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Research Article

Heterosis of Highland Maize (*Zea mays* L) Hybrids for Grain Yield and Yield Related Components

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Abstract: The knowledge of gene action and heterosis also helps in identification of superior F1 hybrids in order to use further in future breeding programs. The objectives of this study was, therefore, to estimate heterosis and combining ability of maize inbred lines for yield and yield related traits. The analysis of variance showed there is highly significant variation between the hybrids for all the traits considerd. All crosses showed significant and positive heterotic effects over mid and better parents for grain yield. None of the crosses showed significant standard heterosis in desired direction. Mid-parent heterosis of day's maturity ranged from -5 to 13.9%, whereas that of better parent heterosis ranged from -5 to 105%. Indicating that the hybrids tend to be earlier in maturity than the parents. 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.

Keywords: Heterosis, yield, hybrids and gene.

INTRODUCTION

Maize is the third most important cereal crops widely grown throughout the world after wheat and rice. The world maize production area in 2017 was around 190.63 million hectares, and that of wheat and rice was 220 million and 162.31 million hectares, respectively [1]. Maize surpasses wheat and rice in terms of actual production. Worldwide maize production was around 1033.74 billion tons in 2017 - considerably more than wheat (~757.92 million tons) or rice (~488.6 million tons). In that year, the United States was the largest producer of maize with a production volume amounting to about 370.96 million metric tons. China and Brazil rounded off the top maize producing countries [1]. The share of Africa's maize production in 2017 was 58.21 million tons harvested from 23.71 million hectares.

Similarly, the demand for maize has been steadily growing in Ethiopia. It contributes to the greatest share of production and consumption along with other major cereal crops such as tef (*Eragrostis tef* (Zucc.) Trotter), wheat (*Triticum aestivum* L.) and sorghum (*Sorghum bicolor* L.) In 2016/17 main cropping season, cereals were cultivated on 10.3 million hectares, producing 25.38 million metric tons of grain [2]. This represents 81.27% of the total production area and 87.42% of grain production in the country. Among the cereal crops, maize ranks second to *tef* in area coverage and first in total production. The production of maize has been increasing over the years in the major maize producing regions of the Ethiopia. Recent reports of the Central Statistical Agency of Ethiopia showed that maize was produced on about 3.02 million hectares with total production of about 7.85 million tons in 2016/17 main cropping season. During the same year, an average national yield of 3.67 t ha^{-1} was recorded [2].

During the early stages of maize breeding in Ethiopia, the focus was the development of open pollinated varieties (OPVs) [3]. This was mainly due to the assumption that small-scale farmers did not have the skill required to manage hybrid maize [4], unavailability of improved germplasm locally for hybrid development, lack of experience in hybrid development and absence of seed producers. Later, the high yield realized on the state farms with hybrids imported from Kenya, Zimbabwe and Malawi in the early 1980s together with high yield potential recorded from some experimental hybrids in the research centers convinced the breeders to go for wide development and testing of maize hybrids locally. This led to a shift in the breeding strategy from development of only OPVs to development of both hybrids and OPVs in the early 1980s [5].

Currently, concentrated efforts are underway in the country by different maize research institutions to move more toward the use of hybrids varieties. To fulfill this aim, combining ability studies have prime importance in maize hybrid development since it provides information for the selection of parents and provides information on the nature and magnitude gene actions. With this aim in mind, this research was conducted with the objective to study heterosis and combining ability in maize (*Zea mays* L.) for yield and yield related traits.

MATERIALS AND METHODS

Planting Materials

The experiment was consisted of 48 testcrosses produced by crossing 24 inbred lines to two testers in line x tester mating design plus the parental lines and two standard checks (AMH851 and AMH853). The description of the lines is depicted in table 1. The Ambo Highland Maize Research Project introduced the inbred lines from CIMMYT-Zimbabwe in 2014.

