.3*	-22.5*	35.15**	23.8**	39.1**	38.1**	10.6	-9.8	5.12*	5.05*	9.7**	6.6	32.1**	21.7**	22.1	20.4
L5xT2	-8	-8	50.98**	47.4*	43.0**	39.0**	-3.1	-27*	2.17	1.33	15.7**	12.2**	49.2**	47.2**	30.4*	20.0
L5xT3	12	12	33.76**	32.1**	21.2*	15.4	-4.8	-9.1	1.35	1.15	9.5*	6.8	48.9**	44.3**	30	23.8
L5xT4	-26.5	-28.8**	40.17**	40.2**	24.7**	12.2	22.4	16.9	1.25	1.15	16.7**	14.2**	39.2**	29**	27.7*	15.4
L6xT1	-43.1**	-52.0**	36.43**	25.3**	51.2**	38.1**	-7.2	-26.2	5.16*	5.05*	15.7**	14**	43.6**	21.7**	23.6	1.9
L6xT2	-42.4**	-52.0**	62.88**	58.7*	45.8**	30.5**	-27.9	-47**	3.81	2.92	10**	5.3	59.6**	43.8**	38.5*	8.0
L6xT3	-20.0*	-33.3**	46.95**	45.4**	41.5**	24.4*	26.8	25	2.94	2.77	18.1**	13.6**	75.4**	64.8**	45.5**	26.3
L6xT4	-40.8**	-49.3**	36.46**	36.2**	28.3**	7.2	26.8	25	2.30	2.23	14.3**	13.4**	51.5**	29**	30**	0.0
L7xT1	7.3	-3.1	21.74**	19.7**	24.8**	24.8*	0.5	-9.8	2.40	1.45	19.5**	15.4**	40.8**	27.5**	28.1	6.5
L7xT2	-12.7	-20	47.95**	30.7*	37.7**	34.7**	-2.8	-20	2.09	1.92	17.2**	14.4**	48.5**	43.8**	52.7**	20.0
L7xT3	-3.9	-12	31.90**	20.4**	29.7**	24.4*	7.8	-7.2	2.81	1.59	11*	8.9	59.1**	57.1**	56.2**	36.8
L7xT4	-20	-28.8**	28.84**	16.3	20.6*	9.4	31.7	13.4	1.57	0.46	23.5**	20.1**	48.1**	34.9**	43.9**	11.5
L8xT1	-24.4*	-34.1**	28.87**	19.9*	20.4*	18.8	11.6	-1.6	5.65**	4.26	14.2**	10.3*	34.4**	24.6**	11.1	0.0
L8xT2	-5	-16	71.18**	64.5**	42.6**	41.5**	-1.2	-20	3.00	2.43	20.5**	17.6**	48.1**	47.2**	3.8	0.0
L8xT3	4.1	-8	50.21**	49.6**	37.1**	33.3**	35	18.3	3.80	2.16	11.8**	9.7	54.9**	49.2**	30.4*	11.1
L8xT4	-17.2	-28.8**	40.34**	38.0**	19.1*	9.4	-1.8	-14	3.63	2.10	19.7**	16.4*	38.4**	29**	9.4	7.4
L9xT1	-9.4	-10.9	34.03**	13.5	44.8**	30.1**	44**	14.8	3.31	2.73	11.9**	8.5	41.1**	30.4**	5.5	4.5
L9xT2	-4	-4	52.15**	42.6**	40.4**	23.7*	-0.9	-27*	4.45*	4.24	18.3**	8.5	55.4**	53.8**	6.4	0.0

Crosses	CRL		KPR		EL		EPP		DM		KPE		ED		TKW	
	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
L9xT3	4	4	54.94**	40.4**	36.2**	17.9	-1.4	-2.8	-1.31	-2.13	11**	2.3	59**	53.6**	31.7*	22.7
L9xT4	-18.8	-21.3*	58.04**	44.9**	35.4**	11.5	12.7	11.1	3.49	2.73	14.1**	9.9*	48.3**	37.8**	12.5	3.8
SE(d)	0.25	0.3	2.37	2.7	1.05	1.2	0.16	0.2	3.12	3.6	0.56	0.6	0.17	0.2	0.03	0.037
Maximum	12	12	71.18	67.7	53.8	41.5	63.3	55.8	5.6	5.06	24.07	23.4	75.4	64.8	68.8	50.0
Minimum	-43.1	-52	21.74	13.5	17.5	2.2	-27.9	-46.7	-1.3	-2.13	7.87	2.3	32.1	21.7	1.9	-24.0
CDα=0.01	0.4	0.46	3.8	4.41	1.7	1.97	0.3	0.29	5.0	5.82	0.9	1.05	0.3	0.31	0.1	0.06
CDα=0.05	0.35	0.4	3.33	3.84	1.48	1.71	0.22	0.26	4.39	5.07	0.79	0.91	0.24	0.27	0.04	0.05

GY=grain yield, DA= days to Anthesis, DS=days to silking, PH=plant height, EH= ear height, GLS=gray leaf spot, TLB= turcicum leaf blight, CLR=common leaf rusts, NKPR=number of kernels per rows, EL=ear length, EPP=ear per plant, TKW=thousand kernels weight, DM= days to maturity, ED= ear diameter SE (LxT) =standard error of specific combining ability of lines by testers, SE (Sji-Skl) =standard error differences of specific combining ability effects of lines by testers.

3.4. Standard Heterosis

The values of standard heterosis estimated for grain yield and other traits across locations presented in Table 5.

In the combined analysis, for grain yield, about twelve crosses displayed negative and significant advances over the standard check BH540 with vacillated of (6% to -39.8%) and nine crosses expressed positive and significant advantages over the standard check BH545 with range of (33.3% to -24.2%), whereas above half of the crosses manifested negative and significant values over the standard check BH546 with oscillated of (-10.3% to -49% and about half of the crosses exhibited negative and significant benefit over the standard check of BH547 with oscillated of (1.7% to -44.1%) for grain yield (Table 5). The crosses showed positive and significant standard heterosis for grain yield over BH545, indicating the presence of high magnitude of standard heterosis over commercial checks which could be used in the maize breeding program to exploit the hybrid vigor. Positive heterosis is desired as it indicates increased yield over the existing standard check. In crop breeding, those hybrids perform better than the best standard variety could be of commercial importance [28]. Others authors described that inbreeding program, hybrids perform better than checks could be used as a commercial production [10, 14, 16, 33].

