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Research Article

Standard heterosis of pipeline maize (*Zea mays L.*) hybrids for grain yield and yield related traits at Pawe, Northwestern Ethiopia

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The knowledge of gene action and heterosis also helps in identification of superior F_1 hybrids in order to use further in future breeding programs. The objective of this study was to estimate the amount of standard heterosis of the pipeline maize hybrids for grain yield and yield related traits. A total of eleven pipeline maize hybrids and two standard checks (BH546 and BH547) were evaluated using randomized complete block design with three replications during the 2015 main cropping season at Northwestern Ethiopia. Mean squares due to genotypes were highly significant ($P \leq 0.01$) for most grain yield and yield related traits indicating the existence of genetic variation among the evaluated genotypes. The standard heterosis ranged from -38.72 to 33.65%and the highest heterosis was recorded for CML395/CML202//CML464 cross. The observed highest heterosis for grain yield and related traits indicated the possibility of increasing yield by exploiting heterotic potential of maize genotypes. The information generated by this study could be useful for researchers who need to develop high yielding maize hybrids.

Key words: Maize, *Zea mays,* Grain yield, Heterosis, Hybrid

INTRODUCTION

Maize (*Zea mays* L.) is the third important cereal crop globally after wheat and rice (FAO, 2014). Maize is the most important cereal food crop in Sub-Saharan Africa, particularly in Eastern and Southern Africa. In these regions, about 30-70% of total caloric consumption was that of maize (Langyintuo *et al*., 2010).

Maize research in Ethiopia started in 1950's with the evaluation of introduced materials focusing mainly on grain yield, early maturity, decreased plant height, lower ear placement resistance to major biotic stresses (Benti 1992). Since then, the research system has developed and released a number of improved varieties with their accompanying agronomic practices and plant protection technologies for all maize growing agro-ecologies of the country (Berhanu, 2009).

Maize ranks second after *Teff* in area coverage and first in total production. The results of the year 2013/14, Meher season post-harvest crop production survey indicated that the national average yield of maize is about 3.25 t/ha (CSA, 2014), this is by far below the world's average yield which is about 5.55 t/ha (USDA, 2015).

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Heterosis is a major factor for yield increase in all breeding schemes except line breeding (Schnell, 1982). Shushay (2014) reported significant standard heterosis of crosses over the commercial checks for traits such as grain yield, plant height, ear height, ear length, ear diameter, number of kernel rows per ear, number of kernels per row, thousand kernel weight, and number of ears per plant. Grain yield of the crosses over the standard checks ranged from -32.16 to 13.20%. Similarly, Koppad (2007) reported significant heterosis over the standard checks in plant height, ear height, ear girth, number of kernels per row, number of kernel row per ear, hundred grain weight, shelling percentage and grain yield per hectare in his study on identification of superior parental combinations based on three way cross hybrid performance comprised of hybrids involving 28 parents along with four checks in maize.

Production and productivity of maize increases by use an appropriate agronomic practices and improved hybrid maize genotypes. The knowledge of gene action and hybrid vigor or heterosis also helps in identification of superior F_1 hybrids in order to use further in future breeding programs (Radhica *et al*., 2001). Gudeta (2007) reported both positive and negative heterosis over better parent heterosis ranging from -14.33% to 331.65% at Ambo, -33.39% to 183.69% at Haramaya and -23.5% to 412.9 % at Holeta for grain yield in line by tester crosses of highland maize materials. He also reported significant better parent heterosis for other agronomic traits such as plant and ear height, days to anthesis and silking, kernel rows per ear, kernels per row, 1000 kernel weights in each of the locations. Legesse *et al*. (2009) and Mossisa *et al*. (2009) also reported positive and negative standard heterosis over checks for mid altitude maize growing areas of Ethiopia. Such information is unavailable for maize under Pawe condition. Thus**,** the present study was conducted to determine the magnitude of standard heterosis for yield and yield related traits of pipeline maize hybrids.

