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Standard Heterosis of the Selected Maize (Zea mays L.) Inbred Lines Hybrids for Grain Yield and Yield Component at Jimma, South West Oromia Region, Ethiopa

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Abstract

The study was carried out at Jimma Agricultural Research Center during 2015 cropping season. The objective was to evaluate standard heterosis for grain yield and yield components in maize hybrids. Ten selected inbred lines were crossed in a half diallel following Griffing's Model 1, Method4 and the resulting 45 F_1 hybrids (excluding parents) were evaluated with four commercial hybrid checks in 7x7 alpha lattice designs with three replication. For analysis of variance ear length, ear diameter, number of rows per ear, number of kernel rows per ear, number of grain per row, thousand grain weights and grain yield data were collected. The Statistical Analysis Systems (SAS) was used to analyze the data. Analysis of variance indicates highly significant ($P \leq 0.01$) and significant ($P \leq 0.05$) difference for all traits except for thousand grain weights. Among the crosses L6 x L7 (8.9%), L7 x L10 (10.7%), L2 x L9 (11.1%) and L7 x L9 (15.6%) t/ha exhibited the highest standard heterotic effects for grain yield over the best commercial check BH546. Therefore maize breeding program can engage in hybrid variety formation based on the information of inbred lines with high grain yield. However, hybrids with the highest grain yield than the best commercial check can advanced to multi-location trail for further study to be released, since this experimental study was carried out only at one location.

Keywords: Inbred line, Standard heterosis

1. INTRODUCTION

In Ethiopia, maize grows under a wide range of environmental conditions between 500 to 2400 meters above sea level. The mid- altitude sub-humid agro-ecology is the most important maize producing environment in Ethiopia (Kebede, *et al.,* 1993). Maize is Ethiopia's leading cereal in terms of production, with 7.2 million tons produced in 2014/2015 by 9.3 million farmers across 2.1 million hectares of land (CSA, 2015). Over half of all Ethiopian farmers grow maize, mostly for subsistence, with 75% of all maize produced being consumed by the farming household. Following the hybrid production in the country the annual rate of growth for the number of households cultivating maize grew at 3.5 % each year between 2004 and 2013 (Tsedeke *et al*., 2015). During the last 10 years, average farm yield of maize increased from 1.8 t/ha to 3.7 t/ha (205%) on farmers' field. That means, hybrid variety development program in this crop has played a crucial role in increasing food grain production over the years (Dawit *etal*., 2014).

Although there is improvement in maize production from year to year in Ethiopia, still there is inadequate information for selection of inbred line in developing hybrid varieties which have higher yield advantage over the recently developed hybrid variety. Study conducted in Ethiopia on heterosis and combining ability in breeding populations, indicated that most crosses of the populations had low yield heterosis (Mandefro and Habtamu, 2001; Leta, 2004).Therefore Maize productivity in farmers' field throughout the country is generally low due to limitation of high yielding improved maize hybrid varieties (Hailegebrial *et al*., 2015b). According to Central Statistical Agency (CSA, 2015) in Ethiopia the national average yield is about 3.4 t/ha, but World average yield for maize is about 5.5 t/ha and that of developed countries is 6.2 t/ha, with some other country of 10 t /ha being common(ATA, 2014).

Heterosis and combining ability is prerequisite for developing a good economically viable open pollinated hybrid variety or hybrid variety. Information on the heterosis and combing ability among maize germplasm is essential in maximizing the effectiveness of hybrid development (Beck *et al.,* 1990). A new hybrid must be superior to the standard hybrids in terms of grain yield and other economic traits (Gurung *et al.,* 2010). One of the most important methods used to exploit heterosis is standard heterosis, which refers to the superiority of F_1over the standard commercial check variety and indicates the usefulness of the hybrid when compared to the checks (Atnafua and Tnaro, 2013). The superior hybrids over the checks for grain yield and other agronomic characters can be exploited further in breeding programs for improving such important quantitative and qualitative traits. Since heterosis in F_1 hybrid over better parents and mid-parent, may not show positive and significant standard heterosis over the commercial hybrid variety.

Therefore, high yielding and farmer-preferred maize varieties should be developed and made available to growers to enhance maize production and to ensure food security in the country. Based this the experiment was conducted to determine standard heterosis and promising single cross for further breeding program based on their performance by comparing with standard checks

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was carried out in the main cropping season of 2015 at Jimma Agricultural Research Centre (JARC) located at Melko. It is located in south western part of Oromia Region 358 km from Addis Ababa and 12km from Jimma Town. The center is located at 7º40' N' latitude and 36º E longitude at an altitude of 1753 m.a.s.l. The climate of the area is characterized as sub-humid with mean monthly maximum and minimum temperature of 26.3 ºC and 11.6 ºC, respectively. It is characterized as high rain fall area with mean annual rainfall of 1572 mm. The soil type of the experimental area is Eutric Nitosol and Cambiosl (reddish brown) of upland and fluvisol of bottom land with pH around 5.2 (Institute of Agricultural Research (IAR), 1997).

