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Estimation of Heterosis of Elite Maize (Zea mays L.) Hybrids in 2014 at Bako, Ethiopia

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Abstract

Maize (Zea mays L.) is an important food crop in Ethiopia, but its productivity in farmers' fields throughout the country is generally low due to use of traditional low-yielding open-pollinated maize varieties and limitation of improved maize varieties. Exploitation of maize heterosis through the development of modern high yielding hybrids and synthetics has gradually replaced the low yielding maize populations at a faster rate in maize growing regions of the world. The tested 48 single cross hybrids were developed by crossing eight inbred lines as females along with six other inbredlines as males using design II mating schemes (l x t) in the year 2013. The hybrids along with standard checks were evaluated at Bako national maize research center during 2014 main season using 5 x 10 alpha lattice design with two replications. The objectives were to evaluate the heterotic performance of the elite maize hybrids with respect to yield and yield related traits. Line × tester analysis was used to estimate the combining ability for yield related traits. The Statistical Analysis Systems (SAS) was used to analyze the data. Data were recorded for grain yield and yield related traits. Analysis of variance revealed significant variation at ($p< 0.01$) for most of traits and at ($p<0.05$) for days to maturity, number of kernels per row among genotypes except number of ears per plant. The hybrids also showed significant variation except ears per plant and number of kernels per rows. L6 x T2 (13.2 t ha^{-1}), L4 x T2 (12.5 tha^{-1}) and L3 x T3 (10.9 t ha^{-1}) performed better for grain yield and higher heterosis for most traits studied. Besides, high positive heterosis for grain yield and its components was found for greater than twenty four of the studied hybrids. It can be concluded that for the heterotic hybrids further evaluation of these breeding materials at more locations and year, is advisable to confirm the promising results observed in the present study.

Key words: Grain yield, Heterosis, Maize

1: Introduction

Maize (*Zea mays L.*, 2n=20) is an important cereal crop belonging to the tribe *Maydeae*, of the grass family, *Poaceae*, Genus *Zea*, Species *mays* (Piperno and Flannery, 2001). Depend on report of IFAD (2002),(as cited Susan, 2011) agriculture is still the economic engine of most countries of Sub-Saharan Africa (SSA) contributing at least their 70 percent of employment, 40 percent of export earnings, 30 percent of Gross Domestic Product (GDP) and up to 30 percent of foreign exchange earnings. But , there is a wide gaps between potential and realized yields for several types of crops especially maize and rice (Licker *et al.,* 2010; Neuman *et al.,* 2010). The yield gap of maize is large in Africa varying from around 2.5 to over 12.5 tones ha^{-1} per harvest (Meijerinka *et al*., 2011).

According to the report of Environmental Teratology Information Center (E-TIC, 2012) low yields of maize in sub Saharan Africa can be attributed to a multiplicity of factors including: the use of low quality seeds, poor seed selection and limited use of new improved commercial varieties, and unsuitable crop husbandry practices such as late planting, poor weed management, insect pest and disease attacks (especially stem borers) and *striga* weed infestation. To achieve the growing need for maize in Africa, it is necessary to boost its productivity through reducing yield losses incurred by using low productive varieties as well as by various stress factors including diseases and insect pests (Dagne, 2008).

To improve maize productivity, measures have to be taken to reduce the yield gap that causes frequent deficits and severe food shortages. The only way to increase maize production is to increase yield per unit area using improved hybrid maize genotypes and application of appropriate agronomic practices. So, estimation of standard heterosis and development of superior hybrids over the existed varieties is important, since heterosis increased vigour, size, fruitfulness, speed of development, productivity, expression of hybrid vigour, resistance to disease and insect pests, or climatic rigors of any kind, manifested by crossbred organisms as compared with corresponding inbred and commercial variety Shull (1952). From the genetic point of view, heterosis is a result of intra-allelic (dominance and super dominance) and inter-allelic interaction (epistasis). Heterosis is successfully attained by crossing genetically divergent self-pollinated homozygous lines (inbred lines). Nonetheless, crossing any two lines does not necessarily cause heterosis, since lines can be genetically related. Due to this, it is needed to test combining abilities of the newly-created lines. Final assessment of the value of even most carefully selected inbred lines is performed based on their results in hybrid combinations.

Selection for heterosis and combining ability is mainly responsible for the retention of a huge productivity gap between inbred lines and hybrids (Fasoula and Tollenaar, 2005). In order to bridge this gap, Fasoula and Fasoula (2005) suggested that maize improvement should be focused on line productivity per se in combination with stability, so as to effectively exploit the additive genetic variation.
Hence, this study was proposed to: i) To estimate the heterotic performance of the f1 hybrids over the commercial variety.
ii) To select superior hybrids and go to production.

2. Materials and Methods

The experiment was carried out in 2014 main cropping season at Bako National Maize Research Center (BNMRC). Two sets of maize parents consisting of eight female and six male inbred lines were crossed using design II schemes (line by tester) at BNMRC to generate, 48 single cross hybrids. The crosses along with similarly maturing hybrid maize varieties of BH-546 and BH-547 as standard checks were evaluated, during 2014 main cropping season at Bako. The parental inbred lines used in the crosses were at S6 inbreeding generation stages (Table 1).They were selected based on intermediate maturity, synchronize flowering and *per se* performance for yield and agronomic traits.