MATERIALS AND METHODS

Description of Experimental Site

The experiment was conducted at Pawe Agricultural Research Center during 2015 main cropping season in North Western Ethiopia, Metekel Zone of Benshangul Gumuz Regional State. Pawe Agricultural Center is located 575 kilometers away from Addis Ababa with latitude of 11° 15′N and longitude of 36°05’E at the elevation of 1050 meters above sea level. The mean annual rainfall is 1148.40mm, and the mean minimum and maximum temperatures of the area are 17.06 and 31.47 °C, respectively. The soil is nitosol with a pH ranging from 5.3-6.

Experimental Materials

Eleven pipeline maize hybrids with two checks, namely BH546 and BH547 were used for the study. The description of the experimental pipeline hybrids are depicted in Table 1.

Design and Experimental Managements

The experiment was carried out in randomized complete block design (RCBD) with three replications during 2015/2016 main cropping season. Each plot comprised of 2 rows of 5.1 m long with the spacing of 0.75 m between rows and 0.30 m between plants. Two seeds were planted per hill and later thinned out to one plant per hill after seedlings established well. Phosphate fertilizers in the form of Diammonium Phosphate (DAP) at the recommended rate of 100 kg/ha was applied equally to all plots at the time of planting. Nitrogen was applied in a form of urea (150 kg/ha). Half (75 kg/ha urea) was applied at planting and the remaining half was applied at knee height stage. Weed control and other cultural practices were done as required.

Data Collection

Data on grain yield and other important agronomic traits were collected on plot and individual plant basis. For data individual plant basis, the average of five randomly sampled plants was used.

Data collected on plot basis

1. **Days to anthesis (DA):** The number of days from sowing up to the date when 50% of the plants started pollen shedding.
2. **Days to silking (DS):** The number of days from sowing to the date when 50% of the plants produced about 2-3cm long.
3. **Anthesis-silking interval (ASI)**: It was calculated as the difference between days to 50% silk and anthesis.
4. **Plant aspect (PA)**: It was recorded based on a scale of 1 to 5 where, 1 = best genotype (consider ear size, uniformity, disease infestation, husk cover) and 5 = poor genotype within each plot (Badu *et al*., 2011b).
5. **Days to physiological maturity (DM):** It was recorded as the number of days after sowing to when 50% of the plants in the plot form black layer at the point of attachment of the kernel with the cob.
6. **Stand count at harvest (SH):** It was recorded as the total number of plants at harvest from each experimental unit.
7. **Husk cover (HC):** It was recorded as on a scale of 1 to 5; where 1 = tightly covered husk extending beyond the ear tip and 5 = ear tips exposed.

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

9. Ear aspect (EA): Was recorded based on a scale of 1 to 5, where 1 = clean, uniform, large, and well filled ears and 5 = ears with undesirable features at time of harvesting from each plot.

10. Number of ears per plant (EPP): Was calculated as the total number of ears at harvest divided by total number of plants at harvest in that particular plot at harvest.

11. Thousand kernel weight (TKW): After shelling, random kernels from the bulk of shelled grain in each experimental unit was taken and thousand kernels were counted using a photoelectric seed counter and weighted in grams and then adjust to 12.5% grain moisture.

12. Above ground biomass yield (AGB): Plants from the experimental unit were harvested atphysiological maturity and weighed in kg after sun drying and converted to hectare basis.

13. Harvest index (HI): The harvest index was calculated by dividing the economic (grain) yield (kg/ha) by above ground biomass (kg/ha) and expressed in percentage (Donald, 1962).

14. Grain yield (GY): After harvest, the total weight of ears per plot was recorded and then adjusted to 12.5% moisture and converted to hectare basis.

Data collected on plant basis

1. Ear height (EH): The height from the ground level to the upper most ear- bearing node of five randomly taken plants from each experimental unit was measured in centimeters. The measurement was made two weeks after pollen shedding had ceased.

2. Plant height (PH): The height from the soil surface to the first tassel branch of five randomly taken plants from each experimental unit was measured in centimeters. Like ear height, this was also measured two weeks after pollen shedding had ceased from the same plant that EH measured.

3. Ear length (EL): Length of ears from the base to tip was measured in centimeters. Data recorded represents the average length of five randomly taken ears from each experimental unit.

4. Ear diameter (ED): This was measured at the mid- section along the ear length, as the average diameter of five randomly taken ears from each experimental plot in centimeters using caliper.