2.2 The Experimental Materials

Ten selected inbred lines (Table 1) were crossed in a half diallel following Griffing's Model 1, Method 4 (Griffing, 1956) and the resulting 45 F_1 hybrids (excluding parents) were evaluated with four commercial hybrids (BH540, BH543, BH546 and BH547) included as standard checks. It was sought to generate information on the superiority of the F1 hybrids over the commercial hybrid varieties commonly grown in the mid-altitude maize growing environments.

TABLE 1 LIST OF PARENT INBRED LINES USED IN THIS STUDY

Lines Code number	Pedigree
1	[LZ-956343/LZ956003]-B-1-1-2-B-B/124-b(113)-3-1-1
2	Gibe1-91-1-1-1-1
3	CML444
4	DE78-Z-126-3-2-2-1-1-1(g)
5	30H83-3-5-1-1-1-1-1
6	CLM197
7	ILOO'E1-9-1-1-1-1-1
8	SZNYA99F2-7-2-1-1
9	30H83-7-1-5-1-1-1-1
10	SC-715-56-2-1-2-1-1

2.3 Design and Experimental Managements

The treatments were evaluated in a 7 X 7 alpha lattice design (Patterson and Williams, 1976*)* in three replications. Each treatment was planted in two rows of 5.1 m length with spacing of 0.75 m between rows and 0.30 m between plants within the rows. Two seeds were planted per hill and then thinned to one plant per hill to achieve standard plant density of 44, 444 plants per hectare. Fertilizer was applied through Diammonium phosphate (DAP) having 46% P_2O_5 and 18% nitrogen and UREA having 46% nitrogen at the rate of 150 and 200 kg/ha, respectively. Full dose of DAP was applied at planting while UREA was given through top dressing at knee height stage of the crop. Other agronomic management practices were done following research recommendations for the area.

2.4 Data Collected

To record data on plants basis, ten plants were selected randomly in each plot and labeled. These plants were measured individually and the mean value was recorded for the plot.

Ear diameter: The diameter of ears harvested from the ten randomly selected plants was measured using Digital caliper and the average was recorded for the plot

Ear length: The length of ears harvested from the ten randomly selected plants was measured using ruler and the average was recorded for the plot.

Number of rows per ear: The total number of rows was counted in ten randomly taken ears and the average value was recorded as number of rows per ear

Number of kernel rows per ear: The total number of kernel rows was counted in ten randomly taken ears and the average value was recorded as kernel rows per ear.

Number of grains per row:The total number of grains was counted in ten randomly selected ears and divided by the number of rows per ear and the average was recorded for the plot.

Grain yield: Grain yield was determined as weight of the total shelled grain after adjusting grain moisture to 12.5% and then converted to ton per hectare.

2.5 Data Analysis

2.5.1 Statistical analysis

The statistical analysis of the data was carried out using SAS computer software version 9.2 (SAS, 2008) software. The statistical methods adopted were as follows. Plot mean(x)= $\frac{\sum x}{N}$, where x= value of observations recorded on individual plants in the plot

N= number of plant measured

2.5.2 Analysis of variance (ANOVA)

The plot based mean values for grain yield and yield component traits were subjected to ANOVA as described in Gomez and Gomez (1984).

2.5.3 Estimation of standard heterosis

Percent standard heterosis was calculated for those traits that showed statistically significant differences among genotypes as suggested by (Falconer and Mackay, 1996). This was computed as percentage increase or decrease of the cross performances over the best standard check as:

Standard Heterosis (SH) = $\frac{F1 - SC}{SC} x100$

Where,
F1 = Mean value of a cross
SC = Mean value of standard check variety

Test of significant for percent heterosis was done using the t-test. The standard errors of the difference for heterosis were calculated as follow:

SE (d) = $(2Me/r)^{1/2}$

Where, SE (d) = standard error of the difference Me = error mean square r = number of replications. Calculated t was tested against the tabulated t-value at error degree of freedom, Critical difference for heterosis over standard checks (SC)

CD (SH) = $(2MSe/r)^{½}$*t (Hailegebrial *et al.* 2015)

Where MSe is the error mean square, r is the number of replication and t is the table value at 5% and`1%

3. RESULT AND DISCUSION

3.1 RESULT

Analysis of variance for hybrids and checks revealed that the mean sum of squares were significant for all of the traits except thousand kernel weight (Table 2) indicating that the tested hybrids varied from each other.