Across locations, regarding days to anthesis, only three crosses exhibited negative and significant values over the standard checks BH540 with the oscillated of 4.3% to -5.4% and BH546. Only eight crosses exhibited negative with vacillated of 4.1% to -5.6% and significant over the standard check of BH545 with a range of 2.8% to -6.8%, whereas among the crosses, only one cross expressed negative and significant advantage over the standard check of BH547 with 4.7% to -5% oscillated, respectively. For days to silking, only three crosses expressed negative and significant values over BH540, and seven crosses exhibited negative and significant values over the standard check BH545, whereas only five and three crosses manifested significant heterosis over the standard checks BH546 and BH547, respectively (Table 5). In agreement with the present results, both desirable and undesirable for both traits standard heterosis has been described by several academics [27, 7, 29, 10, 14, 16].

Concerning, plant height standard heterosis, out of thirty-six crosses about nine crosses were displayed negative and significant heterosis over BH540 and about seven crosses expressed negative and significant values over the standard checks BH545 and BH547, whereas about 77.78% (28) of crosses articulated negative and significant heterosis over standard check BH546. For ear height, about twelve crosses verbalized negative and significant heterosis over standard check BH540 and only four crosses, expressed negative and significant values over the BH545, whereas half and above half of the crosses were articulated negative and significant heterosis over the standard checks BH546 and BH547, respectively (Table 5). In agreement with the present results, both desirable and undesirable for both traits standard heterosis has been stated by several authors [7, 28, 29, 10, 11, 13, 16]. The negative heterosis for plant and ear height is desirable to enable the selection of effective shorter plants since it indicated a decrease of lodging effect.

The estimated standard heterosis for GLS disease traits, only one cross (L5xT3) articulated positive and significant heterosis over the standard check BH546, whereas the others expressed non-significant heterosis over all the standard checks. Regarding TLB disease out of thirty-six, only four crosses expressed negative and significant heterosis over the check BH540 and three crosses exhibited both positive and negative significant heterosis over the standard checks BH545 and BH546, whereas above half of the crosses articulated negative and significant values over the standard check BH547. In others case, for CLR disease, about seven crosses verbalized positive and significant heterosis over a standard check of BH540 and about nine crosses expressed positive and significant values over the standard check of BH547, while about fifteen crosses and about half pronounced negative and significant heterosis over the standard checks of BH545 and BH546, respectively (Table 5). In conformity with the current findings, both positive and negative for traits standard heterosis has been described by [7, 8, 14].

The expected standard heterosis, for number of kernels per row, only one cross (L8xT1) expressed positive and significant heterosis over standard check BH540 and only one cross (L8xT2) displayed positive and significant heterosis over standard check BH547, whereas only one cross (L2xT4) was articulated positive and significant heterosis over standard check BH547 for ear length. Regarding ear per plant, out of thirty-six about fourteen crosses were articulated negative and significant heterosis through vacillated -3.2% to -51.6% over the standard check BH545 and about seven crosses exhibited negative and significant heterosis with vacillated -3.98% to -51.9% over BH546, whereas among crosses about five crosses were expressed positive and significant values with ranged 83.5% to -8.3% over BH547 for this trait (Table 5). Both direction's significant standard heterosis for these traits results and like these findings were described by several researchers, for instance, both negative and positive heterosis for these traits in maize has been reported by [28, 10, 14]. Generally, according to Dufera [14], suggested that in standard heterosis with negative direction are desired for traits like days to anthesis, silking and maturity, anthesis silking interval, plant and ear height, ear position and bad husk cover as negative standard heterosis for these traits is directly contributed for earliness, a short number of days between anthesis and silking, short plant stature, which is resistant to lodging, and firm husk cover, which prevents the ear from rotting and external damage.

Similarly, standard heterosis for a disease is the direct impression that might be realistic, which means negative directions are signifying resistant to disease whereas for yield and yield contributors the versus is true by means the positive directions are desirable. Finally, the evidence from this finding could be valuable for investigators who required doing in advance to improve high yielding and other characters of varieties of quality protein maize to select the alternative cultivars. The presence of genetic difference for grain yield and its components characters offers an additional route for maize breeders mainly those who are attentive in heterosis breeding.

Table 5. *Standard heterosis value for the quality protein maize crosses evaluated across locations, 2019.*