Methods

The 48 F1 hybrids and the parental lines were tested in 2017 cropping seasons Kulumsa Agricultural research center in alpha-lattice design [18] and Randomized complete block design with two replication respectively in adjacent field. Each plot consisted of two rows with row length of 5.1m. Two Seeds were sown per hill and at 4-5 leaf stage thinned to one plant per hill. The distance between rows and between plants with in the row was maintained at 0.75m and 0.25m, respectively. At sowing, P2O5 at the rate of 46kg/ha in a form of DAP and 35 kg/ha of N in a form of urea was applied. At about booting stage, 35 kg/ha, N was also applied. All other field management practices including stalk borer and armyworm control were done as required. Data were collected on days to maturity, ear length, ear diameter, number of rows per ear, number of kernel rows per ear, 1000 kernel weight (g) and grain yield in t/ha. Before analysis of the data, both grain yield and 1000-kernel weight were adjusted to 12.5% moisture content.

STATISTICAL ANALYSIS

Analysis of variance was conducted with the PROC MIXED procedure in [4] considering genotypes as fixed effects and replications and blocks within replications as random.

Heterosis expressed as increase or decrease of F1 hybrid value over mid-parent (relative heterosis), better parent (heterobeltiosis) and over the best commercial check (standard heterosis) were calculated for each character using the following formulas suggested by Hayes *et al.* [6].

$$\left(\frac{F1 - MP}{MP}\right) \text{ x } 100 = \text{Heterosis over mid parent (relative heterosis)}$$

$$\left(\frac{F1 - BP}{BP}\right) \text{ x } 100 = \text{Heterosis over better parent (heterobeltiosis)}$$

$$\left(\frac{F1 - STV}{STV}\right) \text{ x } 100\text{Heterosis over check (standard heterosis)}$$

Where: F1= mean performance of F1, MP= mean mid-parental value= (P1+P2)/2, P1= mean performance of parent one, P2=mean performance of parent two, BP=mean performance of better parent, CC=mean performance of the best commercial check.

Table-1: The Pedigree and source of the lines and testers used in the study

Line code	Pedigree	Source
L1	(LPSC7-F96-1-2-1-1-B-B-B*/OFP9)-3-1-1-1-1-B-B-#	CIMMYT/AHMBP
L2	(LPSC7-F96-1-2-1-1-B-B-B*/OFP39)-6-1-1-1-1-B-B-#	CIMMYT/AHMBP
L3	(LPSC7-F71-1-2-1-2-B-B-B*/OFP1)-B-14-4-1-B-B-B-#	CIMMYT/AHMBP
L4	(LPSC7-F71-1-2-1-2-B-B-B*/OFP2)-B-1-3-1-B-B-B-#	CIMMYT/AHMBP
L5	(LPSC7-F71-1-2-1-2-B-B-B*/OFP3)-B-18-1-1-B-B-B-#	CIMMYT/AHMBP
L6	CML539-B-#	CIMMYT/AHMBP
L7	(CML539*/OFP9)-4-1-1-2-1-B-B-#	CIMMYT/AHMBP
L8	(CML539*/OFP27)-2-1-2-1-1-B-B-#	CIMMYT/AHMBP
L9	(CML539*/OFP14)-2-1-1-2-1-B-B-#	CIMMYT/AHMBP
L10	(CML539*/OFP14)-2-1-3-1-2-B-B-#	CIMMYT/AHMBP
L11	CML539*/OFP1)-B-6-1-1-B-B-B-#	CIMMYT/AHMBP

Line code	Pedigree	Source
L12	CML539*/OFP1)-B-11-2-1-B-B-B-#	CIMMYT/AHMBP
L13	(CML539*/OFP4)-B-12-1-1-B-B-B-#	CIMMYT/AHMBP
L14	CML442-#	CIMMYT/AHMBP
L15	(CML442*/OFP1)-B-14-4-2-B-B-B-#	CIMMYT/AHMBP
L16	(CML442*/OFP1)-B-18-2-2-B-B-B-#	CIMMYT/AHMBP
L17	(CML442*/OFP4)-B-4-1-2-B-B-B-#	CIMMYT/AHMBP
L18	(CML442*/OFP4)-B-17-3-2-B-B-B-#	CIMMYT/AHMBP
L19	(CML395*/OFP105)-1-2-3-1-2-B-B-#	CIMMYT/AHMBP
L20	(CML444*/OFP23)-6-3-1-1-2-B-B-#	CIMMYT/AHMBP
L21	([CML312/[TUXPSEQ]C1F2/P49-SR]F2-45-3-2-1-BB//INTA-F2-192-2-1-1-1-BBBB]-1-5-1-1-1-BBB-B-B-B*/OFP106)-1-2-2-2-2-B-B-#	CIMMYT/AHMBP
L23	(CML495*/OFP6)-B-3-3-3-B-B-#	CIMMYT/AHMBP
L24	(CML495*/OFP6)-B-27-1-1-B-#	CIMMYT/AHMBP
	TESTER	
T1	FS59	AMBO
T2	FS67	AMBO
	CHECKS	
1	KOLBA (AMH853)	AMBO
2	JIBAT (AMH 851)	AMBO