Table 2 Analysis of variance for 45 hybrids and four checks for grain yield and major yield component traits at Jimma, 2015

SV	Df	ED	LE	NRPE	NKRPE	NGPR	TKWT	GY
Rep	2	0.2ns	12.4*	0.1ns	0.1ns	19.3ns	13272.5*	5.7*
Block(Rep)	18	0.1ns	2.4ns	1.6ns	1.6ns	8.9ns	2821.4ns	1.1ns
Genotype	48	0.2**	4.4**	2.4*	2.4*	15.6*	2843.4ns	3.6**
Error	78	0.1	1.2	1.4	1.4	8.8	2251.4	1.3
CV		6.5	6.6	7.9	7.8	8.1	13.1	15
EMS		0.1	1.16	1.37	1.36	8.77	2251	1.31

ns,* and** = non-significant, significant and highly significant at 0.05 and 0.01, respectively , ED=Ear diameter(cm), GY= grain yield per hector (ton/ha), LE= Ear length(cm), NGPR= number of grain per row, NKRPE= number of kernel rows per ear ,NRPE=number of rows per ear , TKWT= thousand kernel weight(gm.), SV= source of variation

3.1.1 Standard Heterosis

The estimates of standard heterosis over the standard check were computed for grain yield and major yield component traits that showed statistically significant differences among genotypes. It is important to know the performance of the F_1 hybrids before proposing for commercial production. Therefore standard heterosis for grain yield and major yield components of the forty five F_1 hybrid combinations generated among the ten inbred lines is presented below (see Table 3 and 4). The range of standard heterosis for grain yield over the four hybrid checks is ranged from -61.2% for L5 x L6 to 59.4% for L7 x L9 (tone/ha) (Table 3). The magnitude of standard heterosis for ear diameter varied from -10.3 % for L4 x L8 to 18 % for L7 x L9 (cm) over all four hybrids were, as for ear length varied from -21.3% for L4 x L5 to 44.9% for L7 x L10 (Table 3). In this study the magnitude of standard heterosis for number of rows per ear is ranged from -21.1 % for L1 x L8 to 29 % for L6 x L9 over four hybrid checks. On another hands magnitude of standard heterosis for number kernel row per ear and number of grain per row varied from -14% for L1xL8 to 29.9% for L68 x L9 and -23% for L4 x L5 to 33.7% for L7 x L10 respectively over the four commercial hybrid checks.

TABLE 3 THE MAGNITUDE OF STANDARD HETEROSIS FOR TESTED HYBRIDS RELATED TO FOUR COMMERCIAL CHECKS FOR GY, LE, AND ED, 2015