5. Number of kernel rows per ear (NKRE): This was recorded as the average number of kernels row per ear from the five randomly taken ears for ear length and ear diameter measurements.

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

Analysis of variance (ANOVA)

The data collected for all yield and yield-related traits were analyzed using PROC MIXED procedure in SAS computer software (SAS, 2002).

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 follows. BH-546 and BH-547 were used as standard check.

$$\mathrm{SH}\ (\%) = \frac{\mathrm{F1} - \mathrm{SV}}{\mathrm{sv}} \mathrm{X100}$$

F_1 = Mean value of a cross
SV = Mean value of standard check variety
Test of significance for percent heterosis was made using the t-test. The standard errors of the difference for heterosis and t-value were computed as follows (Saleh*et al*., 2002).

$$\mathrm{t(standardcross)} = \frac{\mathrm{F1} - \mathrm{SV}}{\mathrm{SE(d)}} \mathrm{X100}$$

SE (d) = $\pm$ (2Me/r) $^{1/2}$
Where, SE (d) = standard error of the difference
Me = error mean square
r = number of replications
The computed t value was tested against the t-value at degree of freedom for error.

RESULTS AND DISCUSSION

Analysis of Variance (ANOVA)

The analysis of variance revealed that mean squares due to genotypes were highly significant ($P \leq 0.01$) for grain yield, number of ears per plant, ear diameter, ear length, number of kernel rows per ear, number of kernels per row, thousand kernel weight and harvest index (Table 2).

Standard Heterosis

The estimates of standard heterosis over the best standard checks were computed for grain yield and yield related traits that showed significant differences among genotypes are presented in Table 3 and 4.

Table 1. List of experimental materials used in the study

Entry	Stock ID	Pedigree
1	BK172-6	CML395/CML202//ILOO'E-1-9-1-1-1-1-1
2	BK172-3	CML395/CML202//CML312
3	BK172-17	CML395/CML32
4	BK123-97	Kuleni-320-2-3-1-1-1/DE-78-Z-126-3-2-2-1 1(g)//CML312
5	BK123-91	DE-78-Z-126-3-2-2-1-1(p)/Gibe-1-91-1-1-1//CML395
6	BK172-4	CML395/CML202//CML464
7	BK158-14	ILOO'E1-9-1-1-1-1/124 -b(109)
8	BK160-15	CML543/CML56
9	BK155-26	BK002/BK003
10	BK156- 18	BK002/CML312
11	BK159-17	ILOO'E1-9-1-1-1-1/CML312
12	Check 1	BH546
13	Check 2	BH547

Table 2. Mean squares due to genotypes and errors for grain yield and yield related traits of maize pipeline hybrids evaluated at Pawe, 2015

Trait	Mean squares		
	Entry (df=12)	Replication (df=2)	Error (df=24)
Grain yield	9012605.00**	8380147.70	1373483.90
Days of anthesis	0.76ns	0.10	0.52
Days of silking	0.84ns	0.08	0.60
Anthesis-silking interval	0.13ns	0.03	0.16
Days of physiological maturity	3.03ns	0.41	2.08
Plant height	9.69ns	40.69	7.76
Ear height	248.76ns	232.79	134.31
Plant aspect	2.74ns	1.40	0.13
Ear aspect	0.09ns	0.08	0.05
Table 2. Cont.			
Husk cover	0.04ns	0.20	0.03
Number of ears per plant	0.03**	0.00	0.01
Ear diameter	1.31**	0.45	0.03
Ear length	2.76**	0.21	0.84
Number of kernel rows per ear	2.93**	1.69	0.59
Number of kernels per row	18.81**	0.42	2.90
Thousand kernels weight	1667.69**	155.43	397.32
Harvest index	61.56**	42.91	16.01

*and ** = Significance and highly significant, respectively, ns= non- significance

For grain yield, nine hybrids exhibited significant and negative standard heterosis over the best check BH546, while CML543/CML56 (8.62%) and kuleni-320-2-3-1-1-1/DZ-78-Z126 3-2-2-1 1(g)//CML312 (4.04%) showed significant and positive standard heterosis. Standard heterosis over BH546for this trait ranged from -38.72%