AHMBP = Ambo Highland Maize Breeding Program

RESULTS AND DISCUSSIONS

Effect of genotypes on the genetic variation of maize

The analysis of variance showed highly significant differences between the genotypes for grain yield, days to maturity and yield component traits indicating there is sufficient genetic variation among the tested genotypes. Several maize researchers also found statistically significant differences between the genotypes for grain yield and yield related traits in their study on heterosis and combining ability of maize [7-11].

Table-2: Line x tester analysis of variance for grain yield and yield related traits at Kulumsa in 2017

Source	d.f.	MD	EL(cm)	ED (cm)	KRPE	NKPR	TKW(g)	GYF t/ha
Rep	1	10.56 ^{ns}	0.10 ^{ns}	0.09 ^{ns}	1.17 ^{ns}	43.78*	111.3^{ns}	1.04^{ns}
Genotype	71	36.36**	25.37**	0.31**	1.97*	40.27**	16147.6**	28.49**
Hybrid	49	29.07*	3.76*	0.10**	1.52*	18.39*	4350.73**	2.24**
Cross	47	31.71*	3.73**	0.11**	1.70**	21.21**	4539.40**	2.30*
Parent	23	38.90*	6.06**	0.38**	1.60^{ns}	16.55**	908.23**	1.69**
GCAL	23	42.84**	4.80**	0.17**	2.02**	28.58**	5130.90**	2.22 ^{ns}
GCAT	1	117.04*	7.61*	0.02^{ns}	13.72**	1.26 ^{ns}	58641.3**	22.18**
SCALxT	23	16.87 ns	2.51*	0.06**	0.85 ^{ns}	14.71 ^{ns}	1595.6**	1.51ns
error		18.82	1.23	0.02	1.72	7.84	721.9	0.94

*, **, = Significant at 0.05 and 0.01, GYF=grain yield t ha^{-1}; MD=days to maturity (days), EL=ear length (cm), ED=ear diameter (cm); NRPE=number of rows per ear (#); NKPR= number of kernels per row (#); TKW= thousand kernel weight (g).

Heterosis for yield and yield related traits

Percent (%) mid-parent (MPH), better parent (BPH) and standard heterosis (STH) were computed for grain yield and related traits (table 4). STH was considered only for grail yield. Both mid-parent and better parent heterosis for days to maturity are negative for eight and twenty-seven crosses respectively. For this trait, mid-parent heterosis ranged from -5 to 13.9% and better parent heterosis -5 to 105%. This showed that hybrids tend to be earlier in maturity Compared to their parents. In this study, ear per plant, ear diameter, and number of rows per ear showed low/negligible level of heterosis (data not shown), whereas number of kernels per row and 1000 kernel weight produced relatively high and positive heterosis. Similar findings were reported by Zeleke [12], Kumar and Babu [13]. In their study on Combining ability and heterosis in maize for grain yield and yield components.

All crosses showed significant and positive heterotic effects over mid and better parent. The range of mid-parent and better parent for number of kernels per row was 21.4 to 68.4% , 13.6% to 57.4% respectively, whereas mid-parent, better parent for 1000 kernel weight was -101.1 to 47.4% ,-35.4 to 21.3% respectively (table 3). Kumar and Babu [13], in their study on Combining ability and heterosis in maize (Zea mays L.) for grain yield and yield components reported positive and significant heterosis for yield component traits. Rajesh *et al*. [14] and Talukder *et al*. [15] reported similar findings in their study on maize. Shushay [16] and Ziggiju [17], in their study on standard heterosis reported significant difference among genotypes for, number of kernels per row and thousand-kernel weight.