TRAITS	GY(t/ha)				ED (cm)				LE(cm)			
Crosses	BH540	BH543	BH546	BH547	BH540	BH543	BH546	BH547	BH540	BH543	BH546	BH547
L1xL2	32.8**	6.7**	-3.7**	25.1**	15.6**	8.6**	16.5**	9.5**	3.5**	-4.8**	-14.6**	17.4**
L1xL3	16.4**	-6.4**	-16**	9.7**	5.2**	-1.2**	5.9**	-0.4	-1.1	-9.1**	-18.4**	12.2**
L1xL4	11.8**	-10.2**	-19**	5.3**	-1.5**	-7.4**	-0.8**	-6.7**	1.8*	-6.5**	-16.1**	15.4**
L1xL5	10.0**	-11.6**	-20**	3.6**	4**	-2.3**	4.7**	-1.6**	12.3**	3.2**	-7.4**	27.4**
L1xL6	27.5**	2.5**	-7.5**	20.1**	5.0**	-1.3**	5.8**	-0.6**	16.9**	7.5**	-3.6**	32.6**
L1xL7	20.7**	-3.0**	-12**	13.7**	10**	3.3**	10.8**	4.1**	12.3**	3.2**	-7.4**	27.4**
L1xL8	20.6**	-3.1**	-13**	13.5**	-1.1**	-7. 1**	-0.4	-6.4**	8.3**	-0.4	-10.7**	22.9**
L1xL9	30.4**	4.8**	-5.4**	22.8**	9.3**	2.7**	10.1**	3.5**	5.7**	-2.8**	-12.8**	19.9**
L1xL10	15.6**	-7.1**	-16**	8.9**	6.9**	0.5*	7.8**	1.3**	10.3**	1.4	-9.0**	25.1**
L2xL3	40.6**	12.9**	1.96*	32.4**	16.9**	9.8**	17.8**	10.7**	0	-8.1**	-17.5**	13.4**
L2xL4	34.9**	8.4**	-2.2*	26.9**	14.1**	7.2**	14.9**	8**	5.0**	-3.4**	-13.4**	19.2**
L2xL5	17.7**	-5.4**	-15**	10.8**	9.0**	2.5**	9.9**	3.2**	9.4**	0.6	-9.8**	24.1**
L2xL6	22.6**	-1.5	-11**	15.5**	6.3**	-0.07	7.1**	0.7**	1.1	-7.1**	-16.6**	14.7**
L2xL7	37.9**	10.8**	0.03	29.9**	9.9**	3.3**	10.8**	4.1**	6.8**	-1.8*	-11.9**	21.1**
L2xL8	41.6**	13.8**	2.7**	33.3**	12.8**	6.04**	13.7**	6.9**	14.2**	5.0**	-5.8**	29.6**
L2xL9	53.2**	23.1**	11.1**	44.3**	14.2**	7.3**	15.1**	8.1**	5.0**	-3.4**	-13.4**	19.2**
L2xL10	48.5**	19.3**	7.7**	39.8**	14.2**	7.3**	15.1**	8.1**	1.3	-6.9**	-16.5**	14.9**
L3xL4	37.9**	10.9**	0.06	29.9**	5.8**	-0.6*	6.6**	0.2	-2.6**	-10**	-19.7**	10.4**
L3xL5	18.7**	-4.6**	-14**	11.7**	-1.4**	-7.4**	-0.68**	-6.7**	5.7**	-2.8**	-12.8**	19.9**
L3xL6	12.1**	-9.9**	-19**	5.5**	4.6**	-1.8**	5.3**	-0.99**	-0.7	-8.7**	-18.1**	12.7**
L3xL7	1.5	-18.4**	-26**	-4.4**	13**	6.2**	13.8**	7.01**	10.3**	1.4	-9.0**	25.1**
L3xL8	28.4**	3.2**	-6.9**	20.9**	5.8**	-0.6*	6.5**	0.14	10.3**	1.4	-9.0**	25.1**
L3xL9	46.5**	17.7**	6.2**	37. **9	10.8**	4.1**	11.6**	4.9**	1.1	-7.1**	-16.6**	14.7**
L3xL10	37.7**	10.6**	-0.2	29.6**	8.1**	1.5*	8.9**	2.3**	14.9**	5.6**	-5.2**	30.3**
L4xL5	-0.38	-20**	-28**	-6.2**	7.3**	0.8**	8.1**	1.6**	-4.6**	-12**	-21.3**	8.21**
L4xL6	6.9**	-14.1**	-22**	0.7	3.7**	-2.6**	4.4**	-1.8**	-1.5	-9.5**	-18.8**	11.7**
L4xL7	42.9**	14.8**	3.6**	34.6**	14.1**	7.2**	14.9**	8**	3.9**	-4.4**	-14.3**	17.9**
L4xL8	7.6**	-13.5**	-22**	1.3	-4.5**	-10.3**	-3.8**	-9.6**	-2.6**	-10**	-19.7**	10.4**
L4xL9	39.8**	12.4**	1.4	31.7**	6.6**	0.2	7.5**	0.99**	-1.1	-9.1**	-18.4**	12.2**
L4xL10	33.0**	6.9**	-3.5**	25.3**	7.7**	1.2**	8.5**	1.98**	15.8**	6.4**	-4.5**	31.3**
L5xL6	-46.5**	-57**	-61**	-49.7**	-4.1**	-9.9**	-3.4**	-9.2**	-2.4**	-10**	-19.5**	10.7**
L5xL7	23.1**	-1.0	-11**	15.9**	6.8**	0.4	7.6**	1.1**	9**	0.2	-10.1**	23.6**
L5xL8	10.2**	-11.4**	-20**	3.8**	3.4**	-2.8**	4.2**	-2.1**	16.4**	7.1**	-3.9**	32.1**
L5xL9	29.7**	4.2**	-5.9**	22.2**	6.7**	0.3	7.5**	1.1**	10.9**	2.0**	-8.5**	25.9**
L5xL10	36.1**	9.3**	-1.3	28.15	2.0**	-4.1**	2.8**	-3.4**	21.7**	11.9**	0.4	38.1**
L6xL7	50.2**	20.7**	8.9**	41.4**	11.1**	4.4**	12**	5.2**	15.6**	6.2**	-4.7**	31.1**
L6xL8	20.6**	-3.1**	-13**	13.6**	2.5**	-3.6**	3.3**	-2.9**	13.8**	4.6**	-6.1**	29.1**
L6xL9	29.8**	4.3**	-5.8**	22.3**	0.8**	-5.3**	1.6**	- 4.5**	7.7**	-1	-11.2**	22.1**
L6xL10	24.1**	-0.25	-10**	16.9**	-1.1**	-7.0**	-0.3	-6.3**	15.6**	6.3**	-4.7**	31.1**
L7xL8	15.8**	-6.9**	-16**	9.0**	8.8**	2.2**	9.6**	3.0**	2.9**	-5.4**	-15.2**	16.7**
L7xL9	59.4**	28.0**	15.6**	50.1 **	17.1**	10**	18**	10.9**	5.4**	-3.1**	-13**	19.6**
L7xL10	52.6**	22.7**	10.7**	43.7**	10.2**	3.5**	11**	4.3**	27.8**	17.5**	5.3**	44.9**
L8xL9	8.7**	-12.6**	-21**	2.4*	-3.4**	-9.2**	-2.6**	-8.5**	-1.5	-9.5**	-18.8**	11.7**
L8xL10	23.7**	-0.6	-10**	16.4**	-0.2	-6.2**	0.5*	-5.5**	23.2**	13.3**	1.6	39.7**
L9xL10	24.0**	-0.3	-1	16.8**	4.8**	-1.6**	5.6**	-0.8**	4.2**	-4.2**	-14.1**	18.2**
SEM		1.3						0.09				1.2
CD 0.05		1.9						0.5				1.7
CD 0.01		2.5						0.67				2.3