Crosses	GY				DA				DS				PH			
	BH540	BH545	BH546	BH547	BH540	BH545	BH546	BH547	BH540	BH545	BH546	BH547	BH540	BH545	BH546	BH547
L1xT1	1.2	27.3*	-14.4	-6.1	1.8	0.3	1.5	2.2	2.3	1.1	2.3	1.1	2.3	1.1	2.3	1.1
L1xT2	0	25.8*	-15.4	-7.3	-0.2	-1.6	-0.4	0.2	-0.1	-1.4	-0.1	-1.4	-0.1	-1.4	-0.1	-1.4
L1xT3	-20.5*	0	-32.7**	-26.3**	-2	-3.4	-2.2	-1.6	-2.4	-3.7	-2.4	-3.7	-2.4	-3.7	-2.4	-3.7
L1xT4	-31.3*	-13.6	-41.9**	-36.3**	0	-1.4	-0.2	0.5	1.2	0	1.2	0	1.2	0	1.2	0
L2xT1	-15.7	6.1	-28.6**	-21.8*	2.6	1.2	2.4	3	3.3	2	3.3	2	3.3	2	3.3	2
L2XT2	-12	10.6	-25.6**	-18.4*	0.5	-0.9	0.3	0.9	0.6	-0.6	0.6	-0.6	0.6	-0.6	0.6	-0.6
L2xT3	-28.9**	-10.6	-39.9**	-34.1**	0.2	-1.2	0	0.6	2.4	1.2	2.4	1.2	2.4	1.2	2.4	1.2
L2xT4	-3.6	21.2	-18.5*	-10.6	4.3	2.8	4.1	4.7	3.7	2.4	3.7	2.4	3.7	2.4	3.7	2.4
L3xT1	-10.8	12.1	-24.6**	-17.3	0.4	-1	0.2	0.8	1.1	-0.2	1.1	-0.2	1.1	-0.2	1.1	-0.2
L3xT2	3.6	30.3*	-12.3	-3.9	-4.1	-5.4*	-4.3	-3.7	-4.3	-5.5*	-4.3	-5.5*	-4.3	-5.5*	-4.3	-5.5*
L3xT3	-9.6	13.6	-23.5**	-16.2	-1.7	-3	-1.9	-1.3	-2	-3.2	-2	-3.2	-2	-3.2	-2	-3.2
L3xT4	-1.2	24.2	-16.4	-8.4	-2.6	-4	-2.8	-2.2	-3.2	-4.4	-3.2	-4.4	-3.2	-4.4	-3.2	-4.4
L4xT1	-8.4	15.2	-22.5**	-15.1	-1.8	-3.2	-2	-1.4	-2	-3.2	-2	-3.2	-2	-3.2	-2	-3.2
L4xT2	-7.2	16.7	-21.5*	-14	-3.8	-5.2*	-4	-3.5	-3.8	-5.0*	-3.8	-5.0*	-3.8	-5.0*	-3.8	-5.0*
L4xT3	-28.9**	-10.6	-39.9**	-34.1**	1.9	0.4	1.7	2.3	2.3	1.1	2.3	1.1	2.3	1.1	2.3	1.1
L4xT4	-10.8	12.1	-24.6**	-17.3	-1	-2.4	-1.3	-0.6	-1	-2.2	-1	-2.2	-1	-2.2	-1	-2.2
L5xT1	2.4	28.8*	-13.4	-5	-0.2	-1.6	-0.4	0.2	0	-1.2	0	-1.2	0	-1.2	0	-1.2
L5xT2	6	33.3**	-10.3	-1.7	-4.5	-5.8*	-4.7	-4.1	-4.6	-5.8*	-4.6	-5.8*	-4.6	-5.8*	-4.6	-5.8*
L5xT3	-25.3*	-6.1	-36.8**	-30.7**	-5.4*	-6.8**	-5.6*	-5*	-5.6*	-6.8**	-5.6*	-6.8**	-5.6*	-6.8**	-5.6*	-6.8**
L5xT4	-10.8	12.1	-24.6**	-17.3	-3.8	-5.2*	-4	-3.5	-4.4	-5.6*	-4.4	-5.6*	-4.4	-5.6*	-4.4	-5.6*
L6xT1	-20.5*	0	-32.7**	-26.3**	4.3	2.8	4.1	4.7	4.9*	3.6	4.9*	3.6	4.9*	3.6	4.9*	3.6
L6xT2	-18.1	3	-30.7**	-24.0*	-0.4	-1.8	-0.6	0	-1.2	-2.5	-1.2	-2.5	-1.2	-2.5	-1.2	-2.5
L6xT3	-19.3	1.5	-31.7**	-25.1**	-4.8*	-6.2**	-5*	-4.4	-5.5*	-6.7**	-5.5*	-6.7**	-5.5*	-6.7**	-5.5*	-6.7**
L6xT4	-26.5**	-7.6	-37.8**	-31.8**	0.7	-0.8	0.4	1.1	0.5	-0.8	0.5	-0.8	0.5	-0.8	0.5	-0.8
L7xT1	-9.6	13.6	-23.5*	-16.2	1	-0.4	0.8	1.4	1.2	0	1.2	0	1.2	0	1.2	0
L7xT2	4.8	31.8*	-11.3	-2.8	-1.2	-2.6	-1.4	-0.8	-1.2	-2.5	-1.2	-2.5	-1.2	-2.5	-1.2	-2.5
L7xT3	-32.5**	-15.2	-42.9**	-37.4**	2.8	1.4	2.6	3.3	2.9	1.7	2.9	1.7	2.9	1.7	2.9	1.7
L7xT4	-34.9**	-18.2	-45.0**	-39.7**	0.2	-1.2	0	0.6	0.9	-0.4	0.9	-0.4	0.9	-0.4	0.9	-0.4
L8xT1	4.8	31.8*	-11.3	-2.8	-0.2	-1.6	-0.4	0.2	-0.4	-1.6	-0.4	-1.6	-0.4	-1.6	-0.4	-1.6
L8xT2	4.8	31.8*	-11.3	-2.8	-3.5	-4.8*	-3.7	-3.1	-4	-5.2*	-4	-5.2*	-4	-5.2*	-4	-5.2*
L8xT3	-15.7	6.1	-28.6**	-21.8*	-4.8*	-6.2**	-5*	-4.4	-5.0*	-6.2*	-5.0*	-6.2*	-5.0*	-6.2*	-5.0*	-6.2*
L8xT4	-22.9*	-3	-34.8**	-28.5**	2.2	0.8	2	2.7	1.8	0.6	1.8	0.6	1.8	0.6	1.8	0.6
L9xT1	0	25.8*	-15.4	-7.3	1.3	-0.2	1.1	1.7	1.2	0	1.2	0	1.2	0	1.2	0
L9xT2	-24.1*	-4.5	-35.8**	-29.6**	-0.4	-1.8	-0.6	0	0.5	-0.8	0.5	-0.8	0.5	-0.8	0.5	-0.8
L9xT3	-39.8**	-24.2	-49.0**	-44.1**	-3	-4.4	-3.2	-2.6	-3.1	-4.3	-3.1	-4.3	-3.1	-4.3	-3.1	-4.3
L9xT4	-15.7	6.1	-28.6**	-21.8*	-1.2	-2.6	-1.4	-0.8	-2.4	-3.7	-2.4	-3.7	-2.4	-3.7	-2.4	-3.7
SE(d)	0.82				1.96				1.98				10.49			
Maximum	6	33.3	-10.3	-1.7	4.3	2.8	4.1	4.7	4.9	3.6	4.9	3.6	4.9	3.6	4.9	3.6
Minimum	-39.8	-24.2	-49.0	-44.1	-5.4	-6.8	-5.6	-5.0	-6	-6.8	-6	-6.8	-6	-6.8	-6	-6.8
CD α= 0.01	1.33				3.17				3.19				16.94			
CDα =0.05	1.16				2.76				2.78				14.75			