The 48 F^1 single maize crosses along with two standard hybrid checks (BH-546 and BH-547) were planted at Bako using the experimental design of alpha lattice of 5 x 10 genotype arrangement (0, 1) (Patterson and Willianms, 1976) with two replications. Each entry was placed in a one-row plot of 5.1 m long at 75 cm and 30cm inter and intra-row spacing, respectively. Experimental plots with in replications were separated each other by 75cm, while the replications were separated by 1m apart. Two seeds per hill were sown at prescribed inter and intra-row spacing. Thinning was done after germination to a single healthy seedling to attain a final plant density of 53,332 plants ha^{-1}. Non-experimental lines were planted to minimize the edge border effects. For the plant basis yield related traits data, five competitive plants from the middle of each row was sampled and the yield and yield related traits were recorded for each entry.

Table 3. List of Parental Lines Used to Generate the Single cross Hybrids using line by Tester Mating Design at Bako, 2014

Code	Pedigree	Parental type	Kernel color	Sources of germplasm	Heterotic groups
L1	SZsyyna 99F2-7-2-1-1	Female/line	White	BNMRC	A
L2	ILO’ 003E-47-2-3-1-1	Female/line	White	BNMRC	A
L3	30H83-7-1-3-1-1-1-1	Female/line	White	BNMRC	A
L4	Gibe-1-20-2-2-1-1-1	Female/line	White	BNMRC	A
L5	POOL 9A -128-5-1-1-1-1	female/line	White	BNMRC	A
L6	Gibe-1-91-1-1-1-1	Female/line	White	BNMRC	A
L7	POOL 9A-4-4-1-1-1	female/line	White	BNMRC	A
L8	Kuleni320-2-3-1-1-2-1-1	Female/line	White	BNMRC	A
T1	30H83-5-1-1-1-1-1	Male/tester	White	BNMRC	B
T2	ILO'00E-1-9-1-1-1-1-1	Male/tester	White	BNMRC	B
T3	DE-78-Z-126-3-2-2-1-1-1(g)	Male/tester	White	BNMRC	B
T4	DE-78-Z-126-3-2-2-1-1-1(P)	Male/tester	White	BNMRC	B
T5	30H83-5-1-2-1-1-1-1-1	Male/tester	White	BNMRC	B
T6	GIBE-1-178-2-1-2-1	Male/tester	White	BNMRC	B
V1	BH-546	Check	White	BNMRC	
V2	BH-547	Check	White	BNMRC	

L= Line; Tester, V= Hybrid Variety; BNMRC = Bako National Maize research Center

2.2.1. Standard Heterosis

The estimates of heterosis over the best standard check were computed for grain yield and yield related traits that showed significant differences among genotypes. BH-546 and BH-547 were the best standard checks that are currently released three way hybrids and as it produced highest mean grain yield per hectare the single crosses.
Since parents were not included in this present trial, the standard heterosis in percent was calculated and

compared the magnitude of heterosis for the character that showed significant differences between hybrids following the method suggested by Falconer and Mackay (1996):

Standard Heterosis (%) = $\left[\frac{F1-SC}{SC}\right] * 100$

Where, F1= Mean value of the cross or f^1 hybrids

SC = Mean value of the standard check Varieties

Test of significance for heterosis was made using the t-test. The standard error of the difference for heterosis was calculated as follows:

SE (d) for SH = ± $(2MSE/r)^{1/2} = \sqrt{\frac{2MSE}{r}}$

Where, SE (d) is standard error of the difference, MSE is error mean square and r is 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) = $\sqrt{\frac{2MSE}{r}} * t$

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

3: RESULTS AND DISCUSSION

Analysis of variance for hybrids revealed that the mean sum of squares were highly significant for most of the traits except anthesis–silking interval, number of ears per plot, number of kernels per row and stand count at harvest (Table 2) indicating that the tested hybrids varied from each other.

Table 2.Line x Tester Analysis of Variance of 48 Hybrids for 17 Traits at Bako, 2014

SV	DF	AD	SD	ASI	MD	PH	EH	EL	ED	EP	EWt	NRE	NKR	GY	HKW
Crosses	47	9.9**	11.71*	1.92	16**	536.6**	325.4**	2.4**	0.02**	0.06	0.001**	2.68**	10.08**	4.89**	55.54**
L	7	14.38**	11.32**	7.44**	13.90	1450.2**	1528.5**	4.64**	0.32**	0.16**	0.004**	10.4**	7.96	20.6**	201.9**
T	5	51.32**	70.1**	3.12*	57.0**	2122.6**	333.3**	0.96	0.4**	0.08	0.001	3.04**	27.0**	5.5**	103.5**
L x T	35	3.12	3.45	0.64	10.50	127.30	83.58	2.2**	0.05**	0.04	0.0007	1.0*	8.08	1.66**	19.40
Error	47	2.49	2.40	1.21	7.50	102.20	57.18	0.85	0.02	0.05	0.0006	0.55	6.33	0.90	17.72

Key: GY=grain yield, EPP= ears per plant, TEPP = Total Ears per plot AD=days to anthesis, SD=days to silking, ASI=Anthesis –silking interval, MD= Days to Maturity, PH=plant height, EH=ear height, EL=ear length, ED=ear diameter, EWt= Ear weight, FWt= Field Weight, NRE=number of kernels rows per ear, NKR=number of kernels per row, SCH=Stand Count harvest , HKW=Hundred kernel weight.