* and** = non-significant, significant and highly significant at 0.05 and 0.01, respectively CD= critical difference, ED=Ear Diameter(cm), GY=Grain yield (ton/ha), LE= Ear length(cm),

TABLE 4.THE MAGNITUDE OF STANDARD HETEROSIS FOR TESTED HYBRIDS RELATED TO FOUR COMMERCIAL CHECKS FOR NKRPE, NGRPR AND NRPE, 2015

TRAIT	NKRPE (#)				NGRPR (#)				NRPE**(#)**			
Crosses	BH540	BH543	BH546	BH547	BH540	BH543	BH546	BH547	BH540	BH543	BH546	BH547
L1 xL2	2.7	-8.8**	-8.8**	-7.1**	8.5**	5.5*	-5.7*	21.0**	2.5**	-8.8**	-8.8**	-7. **1
L1xL3	2.7	-8.8**	-8.8**	-7.1**	5.7*	2.7	-8.2**	17.9**	2.4**	-8.8**	-8.8**	-7.1**
L1xL4	-0.7	-12**	-11.8**	-10.3**	0.9	-1.8	-12.3**	12.6**	-0.98**	-11.8**	-12**	-10.3**
L1xL5	4.4**	-7.2**	-7.2**	-5.6**	10.4**	7.3**	-4.1	23.2**	4.4**	-7.0**	-7**	-5.4**
L1xL6	7.6**	-4.4**	-4.4**	-2.9	7.5**	4.6	-6.6**	20**	7.4**	-4.4**	-4.4**	-2.7**
L1xL7	4.7**	-7**	-7.0**	-5.4**	15.1**	11.9**	0	28.4**	4.4**	-7.0**	-7**	-5.4**
L1xL8	-2.7	-14**	-13.6**	-12.1**	6.6**	3.7*	-7.4**	18.9**	-2.9**	-13.6**	-14**	-12.1**
L1xL9	13.1**	0.4	0.4	2.2	3.8	0.9	-9.8**	15.8**	12.8**	0.4	0.4	2.2**
L1xL10	1.2	-10**	-10.1**	-8.5**	3.8	0.9	-9.8**	15.8**	1.5	-9.6**	-9.6**	-8.0**
L2xL3	9.1**	-3.1	-3.1	-1.3	2.8	0	-10.7**	14.7**	9.4**	-2.6**	-2.6**	-0.9
L2xL4	14.8**	1.9	1.9	3.8*	-1.9	-4.6	-14.8**	9.5**	16.3**	3.5**	3.5**	5.4**
L2xL5	3.2	-8.3**	-8.3**	-6.7**	1.9	-0.9	-11.5**	13.7**	2.9**	-8.3**	-8.3**	-6.7**
L2xL6	7.6**	-4.4**	-4.4**	-2.7	-3.8	-6.4**	-16.4**	7.4**	7.4**	-4.4**	-4.4**	-2.7**
L2xL7	6.7**	-5.3**	-5.3**	-3.6*	4.7	1.8	-9.0**	16.8**	6.4**	-5.3**	-5.3**	-3.6**
L2xL8	14.6**	1.7	1.7	3.6*	4.7	1.8	-9.0**	16.8**	14.3**	1.8	1.7	3.6**
L2xL9	21.9**	8.3**	8.3**	10.3**	6.6**	3.7	-7.4**	18.9**	21.7**	8.3**	8.3**	10.3**
L2xL10	4.7**	-7**	-7.0**	-5.4*	2.8	0	-10.7**	14.7**	4.4**	-7.0**	-7**	-5.4**
L3xL4	8.1**	-3.9*	-3.9*	-2.2	-2.8	-5.5*	-15.6**	8.4**	7.9**	-3.9**	-3.9**	-2.2**
L3xL5	8.6**	-3.5*	-3.5*	-1.8	4.7	1.8	-9.0**	16.8**	8.9**	-3.1**	-3.1**	-1.3
L3xL6	16.3**	3.3*	3.3*	5.1**	-1.9	-4.6	-14.8**	9.5**	16.3**	3.5**	3.5**	5.4**
L3xL7	11.6**	-0.9	-0.9	0.9	2.8	0	-10.7**	14.7**	11.3**	-0.9	-0.9	0.9
L3xL8	8.6**	-3.5*	-3.5*	-1.8	0	-2.7	-13.1**	11.6**	8.4**	-3.5**	-3.5**	-1.8