Crosses	EH				GLS				TLB				CLR			
	BH540	BH545	BH546	BH547	BH540	BH545	BH546	BH547	BH540	BH545	BH546	BH547	BH540	BH545	BH546	BH547
L1xT1	-0.2	10.3	-4.1	-8.5	0	5.9	20	0	0	14.3	0	14.3	0	14.3	0	14.3
L1xT2	-5	4.9	-8.8	-13.0*	-13.3	-8.2	4	-13.3	-5	8.6	-5	8.6	-5	8.6	-5	8.6
L1xT3	-19.5*	-11.1	-22.7**	-26.3**	-13.3	-8.2	4	-13.3	-10	2.9	-10	2.9	-10	2.9	-10	2.9
L1xT4	-10.1	-0.7	-13.7*	-17.6**	13.3	20.1	36	13.3	-10	2.9	-10	2.9	-10	2.9	-10	2.9
L2xT1	-10.4	-1	-13.9*	-17.9**	-26.7	-22.3	-12	-26.7	-15	-2.9	-15	-2.9	-15	-2.9	-15	-2.9
L2xT2	-6.1	3.7	-9.8	-14.0*	-6.7	-1.1	12	-6.7	-15	-2.9	-15	-2.9	-15	-2.9	-15	-2.9
L2xT3	-3	7.2	-6.8	-11.1	-20	-15.3	-4	-20	-10	2.9	-10	2.9	-10	2.9	-10	2.9
L2xT4	2.7	13.4	-1.4	-5.9	-13.3	-8.2	4	-13.3	-15	-2.9	-15	-2.9	-15	-2.9	-15	-2.9
L3xT1	-1.5	8.8	-5.4	-9.8	-20	-15.3	-4	-20	-35**	-25.7*	-35**	-25.7*	-35**	-25.7*	-35**	-25.7*
L3xT2	-11.2	-2	-14.8*	-18.7**	-13.3	-8.2	4	-13.3	-25.0*	-14.3	-25.0*	-14.3	-25.0*	-14.3	-25.0*	-14.3
L3xT3	-7.4	2.3	-11.1	-15.2**	0	5.9	20	0	-10	2.9	-10	2.9	-10	2.9	-10	2.9
L3xT4	-15.4*	-6.6	-18.8**	-22.5**	-6.7	-1.1	12	-6.7	-5	8.6	-5	8.6	-5	8.6	-5	8.6
L4xT1	-11.9	-2.6	-15.4*	-19.3**	6.7	13	28	6.7	-30**	-20	-30**	-20	-30**	-20	-30**	-20
L4xT2	-3.9	6.2	-7.7	-12.0*	-13.3	-8.2	4	-13.3	-10	2.9	-10	2.9	-10	2.9	-10	2.9
L4xT3	-17.7**	-9.1	-21.0**	-24.6**	13.3	20.1	36	13.3	5	20	5	20	5	20	5	20
L4xT4	-4.9	5.1	-8.6	-12.8*	0	5.9	20	0	15	31.4*	15	31.4*	15	31.4*	15	31.4*
L5xT1	-13.0*	-3.9	-16.5*	-20.3**	-13.3	-8.2	4	-13.3	-10	2.9	-10	2.9	-10	2.9	-10	2.9
L5xT2	-5.9	3.9	-9.7	-13.8*	-20	-15.3	-4	-20	-20	-8.6	-20	-8.6	-20	-8.6	-20	-8.6
L5xT3	-30.8**	-23.5**	-33.5**	-36.6**	20	27.1	44*	20	0	14.3	0	14.3	0	14.3	0	14.3
L5xT4	-20.4**	-12.1	-23.5**	-27.1**	-6.7	-1.1	12	-6.7	-10	2.9	-10	2.9	-10	2.9	-10	2.9
L6xT1	-15.9*	-7.2	-19.3**	-23.0**	-13.3	-8.2	4	-13.3	-20	-8.6	-20	-8.6	-20	-8.6	-20	-8.6
L6xT2	-19.5**	-11.1	-22.7**	-26.3**	-6.7	-1.1	12	-6.7	-35**	-25.7*	-35**	-25.7*	-35**	-25.7*	-35**	-25.7*
L6xT3	-19.0**	-10.5	-22.2**	-25.8**	13.3	20.1	36	13.3	-5	8.6	-5	8.6	-5	8.6	-5	8.6
L6xT4	-23.0**	-15.0*	-26.1**	-29.5**	0	5.9	20	0	-10	2.9	-10	2.9	-10	2.9	-10	2.9
L7xT1	5.6	16.7*	1.4	-3.3	-13.3	-8.2	4	-13.3	-10	2.9	-10	2.9	-10	2.9	-10	2.9
L7xT2	-9.2	0.3	-12.8	-16.8**	-6.7	-1.1	12	-6.7	-20	-8.6	-20	-8.6	-20	-8.6	-20	-8.6
L7xT3	-12.1	-2.9	-15.6*	-19.5**	-6.7	-1.1	12	-6.7	-5	8.6	-5	8.6	-5	8.6	-5	8.6
L7xT4	-11.2	-2	-14.8*	-18.7**	-13.3	-8.2	4	-13.3	-10	2.9	-10	2.9	-10	2.9	-10	2.9
L8xT1	4.3	15.2*	0.1	-4.5	-20	-15.3	-4	-20	-15	-2.9	-15	-2.9	-15	-2.9	-15	-2.9
L8xT2	-0.9	9.5	-4.8	-9.2	6.7	13	28	6.7	-20	-8.6	-20	-8.6	-20	-8.6	-20	-8.6
L8xT3	-15.7*	-6.9	-19.0**	-22.8**	-6.7	-1.1	12	-6.7	-5	8.6	-5	8.6	-5	8.6	-5	8.6
L8xT4	-2.6	7.5	-6.5	-10.8	-6.7	-1.1	12	-6.7	-10	2.9	-10	2.9	-10	2.9	-10	2.9
L9xT1	2.3	13	-1.7	-6.3	6.7	13	28	6.7	-10	2.9	-10	2.9	-10	2.9	-10	2.9
L9xT2	-5.3	4.6	-9.1	-13.3*	6.7	13	28	6.7	-5	8.6	-5	8.6	-5	8.6	-5	8.6
L9xT3	-21.3**	-13	-24.4**	-27.9**	13.3	20.1	36	13.3	5	20	5	20	5	20	5	20
L9xT4	-3.3	6.9	-7.1	-11.4*	-6.7	-1.1	12	-6.7	0	14.3	0	14.3	0	14.3	0	14.3
SE(d)	6.98				0.23				0.22				0.29			
Maximum	5.6	16.7	1.4	-3.3	20	27.1	44	20	15	-25.7	-35	-26	15	-25.7	-35	-26
Minimum	-30.8	-23.5	-33.5	-36.6	-26.7	-22.3	-12	-26.7	-35	0.36	0.36	0.4	-35	0.36	0.36	0.4
CDα= 0.01	11.28				0.37				0.36				0.48			
CDα =0.05	9.83				0.32				0.31				0.41			