Table 3. Standard heterosis over BH546 for grain yield and related traits of maize hybrids evaluated at Pawe, 2015

Crosses	GY	EPP	ED	EL	NKRE	NKR	TKW	HI
CML395/CML202//ILOO'E-1-9-1-1-1-1-1	-26.55**	0.00	4.04**	-3.72**	6.28**	-9.86**	0.78	-4.78**
CML395/CML202//CML312	-25.27**	0.00	2.22*	-8.36**	3.58**	-8.84**	-3.42**	-5.41**
CML395/CML32	-25.08**	-7.83**	6.06**	-5.94**	3.58**	-15.24**	7.25**	-1.68
Kuleni-320-2-3-1-1-1/DE-78-Z-126-3-2-2-1 1(g)//CML312	4.04**	-1.74*	6.46**	-0.63	8.99**	-5.94**	-0.08	-7.75**
DE-78-Z-126-3-2-2-1-1(p)/Gibe-1-91-1-1-1//CML395	-8.17**	-3.48**	5.25**	-10.00**	-2.70**	-8.84**	21.26**	-25.28**
CML395/CML202//CML464	-16.28**	20.87**	-2.22*	-10.77**	-6.28**	-3.48**	1.4	-12.12**
ILOO'E1-9-1-1-1-1/124 –b(109)	-6.35**	-0.87	1.62	2.03*	-1.82*	-4.49**	6.54**	16.96**
CML543/CML56	8.62**	16.52**	2.02*	-7.25**	-7.23**	-4.92**	-1.72*	-7.43**
BK002/BK003	-7.51**	-6.09**	7.27**	-11.11**	8.11**	-7.97**	5.68**	2.67*
BK002/CML312	-6.92**	-5.22**	9.70**	-9.52**	13.51**	-11.76**	0.97	-7.98**
ILOO'E1-9-1-1-1-1/CML312	-38.72**	-6.09**	0.4	-11.93**	5.41**	-21.34**	-18.25**	-5.89**
SE(d)	**3.27**	**0.24**	**0.14**	**0.75**	**0.63**	**0.64**	**16.28**	**956.90**

*and ** = Significance and highly significant, respectively, ED= ear diameter, EL= ear length, EPP= number of ears per plant, GY = grain yield, HI= harvest index, NKR= number of kernels per row, NKRE = number of kernel rows per ear, TKW = thousand kernel weight.

Table 4. Standard heterosis over BH547 for grain yield and related traits of maize hybrids evaluated at Pawe, 2015

Crosses	GY	EPP	ED	EL	NKRE	NKR	TKW	HI
CML395/CML202//ILOO'E-1-9-1-1-1-1-1	-24.47**	10.58*	-5.85**	0.25	-5.64**	-2.52**	-12.61**	-5.42**
CML395/CML202//CML312	-23.16**	10.58**	-7.50**	-4.58**	-8.04**	-1.41	-16.26**	-6.04**
CML395/CML32	-22.96**	1.92*	-4.02**	-2.06*	-8.04**	-8.34**	-7.01**	-2.34*
Kuleni-320-2-3-1-1-1/DE-78-Z-126-3-2-2-1 1(g)//CML312	6.98**	8.65**	-3.66**	3.47**	-3.24**	1.72*	-13.36**	-8.36**
DE-78-Z-126-3-2-2-1-1(p)/Gibe-1-91-1-1-1//CML395	-5.57**	6.73**	-4.75**	-6.29**	-13.62**	-1.41	5.14**	-25.78**
CML395/CML202//CML464	-13.91**	33.65**	-11.52**	-7.09**	-16.80**	4.38**	-12.08**	-12.71**
ILOO'E1-9-1-1-1-1/124 –b(109)	-3.70**	9.62**	-8.04**	6.24**	-12.84**	3.30**	-7.62**	16.18**
CML543/CML56	11.69**	28.85**	-7.68**	-3.42**	-17.64**	2.83**	-14.79**	-8.05**
BK002/BK003	-4.89**	3.85**	-2.93**	-7.44**	-4.02**	-0.47	-8.37**	1.99*
BK002/CML312	-4.28**	4.81**	-0.73	-5.78**	0.78	-4.57**	-12.45**	-8.59**
ILOO'E1-9-1-1-1-1/CML312	-36.98**	3.85**	-9.14**	-8.30**	-6.42**	-14.93**	-29.12**	-6.52**
SE(d)	**3.27**	**0.24**	**0.14**	**0.75**	**0.63**	**0.64**	**16.28**	**956.90**