L3xL9	24.4**	10.5**	10.5**	12.5**	2.8	0	-10.7**	14.7**	24.1**	10.5**	10.5**	12.5**
L3xL10	1.7	-9.6**	-9.6**	-8.0**	8.5**	5.5*	-5.7*	21.0**	1.97*	-9.2**	-9.2**	-7.6**
L4xL5	16.3**	3.3*	3.3*	5.1**	-11.3**	-13.8**	-23**	-1.1	16.3**	3.5**	3.5**	5.4**
L4xL6	11.6**	-0.9	-0.9	0.9	-6.6**	-9.2**	-18.9**	4.2	11.3**	-0.9	-0.9	0.9
L4xL7	23.5**	9.6**	9.6**	11.6**	1.9	-0.9	-11.5**	13.9**	23.2**	9.6**	9.6**	11.6**
L4xL8	6.7**	-5.3**	-5.3**	-3.6*	-1.9	-4.6	-14.8**	9.5**	6.4**	-5.3**	-5.3**	-3.6**
L4xL9	24.2**	10.3**	10.3**	12.3**	-5.7*	-8.3**	-18**	5.3*	24.1**	10.5**	10.5**	12.5**
L4xL10	11.6**	-0.9	-0.9	0.9	9.4**	6.4**	-4.9*	22.1**	11.3**	-0.9	-0.9	0.9
L5xL6	9.9**	-2.4	-2.4	-0.7	-10.4**	-12.8**	-22.1**	0	9.4**	-2.6**	-2.6**	-0.9
L5xL7	20**	6.6**	6.6**	8.5**	1.9	-0.9	-11.5**	13.7**	19.7**	6.6**	6.6**	8.5**
L5xL8	11.1**	-1.3	-1.3	0.4	6.6**	3.7	-7.4**	18.9**	10.8**	-1.3	-1.3	0.45
L5xL9	15.1**	2.2	2.2	4.0*	5.7*	2.7	-8.2**	17.9**	16.3**	3.5**	3.5**	5.4**
L5xL10	13.1**	0.4	0.4	2.2	14.1**	11**	-0.8	27.4**	12.8**	0.4	0.4	2.2*
L6xL7	16.5**	3.5*	3.5*	5.4**	5.7*	2.7	-8.2**	17.9**	16.3**	3.5**	3.5**	5.4**
L6xL8	3.2ns	-8.3**	-8.3**	-6.7**	8.5**	5.5*	-5.7*	21.0**	2.9**	-8.3**	-8.3**	-6.7**
L6xL9	29.9**	15.3**	15.4**	17.4**	5.7*	2.7	-8.2**	17.9**	29.6**	15.3**	15.4**	17.4**
L6xL10	10.6**	-1.8	-1.7	0	12.3**	9.2**	-2.5	25.3**	10.3**	-1.7	-1.8	0
L7xL8	4.2*	-7.5**	-7.5**	-5.8**	4.7	1.8	-9.0**	16.8**	3.9**	-7.5**	-7.5**	-5.8**
L7xL9	22.5**	8.8**	8.8**	10.7**	6.6**	3.7	-7.4**	18.9**	22.2**	8.8**	8.8**	10.7**
L7xL10	3.7*	-7.9**	-7.9**	-6.3**	19.8**	16.5**	4.1	33.7**	3.4**	-7.9**	-7.9**	-6.2**
L8xL9	7.6**	-4.4**	-4.4**	-2.7	0	-2.7	-13.1**	11.6**	7.4**	-4.4**	-4.4**	-2.7**
L8xL10	-1.48	-13**	-12.5**	-10.9**	14.1**	11**	-0.8	27.4**	-0.5	-11.4**	-11**	-9.8**
L9xL10	11.1**	-1.3	-1.3	0.5	3.8	0.9	.8*	15.8**	10.8**	-1.3	-1.3	0.45
SEM		1.4				8.8				1.4		
CD0.05		3.3				4.8				1.9		
CD0.01		4.4				6.4				2.5		

* and** = non-significant, significant and highly significant at 0.05 and 0.01, respectively, CD= critical difference , NGRPE=number of grain per row, NKRPE= number of kernel rows per ear, NRPE=number of rows per ear