4.6. Standard Heterosis (%)

4.6 .1 Magnitude of Heterosis over the two Checks

Standard heterosis (against the standard check hybrid variety) was estimated and tested according to (Singh and Singh, 1994). The outcomes of standard heterosis for different characters that had significant mean squares are presented in Table 2. Some findings suggested that the magnitude of heterosis differed from character to character depending on hybrid combination. For example, Latha *et al.* (2013) reported that in rice, the magnitude of heterosis varied from trait to trait and cross to cross and most of the cross combinations recorded significant heterosis for all the traits studied. For days to anthesis, ten hybrids exhibited negative standard heterosis and among those two hybrids (HN15 and HN16) significantly affect for the earliness of days to anthesis as compared with check of BH-546.While seventeen hybrids showed positive and significant, implied contributing to late in days to anthesis as compared BH-546. Heterotic performance of thirty eight hybrids over BH-547 showed negative in magnitude on with three top earlier HN15, HN16 and HN40 (-9.5, 9.5 and -7.4 %) respectively for desirable direction in this trait. On the other side only ten hybrids with two hybrids negative and highly significantly affect (HN35 and HN48) and proved earlier anthesis than BH-547. Significant negative heterosis was considered as desirable one for days to silking, percent standard heterosis for days to silking was also ranged from –9.3% (HN40) to 4.7% (HN35) and most crosses showed negative heterosis. Among these crosses, fifteen hybrids showed significant negative standard heterosis for days to silking over BH-546 and six hybrid had expressed significant positive standard heterosis over BH-546. With this, twenty one and one hybrids showed negative and positive significant over BH-547 respectively. The highest significant positive standard heterosis was manifested by HN 35 (4.7 %) followed by HN 31, 36 and 48 (4.1 %) over BH-546. The highest significant negative standard heterosis was manifested by HN 40 (-9.3 %) followed by HN 27, and 4 (-8.6 % & -8 %) over BH-547 standard checks (Table 2). Negative and significant standard heterosis is desirable direction as it indicates earlier anthesis of the crosses than the standard check and the reverse is true for the crosses with positive and significant standard heterosis. In line with the current finding, both positive and negative and significant level of heterosis for days to silking also reported by Pandey and Kumar (2001) and Amaregouda (2007).

In case of days to maturity, early maturity in maize is most desired for its adoption in semiarid tropics, owing to moisture limiting factor. Hence, negative heterosis is desired for this character. Then eighteen hybrids showed non significant positive standard heterosis for days to maturity over BH-546 and thirty hybrid had expressed non significant negative standard heterosis over BH-546 .With this, thirty six and sixteen hybrids showed positive and negative non significant over BH-547 respectively. The former 36 crosses enhance late flowering while the latter 16 enhance early flowering. The highest non significant positive standard heterosis was manifested by HN32 (2.8%) followed by HN 7 (2.2 %) over BH-546. The highest non significant negative standard heterosis was manifested by HN 4, 34 and 40 (-3.5 %) over BH-546 standard check. The highest non significant negative standard heterosis was manifested by HN 45 (-2.9 %) on BH-547 standard check. In these values with negative magnitude have desirable traits for days to maturity. Negative heterosis is desirable for days to 50% anthesis, silking and maturity as it makes the hybrid to mature earlier compared to their parents.

The cross combination L2 x T3, L3 x T3, L4 x T3, L4 x T4 and L5 x T3 revealed highest negative percentage of economic heterosis for plant height. In this trait decreasing in percentage of economic heterosis over BH-546 checks varied from–17.5 % (HN22) to 6.3% (HN17) out of which 33 of them expressed negative heterosis over BH-546 check. On the other hand heterosis over BH-547 ranged from –17.7 % (HN22) to 6.1% (HN17). More than 98% of the crosses showed negative heterosis over BH-547(Table 3). This implies that large number of crosses were shorter in plant height than BH-547, which is favorable trait for lodging resistance. This result is in agreement with the findings of Saleh *et al.* (2002).

The range of standard heterosis for ear height over two standard checks was wide from –31.8% (HN26) to 14.8% (HN6). Thirty eight and forty seven crosses showed negative heterosis over the standard checks of BH-546 and BH-547 respectively. Among 48 crosses eight and twenty five crosses showed significant negative standard heterosis over BH-546 and BH-547 respectively for ear height. Maximum percentage decrease in ear height was displayed by the hybrid numbers or crosses of 26 and 27. Negative heterosis is favorable character for this trait as short statured hybrids are resistant to lodging and low cob bearing is desired in maize breeding. Similar results have previously been reported by earlier researchers (Saleh *et al.*, 2002; Gadad, 2003). Amanullah *et al.* (2011) and Agarwal (2000) also got highly significant differences among maize hybrids, while studying heterosis in maize crosses.