Crosses	KPR				EL				EPP				KPE			
	BH540	BH545	BH546	BH547	BH540	BH545	BH546	BH547	BH540	BH545	BH546	BH547	BH540	BH545	BH546	BH547
L1xT1	6	0.8	-0.4	6.8	-3.4	-3.3	-1.3	6.2	3.8	-23.9	-24.6	44.2	8.5	-6.7	-5.2	-7.5
L1xT2	4.2	-0.9	-2.1	5	-4.7	-4.6	-2.6	4.8	22.6	-10.1	-10.8	70.4*	14**	-2.0	-0.5	-2.8
L1xT3	0	-4.9	-6	0.8	-3.4	-3.3	-1.3	6.2	3.8	-23.9	-24.6	44.2	10.9*	-4.7	-3.2	-5.5
L1xT4	-6	-11	-11.6	-5.2	-11	-10.9	-9	-2.1	-24.5	-44.7*	-45.1*	4.8	19.4**	2.7	4.3	1.8
L2xT1	2.7	-2.3	-3.5	3.5	-3.4	-3.3	-1.3	6.2	22.6	-10.1	-10.8	70.4*	15.5**	-0.7	0.9	-1.5
L2xT2	3.3	-1.8	-2.9	4.1	-0.9	-0.8	1.3	9	32.1	-3.2	-4	83.5*	15.5**	-0.7	0.9	-1.5
L2xT3	-3.9	-8.6	-9.6	-3.1	-7.2	-7.1	-5.1	2.1	-5.7	-30.8	-31.4	31.1	9.3	-6.0	-4.5	-6.8
L2xT4	8.6	3.3	2.1	9.5	7.2	7.3	9.6	17.9*	-5.7	-30.8	-31.4	31.1	19.4**	2.7	4.3	1.8
L3xT1	3.9	-1.2	-2.3	4.7	-2.8	-2.7	-0.6	6.9	-15.1	-37.8*	-38.3	18	15.5**	-0.7	0.9	-1.5
L3xT2	11.3	5.9	4.7	12.2	0.3	0.4	2.6	10.3	32.1	-3.2	-4	83.5*	14**	-2.0	-0.5	-2.8
L3xT3	10.7	5.3	4.1	11.6	-2.2	-2.1	0	7.6	13.2	-17	-17.7	57.3	12.4*	-3.3	-1.8	-4.2
L3xT4	-1.2	-6	-7.1	-0.4	-4.7	-4.6	-2.6	4.8	-5.7	-30.8	-31.4	31.1	22.5**	5.3	7.0	4.4
L4xT1	11.3	5.9	4.7	12.2	-4.1	-4	-1.9	5.5	3.8	-23.9	-24.6	44.2	11.6*	-4.0	-2.5	-4.8
L4xT2	10.1	4.7	3.5	11	4.1	4.2	6.4	14.5	13.2	-17	-17.7	57.3	13.2*	-2.7	-1.1	-3.5
L4xT3	-9.2	-14	-14.6	-8.5	-9.1	-9	-7.1	0	-15.1	-37.8*	-38.3	18	12.4*	-3.3	-1.8	-4.2
L4xT4	2.1	-2.9	-4	2.9	-6	-5.9	-3.8	3.4	-24.5	-44.7*	-45.1*	4.8	18.6**	2.0	3.6	1.1
L5xT1	3.6	-1.5	-2.6	4.4	-2.2	-2.1	0	7.6	3.8	-23.9	-24.6	44.2	12.4*	-3.3	-1.8	-4.2
L5xT2	2.7	-2.3	-3.5	3.5	2.8	2.9	5.1	13.1	3.8	-23.9	-24.6	44.2	11.6*	-4.0	-2.5	-4.8
L5xT3	-5.7	-10	-11.3	-4.9	-11	-10.9	-9	-2.1	-34	-52**	-52.0*	-8.3	6.2	-8.7*	-7.2	-9.5*
L5xT4	-2.4	-7.2	-8.2	-1.6	-2.2	-2.1	0	7.6	-15.1	-37.8*	-38.3	18	18.6**	2.0	3.6	1.1
L6xT1	4.8	-0.4	-1.5	5.6	-2.2	-2.1	0	7.6	-15.1	-37.8*	-38.3	18	20.2**	3.3	5.0	2.4
L6xT2	11	5.6	4.4	11.9	-3.4	-3.3	-1.3	6.2	-24.5	-44.7*	-45.1*	4.8	7.8	-7.3	-5.9	-8.1

Crosses	KPR				EL				EPP				KPE			
	BH540	BH545	BH546	BH547	BH540	BH545	BH546	BH547	BH540	BH545	BH546	BH547	BH540	BH545	BH546	BH547
L6xT3	3.9	-1.2	-2.3	4.7	-4.1	-4	-1.9	5.5	-15.1	-37.8*	-38.3	18	16.3**	0.0	1.6	-0.9
L6xT4	-4.8	-9.4	-10.4	-4	-6.6	-6.5	-4.5	2.8	-15.1	-37.8*	-38.3	18	17.8**	1.3	2.9	0.5
L7xT1	3.6	-1.5	-2.6	4.4	-11.6	-11.5	-9.6	-2.8	3.8	-23.9	-24.6	44.2	21.7**	4.7	6.3	3.8
L7xT2	13.1	7.6	6.3	14	-0.3	-0.2	1.9	9.7	13.2	-17	-17.7	57.3	12.4*	-3.3	-1.8	-4.2
L7xT3	4.2	-0.9	-2.1	5	-4.1	-4	-1.9	5.5	-15.1	-37.8*	-38.3	18	7	-8.0	-6.5	-8.8
L7xT4	0.6	-4.3	-5.4	1.4	-4.7	-4.6	-2.6	4.8	3.8	-23.9	-24.6	44.2	24.8**	7.3	9*	6.4
L8xT1	0.3*	-4.6	-5.7	1.1	-13.5	-13.4	-12	-4.8	13.2	-17	-17.7	57.3	16.3**	0.0	1.6	-0.9
L8xT2	18.5	12.7	11.4	19*	4.7	4.8	7.1	15.2	13.2	-17	-17.7	57.3	15.5**	-0.7	0.9	-1.5
L8xT3	7.7	2.5	1.3	8.6	2.8	2.9	5.1	13.1	3.8	-23.9	-24.6	44.2	7.8	-7.3	-5.9	-8.1
L8xT4	-0.6	-5.5	-6.5	0.2	-4.7	-4.6	-2.6	4.8	-24.5	-44.7*	-45.1*	4.8	20.9**	4.0	5.6	3.1
L9xT1	-5.1	-10	-10.7	-4.3	-7.8	-7.7	-5.8	1.4	32.1	-3.2	-4	83.5*	21.7**	4.7	6.3	3.8
L9xT2	-5.4	-10	-11	-4.6	-8.5	-8.4	-6.4	0.7	3.8	-23.9	-24.6	44.2	21.7**	4.7	6.3	3.8
L9xT3	0.3	-4.6	-5.7	1.1	-9.1	-9	-7.1	0	-34	-52**	-52.0*	-8.3	14.7**	-1.3	0.2	-2.2
L9xT4	0.9	-4	-5.1	1.7	-2.8	-2.7	-0.6	6.9	-24.5	-44.7*	-45.1*	4.8	23.3**	6.0	7.7	5.1
SE(d)	2.81				1.22				0.25				0.64			
Maximum	18.5	12.7	11.4	0.65	7.2	7.3	9.6	17.9	32.1	-3.2	-3.98	83.5	24.81	7.33	9.03	6.41
Minimum	-9.2	-14	-14.6	-8.5	-13.5	-13.4	-12	-4.8	-34	-51.6	-52	-8.3	6.20	-8.67	-7.22	-9.45
CDα=0.01	4.55				1.98				0.40				1.06			
CDα=0.05	3.95				1.72				0.35				0.92			