3.2 DISCUSSION

Grain yield

Grain yield improvement is one of the most important aims of every plant breeder. Hybrid varieties cannot be feasible for commercial production, if it is not better than standard commercial variety though it produces reasonable grain yield level. Among forty five crosses nine hybrids exhibited positive and significant economic heterosis over the best standard check (BH546) for grain yield (Table 3). This showed that the studied hybrids have yield advantage over the commercial hybrid checks. Standard heterosis for this trait ranged from -61.2 % for L5 x L6 to 15.2% for L7 x L9 over BH546. On the other hand among the forty five crosses 93.3% and 88.9% of hybrids exhibited positive significant standard heterosis within the range of -46.5% (L5 x L6) to 59.4% (L7 x L9), -49.7% (L5 x L6) to 50.1% (L7 x L9) over the two hybrids, BH540 and BH547, respectively. Out of the 45 crosses twenty two hybrids revealed significant positive heterosis and eighteen hybrids showed negative significant heterosis by a range from -57% (L5 x L6) to 28% (L7 x L9) over BH543. The first five best hybrids that recorded positive and significant economic heterosis over the four standard checks were L6 x L7, L7 x L10, L2 x L9, L7 x L9 and L2 x L10. The crosses which manifested positive standard heterosis are desirable and important to improve grain yield, while those revealed negative standard heterosis are undesirable one as they decrease productivity.

Among the checks BH 546 is the recently released hybrid with hybrid BH 547, whereas check BH 543 was released earlier next to hybrid BH 540, due to this the recently released hybrid checks had yield potential than the early released hybrid. Therefore among the tested hybrids those revealed positive and significant economic heterosis than recently released check could be used to develop high yield maize variety in future breeding program. In this study all of the hybrids which revealed higher positive and significant standard heterosis over the best check BH546 are the crosses among lines which manifested positive and significant GCA effect except L6 x L7. This means that the highest standard heterosis of 7.7% in L2 x L10, 10.7% in L7 x L10, 11.1% in L2 x L9 and 15.6% in L7xL9 were due to cumulative effect of gene action. Due to this reason population improvement is possible in these hybrids breeding program. But the hybrid L6 x L7 ,which had economic heterosis of 8.9% developed from lines with negative and positive GCA effects implied there is dominance or epistasis relationship between the lines. Uddin *et al.* (2008); Amiruzzaman *et al. (*2010); Hailegebrial *et al.* (2015) and Reddy *et al.* (2015) also got similar heterotic effect for grain yield while studying combining ability and heterosis for yield and yield component characters in maize.

Ear diameter and Length

Ear diameter and length are an important yield component and are commonly used as a selection criterion in maize breeding programs because of there is strong relation with grain yield. Magnitude heterotic effects among the forty five crosses range from -4.5% (L4 x L8) to 17.1 % (L7 x L9) over check BH540,-10.3 % (L4 x L8) to 10% (L7 x L9) over BH543, -3.8% (L4 x L8) to18 % (L7 x L9) over BH546 and -9.6 % (L4 x L8) to 10.9 % (L7 x L9) over BH547 (Table 3) for ear diameter. Among the forty five crosses thirty seven hybrids exhibited positive and significant standard heterosis and seven hybrids revealed negative and significant standard heterosis over BH540. Twenty one hybrids revealed positive and significant heterosis and twenty hybrids showed negative and significant heterosis over BH543. On other hand thirty eight hybrids exhibited positive and significant heterosis and five hybrids revealed negative significant economic heterosis over BH546.Twenty five hybrids revealed positive significant heterosis and twenty two hybrids showed negative significant standard heterosis over BH547.

Hybrids L3 x L7, L4 x L7, L2 x L9, L2 x L10, L2 x L8, L2 x L3, L1 x L2 and L7 x L9 had the maximum standard heterosis for ear diameter over all checks. This indicates more prolificacy of the tested crosses over the standard checks. The hybrids which revealed positive standard heterosis for this trait is desirable, as the hybrids which had the highest grain yield were also revealed positive and significant standard heterosis for ear diameter, which indicates the positive relation between grain yield and ear diameter. This result are in consistence with (Uddin *et al.*, 2008 ; Mohammad *et al.,*2015) findings.

Among the forty five crosses thirty one hybrids exhibited positive significant standard heterosis and five hybrids revealed negative significant heterosis with heterotic effects varied from -4.6% for L4 x L5 to 27.8 % for L7 x L10 over check BH540 for ear length. In other hand magnitude of heterotic effect among forty five crosses ranged from -12.3% (L4 x L5) to 17.5 % (L7 x L10), -21.3 (L4 x L5) to 5.3% (L7 x L10) and 8.2% (L4 x L5) to 44.9% (L7 x L10) over standard checks BH543, BH546 and BH547 respectively (Table 3) for ear length. Among 45 crosses fourteen hybrids exhibited significant and positive heterosis and twenty four hybrids revealed negative and significant standard heterosis over BH543, only one hybrids 5.3% (L7 x L10) manifested positive and significant heterosis and forty two hybrids negative and significant heterosis over check BH546. The hybrid L7 x L10 which exhibited the maximum positive and significant standard heterosis which is predominantly due to additive type of gene effects, since both the line of the cross were revealed positive and significant GCA effect for ear length. The 100 % of tested hybrids manifested positive significance standard heterosis over check BH547. This indicates as tested hybrids vigorisity over this standard hybrid check and the cross revealed positive standard heterosis are desirable direction to increase grain yield. This result is supported by (Mohammad *et al.*, 2015). .