Analysis of variance showed highly significant ($P \leq 0.01$) differences among hybrids for ear length (Table 3). These results are in agreement with the work of Amanullah *et al.* (2011) who got similar results of significant differences among maize crosses for ear height, while studying heterosis in diallel crosses of maize. Ear length is an important yield component and its positive heterosis is useful in maize breeding program. Heterotic effects among 48 hybrids ranged from –15% (HN28) and 14.7% (HN23). Among the crosses, nine hybrids revealed significant positive standard heterosis over BH-546 and eleven hybrids divulged significant positive standard heterosis over BH-547. The largest magnitude of significant positive standard heterosis was manifested by HN 23 (13.4%) followed by entry (HN) 36, 40 and entry 20 (9.1 and 8.6%) over BH-546 respectively. The largest magnitude of significant positive standard heterosis was manifested by entry 23 (14.7%) followed by entry 36 and 40 (10.3%) over BH-547.Tang *et al.* (2010) also got similar results of positive heterosis for ear length in maize hybrids, while studying genetic basis of heterosis.

Number of Kernels row ear^{-1} plays vital role indetermination of grain yield. Its extent of standard heterosis also varied from -17.7 (HN40) to 16.5(HN48), with this nine and seven hybrids disclosed significant positive standard heterosis for number of kernels row per ear over BH-546 and BH-547 respectively. Most of the crosses showed negative heterosis over the commercial variety in undesired direction for this trait. HN48 (16.5%) recorded the highest positive standard heterosis followed by HN 45 (8.9%) and 47 (7.6%) over BH-546 and HN 48 (15%) also recorded with highest magnitude of positive standard heterosis over BH-547 , indicating increased in number of kernels row per ear for these crosses as compared to the standard check. The current finding confirms with the previous reported by Gadad (2003) who observed significant positive and negative standard heterosis for number of rows per ear. Amiruzzaman *et al.* (2010) also got similar heterotic effect for number of kernel rows $ear\text{-}^{1}$ while studying combining ability heterosis for yield and component characters in maize.

Analysis of variance regarding grain yield revealed highly significant ($P \leq 0.01$) variation among the crosses. Grain yield improvement is one of the most important aims of every plant breeder. Horner *et al.* (1676) reported that grain yield is the main selection criteria in maize. Percent heterotic effects among 48 testcrosses ranged from -39.6 (HN28) to 33.2% (36) and -42.5% (HN28) to 26.8% (NH36) over BH-546 and BH-547 respectively. Twenty four and seventeen hybrids disclosed significant positive standard heterosis over both checks of BH-546 and BB-547 respectively and hybrid entry 33, 36 and 42 had expressed higher magnitude of significant positive standard heterosis (21.8% for entry 33, 33.2 % for HN 36 and 26.1% for HN 42). HN 25, 26, 27and 28 had significant negative heterosis over both checks and lower grain yield than both checks. It can be concluded that, high positive heterosis for grain yield and its components was found for more than half of the hybrids studied. Hence, these results indicated that these crosses could be selected and used inbreeding programs for improving these traits. Positive heterosis is desirable as it indicates increased yield over the existing standard check. From commercial point of view, the superiority of new hybrids for yield can be judged by comparing their performance with the best cultivated hybrid/s or variety. So, in crop breeding, in the sense those hybrids perform better than the best standard variety could be of commercial importance. In agreement with the current finding, the expression of grain yield heterosis above the standard check in maize has been reported by several investigators (Amiruzzaman *et al.*, 2010; Wali *et al.*, 2010). Similar results of positive and significant heterosis were also observed by Saidaiah *et al.* (2008), while studying heterosis for yield and yield component character in maize.

Kernels weight is an important yield factor and is commonly used as a selection criterion in maize breeding programs because of its strong positive correlation with grain yield. Analysis of variance revealed highly significant ($P \leq 0.01$) differences for 100-kernels weight among hybrids (Table 3). Bajaj *et al.* (2007) also reported similar results of highly significant differences for 100-Kernels weight in high quality protein maize inbred lines. In this trait the economic heterosis percentage over both checks varied from –49.3% (HN44) to 68.8% (HN41). Maximum heterosis was recorded for HN41 (68.8%) over BH-546, HN 41(29.2%) over BH-547, while minimum heterosis was observed HN28 (-42.3%) over BH-546 and HN44 (-49.3%), respectively (Table 3). Out of total 33, 7 hybrids exhibited significant heterosis in positive direction, while 6, 32 hybrids showed negative and significant heterosis over BH-546 and BH-547 respectively (Table 3).This result is matching to the earlier findings by Abou-Deif (2007), Saidaiah *et al.* (2008) who also observed positive significant percent increase in maize crosses for 100-kernels weight.

Generally, a perusal of heterotic behaviour and magnitude of heterosis in the superior experimental hybrids revealed that heterosis for grain yield may be because of the fact that at least one parent involved in these crosses had desirable and significant gca effect suggesting besides genetic diversity GCA effect should also taken in to account for heterosis breeding. The present studies, therefore, suggested that the inbreds L2, L4, L6 and L8 were promising parents giving high heterosis for most of the traits has potential and being exploited in breeding programme may prove useful for improvement for yield and other component traits. The experimental hybrids HN6, HN8, HN10, HN32, HN33, HN37, HN42, HN45 and HN48 manifested heterotic effect for grain yield and other traits indicating such experimental hybrids may be used in yield improvement breeding programmes. According to Rahman *et al*. (2013), the promising crosses were identified as over all high general combiners and these could be utilized for development of either the synthetic varieties or an elite breeding population by allowing through the mixing among them to achieve new genetic recombination and then subjecting the resultant population to recurrent selection.