Heterosis for yield

Percent (%) mid-parent (MPH), better parent (BPH) and standard heterosis (STH) were computed for yield related traits (Table 3). All crosses showed significant and positive heterotic effects over mid and better parents for grain yield. None of the crosses showed significant standard heterosis in desired direction (Table 3). Mid parent heterosis for grain yield ranged from 156 to 384.2%, for best parent heterosis from 102.9 to 278% and for standard heterosis over the best check Kolba ranged from -42.2 to 7.1% (Table 3). Zeleke [12] in his study on heterosis and combining ability for grain yield and yield component traits of maize in Eastern Ethiopia reported similar result. Kumar and Babu [13], in their study on Combining ability and heterosis in maize for grain yield and yield components reported significant values for mid parent, best parent and standard heterosis in desired direction for grain yield.

Table-3: heterosis for grain yield and agronomic traits of crosses among 24 lines and 2 testers evaluated at Kulumsa, 2017

	Days to maturity		Kernels/row		TKW		Grain yield		
cross	MPH	HPH	MPH	HPH	MPH	HPH	MPH	HPH	STH
L1XT1	2.1**	1.8*	23.2**	13.6*	15.4**	-8.6**	231.0**	222.2**	-8.7
L1XT2	-1	-1.9*	48.0**	38.6**	21.8**	-4.4**	195.3**	186.6**	-18
L2XT1	2.3**	1.3	43.3**	35.9**	-0.4	-28.1**	282.4**	227.5**	-7.2
L2XT2	0.5	-2.0*	54.8**	49.3**	23.4**	-11.5**	219.9**	173.3**	-22
L3XT1	-2.0**	-3.8**	47.3**	37.3**	0.4	-24.6**	280.8**	209.4**	-12
L3XT2	-3.7**	-5.0**	31.0**	24.1**	12.8**	-15.9**	196.3**	140.1**	-31.6*
L4XT1	-1	-1.7*	49.9**	40.9**	-10.1**	-35.4**	281.9**	159.9**	-26.4*
L4XT2	-1.9**	-4.4**	58.9**	51.9**	11.7**	-20.2**	239.1**	130.4**	-34.3**
L5XT1	-0	-1.6*	45.5**	37.4**	5.5**	-5.6**	170.2**	156.7**	-19
L5XT2	-1	-1.7*	45.7**	39.9**	11.2**	-1.5**	180.0**	166.8**	-16
L6XT1	0.9	0.3	35.0**	33.7**	17.8**	-13.0**	250.5**	188.8**	-18
L6XT2	-1	-3.0**	34.2**	33.1**	24.6**	-8.6**	227.2**	168.9**	-23
L7XT1	0.8	-0.4	48.7**	43.9**	12.4**	-3.1**	175.7**	160.0**	-26.4*
L7XT2	0	-0.8	43.7**	41.5**	21.7**	4.1**	177.3**	160.7**	-25.7*
L8XT1	0.7	0.1	43.4**	40.3**	27.0**	-2.8**	223.2**	170.7**	-23
L8XT2	-1.4**	-1.9*	32.9**	27.8**	26.5**	-4.0**	244.0**	187.4**	-18
L9XT1	0.9	-0.1	51.0**	32.0**	9.6**	-19.3**	384.2**	231.8**	-6
L9XT2	1.9**	0.4	56.7**	39.1**	31.1**	-4.1**	371.3**	222.3**	-8.1
L10XT1	1.9**	-0.2	50.0**	31.2**	8.9**	-13.5**	250.0**	178.9**	-21
L10XT2	-0	-1	33.9**	18.8**	36.5**	7.6**	287.2**	207.8**	-12
L11XT1	2.8**	2.0*	24.0**	20.9**	16.8**	-8.1**	274.5**	169.0**	-24
L11XT2	-1	-2.2**	23.3**	18.2**	24.0**	-3.1**	325.7**	205.2**	-13
L12XT1	0.6	0	26.5**	22.8**	29. 4**	4.4**	207.4**	150.2**	-29.1*
L12XT2	1	0	23.4**	17.8**	29.5 **	3.6**	208.3**	150.4**	-28.6*
L13XT1	96.1**	2.2*	68.4**	44.7**	3.7**	-14.3**	276.9**	220.8**	-9.1
L13XT2	94.1**	-2.1**	58.0**	37.8**	9.0**	-10.7**	180.5**	138.2**	-32.1*
L14XT1	105.7**	3.9**	43.4**	41.7**	-9.5**	-17.1**	198.6**	186.6**	-19
L14XT2	97.1**	-0.8	22.8**	19.4**	24.3**	12.7**	204.5**	191.3**	-17
L15XT1	99.4**	0.5	51.4**	40.7**	5.3**	-16	198.8**	148.6**	-29.6*
L15XT2	94.3**	-2.2**	32.1**	20.8**	28.9**	1.5**	169.0**	123.2**	-36.4**
L16XT1	101.4**	1.4	41.5**	34.9**	-3.7**	-12.1**	257.5**	162.7**	-26
L16XT2	92.7**	-2.9**	55.6**	50.9**	11.0**	0.4	176.7**	102.9**	-42.2**
L17XT1	101.2**	1.3	33.2**	28.6**	6.1**	-17.2**	234.0**	178.4**	-21
L17XT2	95.5**	-1.6*	39.9**	32.9**	26.2**	-2.2**	193.4**	144.0**	-30.5*
L18XT1	102.1**	1.8*	47.5**	37.3**	3.3**	-27.8**	289.9**	206.7**	-13
L18XT2	95.1**	-1.8*	24.7**	14.3**	47.4**	2.4**	297.3**	211.9**	-11