*and ** = Significance and highly significant, respectively, ED= ear diameter, EL= ear length, EPP= number of ears per plant, GY = grain yield, HI= harvest index, NKR= number of kernels per row, NKRE = number of kernel rows per ear, TKW = thousand kernel weight.

(ILOO'E1-9-1-1-1-1/CML312) to 8.62% (CML543/CML56). The highest negative standard heterosis was manifested by ILOOE1-9-1-1-1-1/CML312 (-38.72%) followed by CML395/CML202 //ILOOE-1-9-1-1-1-1-1 (-26.55%) over BH546. The range of standard heterosis for grain yield over BH547 was wide from -36.98% (ILOOE1-9-1-1-1-1/CML312) to 11.69% (CML543/CML56). Kuleni-320-2-3-1-1-1/DE-78-Z-126-3-2-2-11(g)//CML312 and CML543 /CML56 had significant positive heterosis over both checks for the trait (Table 3 and 4).Those hybrids perform better than the best standard variety could be become promising potential varieties of commercial importance and used in breeding programs for improving yield. In agreement with the current finding, the expression of grain yield heterosis above the standard check in maize has been reported by several investigators (Venugopal *et al.,* 2002; Saidaiah *et al.,* 2008; Amiruzzaman *et al.*, 2010; Wali *et al.*, 2010; Atnafua and Tnaro, 2013). Habtamu (2015) in his study on heterosis and combining ability for grain yield and yield component traits of maize also reported standard heterosis for grain yield ranging from -8.9% to 28.9%.

For number of ears per plant, standard heterosis among hybrids varied from -7.83 (CML395/CML32) to 20.87% (CML395/CML202//CML464) and 1.92 (CML395/CML32) to 33.65% (CML395/CML202// CML464) over BH546 and BH547, respectively. Two hybrids showed highly significant positive standard heterosis over the check BH546; while all hybrids manifested significantly higher positive standard heterosis over the check BH547. This result indicates prevalence of productive attribute among the hybrids over the standard check, BH547. Similarly positive and significant standard heterosis was also observed by Saleh *et al.* (2002), Koppad (2007) and Shushay (2014) for number of ears per plant.

For ear diameter, standard heterosis ranged from -2.22 (CML395/CML202//CML464) to 9.70% (BK002/CML312). Positive and significant standard heterosis manifested in ten hybrids, while CML395/CML202//CML464 showed negative and significant heterosis over BH546 (Table 3). Over BH547, all hybrids showed negative and significant heterosis ranging from -11.52 (CML395/CML202//CML464) to -0.73% (BK002/CML312) (Table 4).Amiruzzaman *et al.* (2010) reported significant positive and negative standard heterosis for ear diameter in maize.

In case of ear length, standard heterosis varied from -11.93 (ILOO'E1-9-1-1-1-1/CML312) to 2.02% (ILOO'E1-9-1-1-1-1/124 –b(109) over BH546. Although ten hybrids showed significance negative standard heterosis, (ILOO'E1-9-1-1-1-1/124 –b(109) with positive and significant standard heterosis was recorded (Table 4). The result of standard heterosis computed relative to BH547 showed that two crosses manifested positive and highly significant heterosis varying from -8.30 (ILOO'E1-9-1-1-1-1/CML312) to 6.24% (ILOO'E1-9-1-1-1-1/124 -b(109) (Table 4). Debnath (1992), Paul and Debnath (1999) and Amiruzzaman *et al.* (2010) reported significant positive and negative standard heterosis for ear length in maize.