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Table 3. The nature and magnitude of standard heterosis for candidate hybrids relative to the two checks in 2014 at Bako

crosses		Traits	SD		MD		EL		NRE		TLB		GLS	
line	tester	Hybrid numbered	BH-546	BH-547	BH-546	BH-547	BH-546	BH-547	BH-546	BH-547	BH-546	BH-547	BH-546	BH-547
1	1	HN 1	2	0	1.9	3.2	-2.2*	-1.1	-5.1**	-6.3**	-22.2**	-22.2**	-14.3**	-45.5**
1	2	HN2	-0.7	-2.7	2.2	3.5	-4.3**	-3.3**	-5.1**	-6.3**	-33.3**	-33.3**	14.3**	-27.3**
1	3	HN3	-5.4**	-7.3**	-1.9	-0.6	0	1.1	-3.8**	-5.0**	-11.1**	-11.1**	28.6**	-18.2**
1	4	HN4	-6.1**	-8.0**	-3.5	-2.2	0.5	1.6	-6.3**	-7.5**	0.0	0.0	42.9**	-9.1**
1	5	HN 5	-3.4*	-5.3**	-2.5	-1.3	4.3**	5.4**	-2.5**	-3.8**	-11.1**	-11.1**	28.6**	-18.2**
1	6	HN 6	1.4	-0.7	-2.2	-1	-5.9**	-4.9**	0	-1.3	22.2**	22.2**	28.6	-18.2**
2	1	HN 7	-1.4	-3.3*	2.2	3.5	3.8**	4.9**	-15.2**	-16.3**	-33.3**	-33.3**	-14.3**	-45.5**
2	2	HN 8	-1.4	-3.3*	0.9	2.2	-0.5	0.5	-6.3**	-7.5**	-22.2**	-22.2**	-14.3**	-45.5**
2	3	HN 9	-5.4**	-7.3**	0.3	1.6	-5.9**	-4.9**	-6.3**	-7.5**	-11.1**	-11.1**	0.0	-36.4**
2	4	HN 10	-2.7	-4.6**	-1.6	-0.3	-1.6	-0.5	-11.4**	-12.5**	-22.2**	-22.2**	-14.3**	-45.5**
2	5	HN 11	0	-2	-0.6	0.6	-3.8**	-2.7**	-10.1**	-11.3**	-33.3**	-33.3**	0.0	-36.4**
2	6	HN 12	1.4	-0.7	0.6	1.9	-5.4**	-4.3**	-10.1**	-11.3**	-44.4**	-44.4**	-14.3**	-45.5**
3	1	HN 13	1.4	-0.7	1.3	2.6	-2.7**	-1.6	-6.3**	-7.5**	-22.2**	-22.2**	28.6**	-18.2**
3	2	HN 14	-2	-4.0*	-1.3	0	-5.9**	-4.9**	6.3**	5.0**	-11.1**	-11.1**	28.6**	-18.2**
3	3	HN 15	-5.4**	-7.3**	-2.8	-1.6	-6.5**	-5.4**	-6.3**	-7.5**	22.2**	22.2**	57.1**	0.0
3	4	HN 16	-4.7**	-6.6**	-1.9	-0.6	-5.4**	-4.3**	-8.9**	-10.0**	22.2**	22.2**	14.3**	-27.3**
3	5	HN 17	2.7	0.7	-0.6	0.6	-4.3**	-3.3**	0	-1.3	0.0	0.0	85.7**	18.2**
3	6	HN 18	1.4	-0.7	1.3	2.6	-3.2**	-2.2*	-12.7**	-13.8**	-33.3**	-33.3**	-14.3**	-45.5**
4	1	HN 19	2.7	0.7	-0.6	0.6	-0.5	0.5	-6.3**	-7.5**	-11.1	-11.1	14.3**	-27.3**
4	2	HN 20	1.4	-0.7	2.8	4.2	8.6**	9.8**	-17.1**	-18.1**	-33.3**	-33.3**	-14.3**	-45.5**
4	3	HN 21	-2	-4.0*	-0.6	0.6	-5.4**	-4.3**	-12.7**	-13.8**	0.0	0.0	14.3**	-27.3**
4	4	HN 22	-0.7	-2.7	2.2	3.5	-2.7**	-1.6	-16.5**	-17.5**	0.0	0.0	-14.3**	-45.5**
4	5	HN 23	2.7	0.7	-0.3	1	13.4**	14.7**	-12.7**	-13.8**	-22.2**	-22.2**	14.3**	-27.3**
4	6	HN 24	-0.7	-2.7	-0.6	0.6	-2.7**	-1.6	-12.7**	-13.8**	-11.1**	-11.1**	0.0	-36.4**
5	1	HN 25	-2.7	-4.6**	-0.6	0.6	-2.2*	-1.1	-5.1**	-6.3**	0.0	0.0	14.3**	-27.3**
5	2	HN 26	-0.7	-2.7	0	1.3	-14.0**	-13.0**	6.3**	5.0**	-22.2**	-22.2**	-14.3**	-45.5**
5	3	HN 27	-6.8**	-8.6**	-2.8	-1.6	-7.5**	-6.5**	-5.1**	-6.3**	0.0	0.0	14.3**	-27.3**
5	4	HN 28	-4.1*	-6.0**	-0.9	0.3	-15.1**	-14.1**	-10.1**	-11.3**	-11.1**	-11.1**	14.3**	-27.3**
5	5	HN 29	2	0	-0.3	1	-1.6*	-0.5	-2.5**	-3.8**	0.0	0.0	128.6**	45.5**
5	6	HN 30	-1.4	-3.3	-1.3	0	-7.5**	-6.5**	1.9*	0.6	11.1**	11.1**	14.3**	-27.3**
6	1	HN 31	4.1*	2	0.6	1.9	-4.8**	-3.8**	-11.4**	-12.5**	-11.1**	-11.1**	42.9**	-9.1**
6	2	HN 32	-0.7	-2.7	2.8	4.2	-5.9**	-4.9**	-7.6**	-8.8**	-11.1**	-11.1**	14.3**	-27.3**
6	3	HN 33	-3.4*	-5.3**	-1.3	0	-3.8**	-2.7**	0	-1.3	-22.2**	-22.2**	-14.3**	-45.5**
6	4	HN 34	-3.4*	-5.3**	-3.5	-2.2	2.7**	3.8**	-3.8**	-5.0**	-11.1**	-11.1**	14.3**	-27.3**
6	5	HN 35	4.7**	2.6*	-0.3	1	-9.7**	-8.7**	-5.1**	-6.3**	11.1**	11.1**	128.6**	45.5**
6	6	HN 36	4.1*	2	0.9	2.2	9.1**	10.3**	5.1**	3.8**	-33.3**	-33.3**	-28.6**	-54.5**
7	1	HN 37	1.4	-0.7	-2.5	-1.3	7.0**	8.2**	-5.1**	-6.3**	-33.3**	-33.3**	14.3**	-27.3**
7	2	HN 38	-1.4	-3.3*	1.3	2.6	1.6	2.7**	-3.8**	-5.0**	-33.3**	-33.3**	-14.3**	-45.5**
7	3	HN 39	-4.1*	-6.0**	-0.6	0.6	-1.1	0	-5.1**	-6.3**	0.0	0.0	14.3**	-27.3**
7	4	HN 40	-7.4**	-9.3**	-3.5	-2.2	9.1**	10.3**	-17.7**	-18.8**	11.1**	11.1**	42.9**	-9.1**
7	5	HN 41	-0.7	-2.7	-0.6	0.6	-3.8**	-2.7**	-8.9**	-10.0**	-11.1**	-11.1**	100.0**	27.3**
7	6	HN 42	-0.7	-2.7	1.3	2.6	1.1	2.2*	-1.3*	-2.5**	-11.1**	-11.1**	-14.3**	-45.5**
8	1	HN 43	4.1*	2	1.3	2.6	-8.6**	-7.6**	6.3**	5.0**	-11.1**	-11.1**	0.0	-36.4**
8	2	HN 44	3.4*	1.3	0.3	1.6	0	1.1	3.8**	2.5**	-22.2**	-22.2**	0.0	-36.4**
8	3	HN 45	-6.1**	-8.0**	-4.1	-2.9	-1.1	0	8.9**	7.5**	-33.3**	-33.3**	0.0	-36.4**
8	4	HN 46	-4.1*	-6.0**	-1.9	-0.6	5.4**	6.5**	-1.3*	-2.5**	-11.1**	-11.1**	0.0	-36.4**
8	5	HN 47	0.7	-1.3	-2.2	-1	-2.7**	-1.6*	7.6**	6.3**	-11.1**	-11.1**	57.1**	0.0
8	6	HN 48	4.1*	2	-1.9	-0.6	-13.4**	-12.5**	16.5	15	-22.2**	-22.2**	-14.3**	-45.5**
SEM ±			1.09		1.95		0.65		0.52		0.26		0.24	
CD 0.05			3.11		5.50		1.85		1.49		0.67		0.75	
CD 0.01			4.15		7.34		2.47		1.99		0.89		1.00	