Crosses	DM				TKW				ED				ER			
	BH540	BH545	BH546	BH547	BH540	BH545	BH546	BH547	BH540	BH545	BH546	BH547	BH540	BH545	BH546	BH547
L1xT1	0.3	1.5	-1.7	-0.1	-9.9	18.5	16.4	3.2	-1.1	7.3	3.1	-4.7	-6.0	-53**	-17.3	10.0
L1xT2	-1.8	-0.4	-3.8	-2.3	-32**	-11.1	-12.7	-22.6*	-7.4	0.5	-3.5	-10.8*	70.9**	-14.2	50.4*	100**
L1xT3	0.9	-2.2	-1.1	0.5	-15.5	11.1	9.1	-3.2	-9.5*	-1.8	-5.7	-12.8**	2.6	-49**	-9.8	20.0
L1xT4	0.2	-0.2	-1.8	-0.2	-23.9*	0.0	-1.8	-12.9	1.1	9.6	5.3	-2.7	28.2	-36*	12.8	50.0
L2xT1	-0.4	2.4	-2.4	-0.8	-18.3	7.4	5.5	-6.5	-3.2	5.0	0.9	-6.8	-57.3*	-78.5**	-62.4**	-50.0
L2XT2	-0.8	0.3	-2.8	-1.2	-23.9*	0.0	-1.8	-12.9	-7.4	0.5	-3.5	-10.8*	70.9**	-14.2	50.4*	100**
L2xT3	2.9	0.0	0.8	2.5	-9.9	18.5	16.4	3.2	-3.2	5.0	0.9	-6.8	-57.3*	-78.5**	-62.4**	-50.0
L2xT4	1.0	4.1	-1.1	0.5	-15.5	11.1	9.1	-3.2	-1.1	7.3	3.1	-4.7	-14.5	-57.1**	-24.8	0.0
L3xT1	0.6	0.2	-1.4	0.2	-26.8*	-3.7	-5.5	-16.1	-7.4	0.5	-3.5	-10.8*	-31.6	-65.7**	-39.8	-20.0
L3xT2	-1.1	-4.3	-3.1	-1.5	-47**	-29.6*	-30.9*	-39**	-7.4	0.5	-3.5	-10.8*	70.9**	-14.2	50.4*	100**
L3xT3	1.3	-1.9	-0.8	0.8	-23.9*	0.0	-1.8	-12.9	-5.3	2.7	-1.3	-8.8	11.1	-44.2**	-2.3	30
L3xT4	-1.5	-2.8	-3.5	-1.9	-23.9*	0.0	-1.8	-12.9	-5.3	2.7	-1.3	-8.8	53.8**	-22.7	35.3	80**
L4xT1	-1.2	-2.0	-3.2	-1.6	-35**	-14.8	-16.4	-25.8*	-7.4	0.5	-3.5	-10.8*	-40.2	-70**	-47.4	-30
L4xT2	-1.2	-4.0	-3.2	-1.6	-35**	-14.8	-16.4	-25.8*	-7.4	0.5	-3.5	-10.8*	2.6	-48.5**	-9.8	20
L4xT3	-1.4	1.7	-3.4	-1.8	-32**	-11.1	-12.7	-22.6*	-9.5*	-1.8	-5.7	-12.8**	11.1	-44.2**	-2.3	30
L4xT4	-0.7	-1.3	-2.7	-1.1	-23.9*	0.0	-1.8	-12.9	-1.1	7.3	3.1	-4.7	-6.0	-52.8**	-17.3	10
L5xT1	1.4	-0.4	-0.6	1.0	-26.8*	-3.7	-5.5	-16.1	-12**	-4.1	-7.9	-14.9**	139.3**	20.2	110.5**	180*
L5xT2	-0.7	-4.7	-2.7	-1.1	-15.5	11.1	9.1	-3.2	-7.4	0.5	-3.5	-10.8*	45.3	-27*	27.8	70*
L5xT3	-2.5	-5.6**	-4.5	-2.9	-26.8*	-3.7	-5.5	-16.1	-12**	-4.1	-7.9	-14.9**	11.1	-44.2**	-2.3	30
L5xT4	-2.5	-4.0	-4.5	-2.9	-15.5	11.1	9.1	-3.2	-7.4	0.5	-3.5	-10.8*	-14.5	-57.1**	-24.8	0.0
L6xT1	1.4	4.1	-0.6	1.0	-38**	-18.5	-20.0	-29*	-12**	-4.1	-7.9	-14.9**	-14.5	-57.1**	-24.8	0.0
L6xT2	0.9	-0.6	-1.1	0.5	-23.9*	0.0	-1.8	-12.9	-9.5*	-1.8	-5.7	-12.8**	2.6	-48.5**	-9.8	20.0
L6xT3	-1.0	-5*	-3.0	-1.4	-32.4*	-11.1	-12.7	-22.6*	-5.3	2.7	-1.3	-8.8	-14.5	-57.1**	-24.8	0.0
L6xT4	-1.5	0.4	-3.5	-1.9	-26.8*	-3.7	-5.5	-16.1	-7.4	0.5	-3.5	-10.8*	2.6	-48.5**	-9.8	20.0
L7xT1	-0.2	0.8	-2.2	-0.6	-35**	-14.8	-16.4	-25.8*	-7.4	0.5	-3.5	-10.8*	28.2	-35.6**	12.8	50.0
L7xT2	0.2	-1.4	-1.8	-0.2	-15.5	11.1	9.1	-3.2	-9.5*	-1.8	-5.7	-12.8**	2.6	-48.5**	-9.8	20.0
L7xT3	-0.1	2.6	-2.1	-0.5	-26.8*	-3.7	-5.5	-16.1	-7.4	0.5	-3.5	-10.8*	28.2	-35.6**	12.8	50.0
L7xT4	-1.2	0.0	-3.2	-1.6	-18.3	7.4	5.5	-6.5	-3.2	5.0	0.9	-6.8	-14.5	-57.1**	-24.8	0.0
L8xT1	3.4	-0.4	1.3	2.9	-23.9*	0.0	-1.8	-12.9	-9.5*	-1.8	-5.7	-12.8**	53.8*	-22.7	35.3	80**
L8xT2	1.5	-3.7	-0.5	1.1	-23.9*	0.0	-1.8	-12.9	-7.4	0.5	-3.5	-10.8*	53.8*	-22.7	35.3	80**
L8xT3	1.3	-5*	-0.8	0.8	-15.5	11.1	9.1	-3.2	-7.4	0.5	-3.5	-10.8*	45.3	-27*	27.8	70*
L8xT4	1.2	2	-0.8	0.8	-18.3	7.4	5.5	-6.5	-7.4	0.5	-3.5	-10.8*	88**	-5.6	65.4**	120**
L9xT1	0.3	1.1	-1.7	-0.1	-35**	-14.8	-16.4	-25.8*	-5.3	2.7	-1.3	-8.8	70.9**	-14.2	50.4*	100**
L9xT2	2.2	-0.6	0.1	1.7	-29.6*	-7.4	-9.1	-19.4	-3.2	5.0	0.9	-6.8	45.3	-27*	27.8	70**
L9xT3	-4.4*	-3.2	-6.4**	-4.9*	-23.9*	0.0	-1.8	-12.9	-5.3	2.7	-1.3	-8.8	11.1	-44.2**	-2.3	30.0
L9xT4	0.3	-1.4	-1.7	-0.1	-23.9*	0.0	-1.8	-12.9	-1.1	7.3	3.1	-4.7	11.1	-44.2**	-2.3	30.0
SE(d)	3.36				0.03				0.21				0.27			
Maximum	3.4	4.1	1.3	2.9	-9.9	18.5	16.4	3.2	1.1	9.6	5.3	-2.7	139.3	20.2	110.5	180.0
Minimum	-4.4	-5.6	-6.4	-4.9	-46.5	-29.6	-30.9	-38.7	-11.6	-4.1	-7.9	-14.9	-57.3	-78.5	-62.4	-50.0
CDα=0.01	5.43				0.05				0.34				0.44			
CDα=0.05	4.73				0.05				0.29				0.38			