	Days to maturity		Kernels/row		TKW		Grain yield		
cross	**MPH**	**HPH**	**MPH**	**HPH**	**MPH**	**HPH**	**MPH**	**HPH**	**STH**
L19XT1	99.9**	0.7	32.6**	29.1**	18.9**	11.0**	168.2**	167.1**	-24
L19XT2	97.5**	-0.5	28.2**	28.2**	31.2**	21.3**	156.0**	155.8**	-26.9*
L20XT1	105.1**	3.2**	55.1**	47.8**	12.7**	-13.0**	347.3**	278.0**	7.1
L20XT2	97.3**	-0.7	48.3**	43.7**	42.3**	9.0**	269.2**	211.2**	-11
L21XT1	100.9**	1.2	52.3**	43.6**	14.3**	-6.8**	250.8**	172.5**	-23
L21XT2	100.4**	0.9	32.3**	26.7**	27.2**	2.9**	278.9**	193.8**	-16
L22XT1	102.6**	2.0*	21.4**	17.7**	8.4**	-19.5**	297.2**	212.0**	-12
L22XT2	97.3**	-0.7	27.9**	22.0**	28.9**	-4.8**	261.4**	183.3**	-19
L23XT1	103.1**	2.2**	36.2**	33.9**	10.1**	-12.9**	253.7**	164.7**	-25
L23XT2	98.4**	-0.2	57.6**	57.4**	27.3**	-0.2	266.1**	173.5**	-22
L24XT1	102.4**	1.9*	27.1**	23.6**	23.9**	-5.1**	267.6**	203.3**	-14
L24XT2	92.2**	-3.3**	29.4**	23.8**	17.0**	-11.0**	249.6**	187.7**	-18
$CD_{(MP)0.05}$	5.5	6.29	5.1	5.9	45.7	53	1.95	2.25	2.25
$CD_{(MP)0.01}$	7.2	8.34	6.8	7.82	60.5	70	2.58	2.98	2.98

$CD_{(BP)}$ = Critical difference for heterosis over better parent; GY= grain yield (t ha^{-1}); MD= days to maturity (days); TKW= thousand kernel weight

CONCLUSION

Maize is the third most important cereal crops widely grown throughout the world after wheat and rice. The demand for maize has been steadily growing in Ethiopia. It contributes to the greatest share of production and consumption along with other major cereal crops. The objectives of this study was, therefore, to estimate heterosis and combining ability of maize inbred lines for yield and yield related traits. The experiment was consisted of 48 testcrosses produced by crossing 24 inbred lines to two testers in line x tester mating design plus the parental lines and two standard checks (AMH851 and AMH853). The analysis of variance showed highly significant differences between the genotypes for grain yield, days to maturity and yield component traits indicating there is sufficient genetic variation among the tested genotypes. Mid-parent heterosis of days to maturity ranged from -5 to 13.9% and better parent heterosis -5 to 105%. This showed that hybrids tend to be earlier in maturity Compared to their parents. All crosses showed significant and positive heterotic effects over mid and better parents for grain yield. None of the crosses showed significant standard heterosis in desired direction.

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