Key: HN 1= L1 x T2, HN2 = L x T2, HN3 = L1 X T3,HN4 = L1 X T4, HN5 = L1 x T5, HN6 = L1 x T6, HN7 = L2 x T1, HN8 = L2 X T2, HN9 = L2 x T3, HN10 =L2 x T4, HN11 = L2 x T5, HN12 = L2 x T6,HN13 = L3 x T1, HN14 = L3 x T2, HN15 = L3 x T3,HN 16= L3 x T4, HN17 = L3 x T5, HN18 = L3 xT6,HN19 = L4 xT1, HN20 =L4 x T2,HN21 = L4 x T3, HN22 = L4 x T4, HN23 = L4 x T5, HN24 = L4 x T6, HN25 = L5 x T1,HN26 = L5 x T2, HN27= L5 x T3, HN28= L5 xT4, HN29= L5 x T5, HN30=L5 x T6, HN31 = L6 x T1, HN32 = L6 x T2, HN33= L6 xT3, HN34 = L6 x T4, HN34= L6 x T5, HN35 = L6 x T6, HN37=L7 x T1, HN38 =L7 x T2, HN39 = L7 x T3, HN40 =L7 x T4, HN41= L7 x T5, HN42 = L7 x T6, HN43 = L8 x T1, HN44= L8 x T2, HN45 = L8 x T3, HN46= L8 x T4, HN47 = L8 x T5, HN48 = L8 x T6.