*=Significance level at 0.05, **=Significance level at 0.01 no asterisk of */**=non-significance at 0.05 and 0.01 levels, CD=critical difference, SE (d) = standard error of difference.

4. Conclusion

In this study, eight promising crosses L2xT4, L3xT4, L4xT4, L5xT2, L6xT3, L7xT2, L9xT1 and L9xT4 which had higher yield as compared to the checks were identified based on their mean performance which can improve the production and productivity of quality protein maize yield were observed. 63.9% and 19.44% of crosses performed greater grain yield than the standard checks BH545 and BH540, respectively while 22.2% crosses performed lower grain yield as compared to the standard check BH545. Hence, promising crosses identified in this study can be used for quality protein maize research platforms as possible candidates for selection and release after approving the permanency of their performance in multi sites and one more season in respectable agro ecology's.

For the estimated mid and better parent heterosis for grain yield across locations, all crosses displayed positive and highly significant variances with range from 386.6% to 111.2% and 288.9% to 72.2%. Heterosis in the positive direction is desirable for grain yield and its related traits that directly contribute to yield. For grain yield, nine crosses expressed positive and significant advantages over the standard check BH545 with range of (33.3% to -24.2%). Almost all of crosses showed significantly negative mid and better parent heterosis for DA and DS. The negative heterosis for DA and DS showed earliness of the crosses as compared to the mean performance of the parents. This indicates the potential for decrease of days to maturity through crossing to develop early maturing hybrid varieties. Heterosis in the positive direction is desirable for grain yield and its related traits that directly contribute to yield such as ED, EL, NKPR and NKPE. The presence of genetic difference for grain yield, and agronomic traits give extra direction for maize breeders particularly those who are concerned in heterosis breeding. Finally, these genotypes help as a source of promising alleles that could be used for future breeding program in the development of quality protein maize cultivars with desirable attributes' composition for mid altitude agroecology of Ethiopia. Yet, further valuation of these and other maize hybrids at more locations and over years is required to confirm the promising results observed in present study.

Conflict of Interest

The authors declare that they have no competing interests.

Acknowledgements

The authors are appreciative to EIAR for financial support. The authors also like to extend their thanks to all maize research staff at Bako National Maize Research Centre and Jimma Agricultural Research center for their assistance during field trail monitoring, evaluation, and data recording. Their efforts are appreciatively accredited.

References

[1] Abate T, M Fisher, T Abdoulaye, GT Kassie, R Lunduka, P Marenya, W Asnake, 2017. Characteristics of maize cultivars in Africa: How modern are they and how many do smallholder farmers grow? *Agriculture & Food Security*.

[2] Abate, T., Shiferaw, B., Menkir, A., Wegary, D., Kebede, Y., Tesfaye, K., Kassie, M., Bogale, G., Tadesse, B. and Keno, T., 2015. Factors that transformed maize productivity in Ethiopia. *Food security*.

[3] Addisalem, M., Wegary, D., Mohamed, W., Tarekegne, A. and Teklewold, A., 2019. Hybrid Performance and Combining Ability of Quality Protein Maize Inbred Lines under Low-Nitrogen Stress and Non-Stress Conditions in Ethiopia. *Ethiopian Journal of Agricultural Sciences*.

[4] Adefris T, Dagne W, Abraham T, Birhanu T, Kassahun B, Dennis F, Prasanna BM. (2015). Quality Protein Maize (QPM): A Guide to the Technology and Its Promotion in Ethiopia. CIMMYT: Addis Ababa, Ethiopia.

[5] Ali Q, Ali A, Awan MF, Tariq M, Ali S, Samiullah TR and Hussain T., 2014. Combining ability analysis for various physiological, grain yield and quality traits of *Zea mays* L. Life. Sci. J.

[6] Amare S, Dagne W and Sentayehu S., 2016. Combining ability of elite highland maize (*Zea mays* L.) inbred lines at Jimma Dedo, South West Ethiopia. *Advances in Crop Science and Technology*.