Number of kernel rows per earis an important yield component. In this trait percent standard heterosis over BH546 varied from –7.23 (CML543/CML56) to 13.51% (BK002/CML312). Seven hybrids expressed highly significant positive standard heterosis over BH546 (Table 3). The standard heterosis computed for this trait over BH547 showed that only BK002/CML312 (0.78) showed positive and non significant standard heterosis while ten hybrids had negative and significant standard heterosis. The highest non- significant positive standard heterosis was manifested by (0.78%) over BH547. Gadad (2003), Amiruzzaman *et al.* (2010) and Shushay (2014)) also found similar heterosis effect for number of kernel rows per earin their study on combining ability and heterosis for yield and component characters in maize.

All hybrids displayed negative significance heterosis for number of kernels per row over BH546 that varied from -21.34 (ILOOEi-9-1-1-1-1/CML312) to-3.48% (CML395/CML202 //CML464). The percent of heterosis ranged from -14.93 (ILOOE1-9-1-1-1-1/CML312) to 4.38% (CML395/CML202//CML464) over BH547. Only four crosses, kuleni-320-2-3-1-1-1/DZ-78-Z-126-3-2-2-11(g)//CML312, CML543/CML56, ILOOE1-9-1-1-1-1/124–b(109) and CML395/202 //CML464 exhibited significant positive heterosis over BH547 (Table 4). In line with the current finding both positive and negative significant standard heterosis for number of kernels per ear also reported by Amiruzzaman *et al.* (2010).

Standard heterosis for thousand kernel weight ranged from -18.25 (ILOO'E1-9-1-1-1-1/CML312) to 21.26% (DE-78-Z-126-3-2-2-1-1(p)/Gibe-1-91-1-1-1//CML395) over BH546.Four hybrids exhibited significant heterosis in positive direction, while three hybrids showed negative and significant heterosis over BH546 (Table 3). Over BH547, only one hybrid showed positive and significant standard heterosis ranging from -29.12 (ILOO'E1-9-1-1-1-1/CML312) to 5.14% (DE-78-Z-126-3-2-2-1-1(p)/Gibe-1-91-1-1-1//CML395) (Table 4). This result is matching with the earlier findings by Saidaiah *et al.* (2008), Amiruzzaman *et al.* (2010) and Shushay (2014).

The range of standard heterosis for harvest index was wide from –25.28 (DE-78-Z-126-3-2-2-1-1(p)/Gibe-1-91-1-1-1//CML395) to 16.96% (ILOO'E1-9-1-1-1-1/124 -b (109)) and -25.78 (DE-78-Z-126-3-2-2-1-1(p)/Gibe-1-91-1-1-1//CML395) to 16.18% (ILOO'E1-9-1-1-1-1/124 -b (109)) over BH546 and BH547, respectively. BK002/BK003 and ILOO'E1-9-1-1-1-1/124 -b (109) showed positive significance standard heterosis over the standard checks of BH546 and BH547, whereas nine hybrids exhibited significant standard heterosis in negative direction over BH546 and BH547. Berhanu (2009) also reported positive and negative significant standard heterosis for harvest index in maize.

CONCLUSION

CML543/CML56 and Kuleni-320-2-3-1-1-1/DE-78-Z-126-3-2-2-1 1(g)//CML312 revealed higher positive significance standard heterosis for grain yield as compared to BH546 and BH547. So CML543/CML56 and Kuleni-320-2-3-1-1-1/DE-78-Z-126-3-2-21 1(g)//CML312 could be recommended for commercial utilization and used for future for the development of high yielding hybrids. In this study, the maximum positive and significance standard heterosis (33.65%) was observed for number of ears per plant, followed by thousand kernels weight (21.26%) and harvest index (16.96%) over both checks BH546 and BH547. It is observed from the crosses CML395/CML202//CML464, DE-78-Z-126-3-2-2-1-1(p)/Gibe-1-91-1-1-1//CML395 and ILOOE1-9-1-1-1-1/124-b(109), respectively. The existence of genetic variation for grain yield, and yield related traits give further direction for maize breeders especially those who are interested in heterosis breeding. However, further evaluation of these and other hybrids at more locations and over years is advisable to confirm the promising results observed in present study.

In general, it may be concluded that the information from this study could be valuable for researchers who intend to develop high yielding varieties of maize.

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