Cont'd to table 2

Crosses		Traits	PH		EH		EWt		GY		HKW	
Line	tester	Hybrid numbered	BH-546	BH-547	BH-546	BH-547	BH-546	BH-547	BH-546	BH-547	BH-546	BH-547
1	1	HN 1	5.8	5.6	3.2	-6.4	-11.1**	-30.4**	6.2**	1.1	11.0*	-15.0**
1	2	HN2	3.1	2.9	2	-7.5	0	-21.7**	-3.5	-8.2**	24.7**	-4.5
1	3	HN3	0	-0.2	7.6	-2.4	5.6**	-17.4**	10**	4.7**	26.1**	-3.5
1	4	HN4	-1.4	-1.6	-0.5	-9.8	2.8**	-19.6**	10.6**	5.2**	27.5**	-2.4
1	5	HN 5	5.1	4.9	3.9	-5.8	16.7**	-8.7**	9.6**	4.4**	66.5**	27.5**
1	6	HN 6	6	5.8	14.8	4	2.8**	-19.6**	7.4**	2.2*	18.3**	-9.4**
2	1	HN 7	-3.5	-3.7	-17.0*	-24.8**	13.9**	-10.9**	-5.8**	-10.3**	38.3**	5.9
2	2	HN 8	0.3	0.1	-12.9	-21.0**	0	-21.7**	14.1**	8.6**	15.3**	-11.7**
2	3	HN 9	-11.5	-11.7	-18.9*	-26.5**	11.1**	-13.0**	-4.3**	-8.9**	43.9**	10.1**
2	4	HN 10	-8.2	-8.3	-17.3*	-25.1**	2.8**	-19.6**	8.6**	3.4**	17.8**	-9.8
2	5	HN 11	1.6	1.4	-5.9	-14.7	2.8**	-19.6**	-7.5**	-11.9**	47.6**	13.0**
2	6	HN 12	-2.6	-2.8	-5.5	-14.4	-8.3**	-28.3**	19.3**	13.6**	31.4**	0.6
3	1	HN 13	-3.3	-3.5	-5.2	-14.1	5.6**	-17.4**	-12.7**	-16.9**	32.0**	1
3	2	HN 14	-3.3	-3.4	-8.8	-17.3*	11.1**	-13.0**	5.7**	0.6	17.2**	-10.2*
3	3	HN 15	-14.6	-14.7	-16.3*	-24.2**	-13.9**	-32.6**	-21.7**	-25.4**	-18.9**	-37.9**
3	4	HN 16	-6.1	-6.3	-14.3	-22.3**	0	-21.7**	-9.2**	-13.6**	20.2**	-7.9
3	5	HN 17	6.3	6.1	-2.8	-11.9	11.1**	-13.0**	5.5**	0.4	38.4**	5.9
3	6	HN 18	-5.4	-5.6	-13.6	-21.7**	-8.3**	-28.3	-2.9**	-7.5**	6.6	-18.4**
4	1	HN 19	-2.4	-2.6	-10	-18.4*	-5.6**	-26.1**	-6.6	-11.1**	10.3*	-15.5**
4	2	HN 20	-7.5	-7.7	-10.9	-19.3*	-2.8**	-23.9**	-6.0**	-10.5	0.8	-22.8**
4	3	HN 21	-14.7	-14.9	-13	-21.1**	-8.3**	-28.3**	-19.8**	-23.7**	7.6	-17.6**
4	4	HN 22	-17.5	-17.7	-22.4**	-29.7**	-16.7**	-34.8**	-18.5**	-22.4**	2.4	-21.6**
4	5	HN 23	-3.8	-4	-13	-21.1**	11.1**	-13.0**	2.1*	-2.8**	22.9**	-5.9
4	6	HN 24	-5.3	-5.4	-8.6	-17.1*	-16.7**	-34.8**	7.6**	2.5*	5.3	-19.4**
5	1	HN 25	-5.8	-6	-12.3	-20.5**	0	-21.7**	-26.9**	-30.4**	5.9	-18.9**
5	2	HN 26	-9.8	-10	-24.8**	-31.8**	-8.3**	-28.3**	-36.8**	-39.9**	2	-21.9**
5	3	HN 27	-12.8	-13	-23.8**	-30.9**	8.3**	-15.2**	-28.7**	-32.2**	9.2*	-16.4**
5	4	HN 28	-8.9	-9.1	-21.3**	-28.7**	-19.4**	-37.0**	-39.6**	-42.5**	-9.4*	-30.7**
5	5	HN 29	-1.6	-1.8	-10.9	-19.3*	19.4**	-6.5**	-15.7**	-19.8**	57.1**	20.3**
5	6	HN 30	-6.7	-6.8	-14.3	-22.3**	-13.9**	-32.6**	-18.7**	-22.6**	2	-21.9**
6	1	HN 31	-5	-5.1	-3.3	-12.4	11.1**	-13.0**	-1.2	-6.0**	24.0**	-5.1
6	2	HN 32	-4	-4.2	-4.8	-13.7	5.6**	-17.4**	18.6**	12.9**	22.7**	-6.1
6	3	HN 33	-7.1	-7.2	-0.5	-9.8	19.4**	-6.5**	21.8**	16**	24.6**	-4.6
6	4	HN 34	-4.7	-4.9	3.2	-6.4	11.1**	-13.0**	14.3**	8.8**	26.6**	-3.1
6	5	HN 35	5.3	5.1	2.9	-6.7	8.3**	-15.2**	0.6	-4.2**	9.1*	-16.4**
6	6	HN 36	0.7	0.5	7	-3.1	16.7**	-8.7**	33.2**	26.8**	13.2**	-13.4**
7	1	HN 37	4.2	4	-3.8	-12.8	22.2**	-4.3**	16.6**	11.0**	59.0**	21.8**
7	2	HN 38	0	-0.2	-11.3	-19.6*	44.4**	13.0**	13.9**	8.4**	37.3**	5.1*
7	3	HN 39	-7.5	-7.7	-9.6	-18.0*	16.7**	-8.7**	6.1**	1	29.9**	-0.5
7	4	HN 40	-5.4	-5.6	-11.3	-19.6*	19.4**	-6.5**	0.6	-4.3**	29.7**	-0.7
7	5	HN 41	4.6	4.4	-5.5	-14.4	13.9**	-10.9**	-4.8**	-9.4**	68.8**	29.2**
7	6	HN 42	1.4	1.2	-4.9	-13.8	25.0**	-2.2**	26.1**	20.0**	30.9**	0.2
8	1	HN 43	-2.5	-2.6	-7.9	-16.5	-16.7**	-34.8**	-9.8**	-14.1**	-13.1**	-33.5**
8	2	HN 44	-0.2	-0.4	-12.3	-20.5**	-22.2**	-39.1**	-3.6**	-8.3**	-33.8**	-49.3**
8	3	HN 45	-3.1	-3.3	-3.3	-12.4	8.3**	-15.2**	9.7**	4.5**	-15.1**	-35.0**
8	4	HN 46	0.9	0.7	-2.3	-11.4	2.8**	-19.6**	2.0*	-2.9**	5.8	-19.0**
8	5	HN 47	3.5	3.3	0.2	-9.2	0.0**	-21.7**	2.6**	-2.4*	-1.1	-24.3**
8	6	HN 48	-2.6	-2.7	-9.4	-17.9*	-22.2**	-39.1**	16.7**	11.1**	-27.1**	-44.2**
SEM			7.15		5.35		0.02		0.68		2.98	
CD0.05			20.32		15.20		0.04		1.91		8.46	
CD0.01			27.09		20.27		0.06		2.54		11.28	