Number of rows per ear

Number of rows per cob is desirable selection character in breeding program, because it is one of the yield components. Magnitude of heterotic effect among the 45 hybrids varied from -3% for L1 x L8 to 29.6% for L6 x L9, -14% (L1 x L8) to 15.3% (L6 x L9), -13.6 % (L1 x L8) to 15.4% (L6 x L9) and -12.1% (L1 x L8) to 17.4 % (L6 x L9) over BH540, BH543, BH546 and BH547 respectively. In this study among forty five crosses forty one hybrids exhibited positive and significant standard heterosis and only one hybrid L1 x L7 revealed negative and significant heterosis over BH540. Twelve hybrids revealed positive and significant heterosis and twenty four hybrids showed negative and significant standard heterosis over both BH543 and BH546 checks (Table 4).

Among the 45 crosses fifteen hybrids exhibited positive significant heterosis and twenty hybrids showed negative significant heterosis over BH547. Hybrids L2 x L9, L7 x L9, L3 x L9, L4 x L9 and L6 x L9 showed maximum number rows per ear and they manifested higher grain yield than checks. The crosses those revealed positive standard heterosis are desirable to improve grain yield, while those revealed negative standard undesirable since they reduce grain yield per cob. This result is in lines with result reported by Ali *et al*. (2014) and Praveen *et al. (*2014) who revealed positive and negative standard heterosis for number of rows per cob.

Number of kernel rows per ear

In determination of grain yield, number of Kernels row per ear plays vital role. Among the forty five crosses thirty seven hybrids exhibited positive significant heterosis with a range varied from -2.7 for L1 x L8 to 29.9 for L6 x L9 over BH540. The extent of standard heterosis for this trait varied from -14 % (L1 x L8) to 15.3% (L6 x L9) over check BH543, -13.6% (L1 x L8) to 15.4% (L6 x L9) over BH546, with twelve positive significant hybrids and twenty one hybrids disclosed significant negative standard heterosis for number of kernels row per cob (Table 4). Out of 45 crosses fourteen hybrids exhibited positive significance and sixteen hybrids revealed negative standard heterosis with range -12.1 (L1 x L8) % to 17.4% (L6 x L9) over BH547. The highest positive significant heterotic effect manifested by hybrids L6 x L9, L3 x L9, L5 x L9, L4 x L7, L7 x L9 and L2 x L9 over four checks. This indicates prolificacy of the tested crosses when it is compared with these commercial checks. The crosses which revealed positive standard heterosis have significant effect to improve grain yield, while the negatives standard heterosis are undesirable as it decrease grain yield. Similar result also reported by Uddin *et al.* (2008) and Praveen *et al.*(2014) which revealed significant positive standard heterotic effect for number of kernel rows per cob.

Number of grain per row

Number of grains per row is an important yield component and is commonly used as a selection criterion in maize breeding programs because of its strong relation with grain yield. Magnitude of the heterotic response of the F_1 crosses varied from -11.3% to 19.8 %, -13.8 to 16.5%, -23% to 4.1% and -1.1% to 33.7% (for L4 x L5 and for L7 x L10 respectively) over BH540, BH543, BH546 and BH547, respectively, (Table 4) for number of grains per row. Among forty five crosses nineteen hybrids revealed positive and significant and four hybrids showed negative significant heterosis over BH540, ten hybrids exhibited positive and significant and six hybrids revealed negative and significant economic heterosis over BH543. Out of 45 crosses 86.6% exhibited negative significant heterosis and 93.3% exhibited positive significant economic heterosis over check BH546 and BH547, respectively. Positive standard heterosis is desirable for this trait, as it increase grain yield, while the negative is undesirable. Similar results have previously been reported by earlier researcher Ali *et al*. (2014) and Praveen *et al*. (2014).

3.3 Conclusion

The magnitude of standard heterosis ranged from -61.2 % (L5 x L6) to 59.4% (L7 x L9) over four standard checks for grain yield. Five hybrids 7.7% (L2 x L10), 8.9% (L6 x L7), 10.7% (L7 x L10), 11.1% (L2 x L9) and 15.6% (L7 x L9) manifested higher positive significant standard heterotic effect over best hybrid check for grain yield and they were recommended for further evaluation for grain yield in multi-location experiment to confirm their yield superiority and stability.

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