[7] Berhanu T. 2009. Heterosis and combining ability for yield, yield related parameters and stover quality traits for food-feed in maize (*Zea Mays* L.) adapted to the mid-altitude agroecology of Ethiopia. MSc. Thesis. Haramaya University, Haramaya, Ethiopia.

[8] Beyene A., 2016. Heterosis and combining ability of mid-altitude quality protein maize (*Zea Mays* L.) inbred lines at Bako, Western Ethiopia. MSc Thesis. Haramaya University, Haramaya.

[9] Bisen, P., Dadheech, A., Namrata, N., Kumar, A., Solanki, G. and Dhakar, T. R., 2017. Combining ability analysis for yield and quality traits in single cross hybrids of quality protein maize (*Zea mays* L.) using diallel mating design. Journal of Applied and Natural Science.

[10] Bitew T, Mideksa D, Temesgen D, Belay G, Girma D, Dejene K, Dagne W, Adefiris T. 2017. Combining ability analyses of quality protein maize (QPM) inbred lines for grain yield, agronomic traits, and reaction to grey leaf spot in mid-altitude areas of Ethiopia. *African Journal of Agricultural Research*.

[11] Bitew T. 2016. Heterosis and Combining Ability of Mid-Altitude Maize (*Zea mays* L.) Inbred Lines for Grain Yield, Yield Related Traits and Reaction to Turcicum Leaf Blight (*Exserohilum turcicum Leonard and Suggs*) at Bako, Western Ethiopia. MSc. Thesis. Haramaya University, Haramaya, Ethiopia.

[12] Dagne W, Habtamu Z, Temam H, M. T. Labuschagne and H. Singh. 2007. Heterosis and combining ability for grain yield and its components in selected maize inbred lines. South African Journal of Plant and Soil.

[13] Dufera T, T Bulti and A Girum 2018. Heterosis and combining ability analyses of quality protein maize (*Zea mays* L.) inbred lines adapted to mid-altitude subhumid agro-ecology of Ethiopia. African Journal of Plant Science.

[14] Dufera T. Tesso, D., and Azmach, D., 2017. Combining Ability, Heterosis and Heterotic Grouping of Quality Protein Maize Zea mays L. Inbred Lines at Bako, Western Ethiopia (Master of sceinces thesis, Haramaya University).

[15] Falconer, D. S. and Mackay, T. F. C. 1996. Introduction to quantitative genetics. (4th ed.), Longman, London, UK.

[16] Gemechu G, 2019. Combining ability and heterosis in maize inbred lines (*zea mays* L.) For yields in mid altitude sub-humid agroecology of Ethiopia (Master of Science thesis, university of Nigeria).

[17] Girma C. Hosana, Sentayehu Alamerew, Berhanu Tadesse & Temesgen Menamo. 2015. Test Cross Performance and Combining Ability of Maize (*Zea Mays* L.) Inbred Lines at Bako, Western Ethiopia, Global Journal of Science Frontier Research: Department of Agriculture and Veterinary.

[18] Gomez, A. K. and Gomeze, A. A (1984). Statistical Procedure for Agricultural Research. 2nd edition. John Wiley and Sons. New York.

[19] Gudeta N, W Dagne, M Wassu, and Z Habtamu. 2017. Mean Performance and Heterosis in Single Crosses of Selected Quality Protein Maize (QPM) Inbred Lines. J. Sci. Sustain. Dev.

[20] Hussain, M. O. Z. A. M. M. I. L., Kiani, T. T., Shah, K. N., Ghafoor, A. and Rabbani, A., 2015. Gene action studies for protein quality traits in (*Zea mays* L.) under normal and drought conditions. *Pakistan Journal of Botany*.

[21] Legesse, B. W., Pixley, K. V. and Botha, A. M., 2009. Combining ability and heterotic grouping of highland transition maize inbred lines. *Maydica*.

[22] Lemi, B., Sentayew, A., Ashenafi, A. and Gerba, D. 2018. Genotype x environment interaction and yield stability of Arabica coffee (*Coffee Arabica* L.) genotypes.

[23] Mbuya, K., Nkongolo, K. K. and Kalonji-Mbuyi, A., 2011. Nutritional analysis of quality protein maize varieties selected for agronomic characteristics in a breeding program. *International Journal of Plant Breeding and Genetics*.

[24] Rahman, H., Arifuddin, Z., Shah, S., Shah, A., Iqbal, M., and Khalil, I. H. 2010. Evaluations of maize S2 lines in test cross combinations I: flowering and morphological traits. *Pakistan Journal of Botany*.

[25] Rawi. 2016. Relative performance and combining ability for yield and yield components in maize by using full diallel cross. *International Journal of Current Research*.

[26] SAS Institute, Inc (2003). SAS proprietary Software and Version 9.0, SAS Inst., Cary, NC.. SAS Institute, Inc, CARY, NC, Canada.

[27] Shashidhara, C. K., 2008. Early generation testing for combining ability in maize (*Zea mays* L.). MSc Thesis. University of Agricultural Sciences, Dharwad.

[28] Shushay W. 2011. Line x tester analysis of maize (*Zea mays* L.) inbred lines for grain yield and yield related traits in central rift valley of Ethiopia. MSc. Thesis, Haramaya University, Haramaya, Ethiopia.

[29] Shushay W., 2014. Standard Heterosis of Maize (*Zea mays* L.) Inbred Lines for Grain Yield and Yield Related Traits in Central Rift Valley of Ethiopia. *Journal of Biology, Agriculture and Healthcare.*

[30] Singh, P. K., Singh, A. K., Shahi, J. P. and Ranjan, R., 2012. Combining ability and heterosis in quality protein maize. The bioscan.

[31] Singh, R. K., and Chaudhary, B. D (1985). Biometrical methods in quantitative genetic analysis. Kalyani Publishers New Delhi, India.

[32] Tilahun B, Girum A, Tolera K, Temesgen Ch, Belay G, Beyene A, Dufera T, Zelalem T & Desalegn Ch,.2018. Test cross performance and combining ability of newly introduced quality protein maize (*Zea mays* L.) inbred lines for grain yield and agronomic traits evaluated in mid-altitude agro-ecological zones of Ethiopia, *South African Journal of Plant and Soil.*

[33] Tolera, K., Mosisa, W. and Habtamu, Z., 2017. Combining ability and heterotic orientation of mid altitude sub-humid tropical maize inbred lines for grain yield and related traits. *African Journal of Plant Science*.