*KEY: * and **=Significance difference at 0.05 and 0.01 levels of probability, HN= hybrid numbered, GY=grain yield, EPP = number ears per plant, AD=days to anthesis, SD=days to silking, ASI=anthesis –silking interval, MD= days to maturity, PH=plant height, EH=ear height, EL=ear length, ED=ear diameter, EWt= ear weight, NRE=number of rows per ear, NKR=number of kernels per row, HKW=hundred kernels weight*

4. Conclusion and Recommendations

4.1 Conclusions

The present study proposed knowledge of heterosis is essential to identify high yielding potential hybrids to improve maize production and productivity. Hence, Lines with greater SCA and standard heterosis used for hybrid development as well as to classify inbred lines into heterotic groups, while GCA could be used for synthetic cultivar development.

High amount of differences were observed among hybrids for most traits, which indicate the possibility of selection for improvement of yield and yield related traits. Since this exploration is a one year and one location trial, it is suggested to be evaluated in multilocation trial on large scale basis before their commercial cultivation of identified promising hybrids for grain yield and their stability over locations and seasons and then used for future breeding work and/or for release. But, even if it is a one year trial, L2, L3, L4, L6 and L8 showed desirable GCA effects for grain yield and yield contributing traits and performance *per se, then* recommended for use to develop high yielding synthetics that can be released as an open pollinated variety or population as well as in further breeding work for the development of superior hybrids.

From a practical and commercial point of view, standard heterosis is the most important than mid and high parent heterosis because it is aimed at developing desirable hybrids superior to the existing high yielding commercial varieties. So, for grain yield in ton per hectare, twenty six hybrids had significant positive standard heterosis relative to both check BH-546 and BH-547 and HN33, 36 and 42 are the three top high yielder hybrids with the heterotic magnitude of (21.8% for HN 33, 33.2 % for HN 36 and 26.1% for HN 42) and those hybrids used for future and additional effort is required for the development of high yielder hybrids.

4.2. Recommendations

The current study demonstrated;

- The existence of genetic variability for grain yield, and yield related traits and this give further direction for maize breeders especially those who are interested in heterosis breeding.
- Identified crosses with high positive heterotic performance for GY were: L2 x T2, L4 x T1, L4 x T2, L4 x T5, L6 x T2, L6 x T4, L6 x T3, L8 x T3, and L8 x T4.
- Generally further evaluation of these breeding materials at more locations, year and separate breeding program for earliness and yield is advisable to confirm the promising results observed in the present study.

Conflict of Interest

The author(s) have not declared any conflict of interests.

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