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Standard Heterosis of Maize (*Zea mays* L.) Inbred Lines for Grain Yield and Yield Related Traits at Southern Ethiopia, Hawassa

[1]Natol Bakala Hundera, [2]Birahanu Abate and [3]Mandefro Nigussie

[1]Natol Bakala Hundera, Yabello Pastoral and Dry Land Agricultural Research Center Ethiopia
[2]School of Plant and Horticultural Science, Hawassa University, Ethiopia
[3]Oxfam America Deputy Regional Director, P.O. Box 85 Ethiopia

Abstract: Maize (*Zea mays* L.) is an important cereal crop mostly used as staple food in the world. A field experiment was therefore conducted at Hawassa national maize research sub center site during 2015 cropping season for yield and yield related agronomic traits. A line x tester analysis involving 64 crosses generated by crossing 32 elite maize inbred lines with two testers. The experiment was planted by using alpha-lattice design (6x11) with two replications. Sixty four hybrids with 2 checks were tested to estimate standard heterosis for yield and yield related traits. Analysis of variance (ANOVA) showed that, there were significant difference among crosses in all traits except anthesis silking interval, ear position and ear per plant. The result of heterosis estimation showed considerable amount of positive and negative heterosis for all studied traits. The highest significant positive standard heterosis for grain yield was manifested by L31XT2 (102.33 and 97.73%) over BH-546 and BHQPY-545 respectively. Thus, hybrid L31XT2 was the best combination in mean grain yield and standard heterosis. Hybrids L31XT2, L8XT1 and L26XT1 had higher magnitude of heterosis check thus, these hybrids exploited for future use and additional effort is required for the development desirable maize variety.

Key words: Heterosis · Hybrid · Line x tester · Maize · Yield

INTRODUCTION

Maize (*Zea mays* L.) is a plant of the tribe *Maydeae* of the grass family *Poaceae*. Maize is cultivated globally leading total yield production of crop and third most important food crops after wheat and rice. It is a versatile crop grown over a range of agro climatic zones. The first three leading countries in production of maize in the world are United States, China and Brazil and they produce approximately 79% of total maize production per year of the world.

Maize is one of the most important crop and mostly grown into six agro-ecological zones based on altitude and annual rainfall in Ethiopia [1]. Major cereal crops grown in Ethiopia are Teff (*Eragrostis tef*), Maize (*Zea mays* L.), Wheat (*Triticum aestivum* L.) and Sorghum (*Sorghum bicolor* L.). Maize is second in area of production whereas it ranks first in total grain production, followed by teff, wheat and sorghum [2]. The popularity of maize in Ethiopia is partly because of its high value as a food, feed and source of fuel for rural families. Approximately 88% of maize produced in Ethiopia is consumed as food, both as green and dry grain.

Hybrid varieties are the first generations of (F1) from crosses between two pure lines, inbred lines, open pollinated varieties, clones, or other populations that are genetically dissimilar. The production and development of hybrid maize is one of the breakthroughs and greatest accomplishments of plant breeding. Breeding strategies based on selection of hybrids require expected level of heterosis. Heterosis is important in breeding program especially for cross pollinated crop and is a great achievement to meet the world's food needs [3]. Standard heterosis is estimated over standard commercial hybrid. The study of standard heterosis among maize germplasm is essential in maximizing the effectiveness of hybrid cultivars selection especially in cross pollinated crops. It has practical importance in plant breeding. It is also referred as useful or economic heterosis. Therefore, the present study is objected to estimate standard heterosis in maize hybrids for yield and yield related traits and to identify potential hybrid for future breeding schemes.

Corresponding Author: Natol Bakala Hundera, Yabello Pastoral and Dry Land Agricultural Research Center Ethiopia.

MATERIALS AND METHODS

Description of Study Area: The experiment was conducted at Hawassa Research center field in 2015 cropping season. Hawassa is situated at 7°4'N and 38°31'E latitude and longitude, respectively, at an altitude of $1700_{m.a.s.l}$. in the central rift valley of Ethiopia. The soil of the study area is characterized by well-drained sandy loam (46% sand, 28% silt and 26% clay), with pH of 7.1. It has 0.21% total nitrogen, 15.65 ppm phosphorus, 14.52 ppm iron and 20.30 meq/100g of calcium [4]. The total annual rainfall for the past 12 years ranges from 776 to 1145 mm (average 988.1 mm) with an average maximum and minimum air temperature of 26.6°C and 13.7°C, respectively [5].

The materials comprised of 32 inbred lines coded as L1, L2…L32 and two testers coded as T1 and T2. The inbred lines crossed with testers in line x tester mating design to generate 64 F1 hybrids at Bako National Maize Research Project (BNMRC) following procedure of [6]. The crosses were planted along with similarly maturing hybrid maize varieties as a check viz BHQPY-545 and BH-546 during 2015 main cropping season at Hawassa. The experiment was planted by using α-lattice design 6x11 genotype arrangement [7] with two replications. Each block comprises of 11 units having 5.1 meter long and 9.75 meter width with the spacing of 0.75 meter between rows and 0.30 meter between plants. All cultural practices like weeding and cultivation was done manually throughout the entire growing season as required. Data of 12 quantitative traits were collected *viz.,* days to 50% emergence, days to 50% anthesis, days to 50% silking, days to maturity, plant height, ear height, ear length, number of rows per ear, ear diameter and number of kernels per row, 1000 kernel weight and grain yield later converted to mean values.

Data Analysis: Collected data subjected to PROC MISED SAS computer software. The magnitude of heterosis was estimated in relation to standard checks for traits that showed significant differences following the method suggested by [8]:

$$\%SH = (F1 - SV)/SV \times 100 \quad (1)$$

Where,
F1 - Mean value of the cross
SV= Mean value of the standard variety
SH = standard heterosis.

The differences in the magnitude of heterosis tested following the procedure of [9]. T-test was used for significance test among crosses and checks. Standard error and critical difference were computed as:

$$SE(d) = (2MSe/r)^{1/2} \quad (2)$$

$$CD = SE(d) \times t \quad (3)$$

Where;
SE (d) is standard error of the difference.
MSe = error mean square from analysis of variance
r = the number of replication
CD =Critical difference
t= value of t at error degree of freedom.

The computed t-value was tested against the t-value at error degree of freedom corresponding to 5 or 1% level of significance.

RESULTS

Analysis of variance (ANOVA) showed that, mean squares of genotypes were significant ($P<0.05$) for all traits except anthesis silking interval, ear position and cob per plant (Table 1). Mean squares due to crosses were significant ($P<0.05$) for days to 50% anthesis, days to 50% silking, days to maturity, number of rows per ear, number of kernel per row, ear length, grain yield, thousand kernel weight, biological yield and harvest index.

The estimates of heterosis over the best standard check were computed for grain yield and yield related traits that showed significant differences among genotypes. Both standard checks used to estimate standard heterosis produce below mean grain yield per hectare. BHQPY-545 was relativity the best standard check in mean grain yield per hectare than BH-546. Significant amount of heterosis was observed for all the traits under study; however the magnitude varied with traits (Table 3).

From crosses evaluated none of hybrids showed significant negative standard heterosis over BHQPY-545 in days to anthesis but eight hybrids showed highly significant positive standard heterosis (Table 3). One cross showed significant negative standard heterosis over BH-546 while three crosses showed significant positive standard heterosis over BH-546 (Table 3). Three hybrids showed significant positive standard heterosis for days to maturity over both BH-546 and BHQPY-545.

Table 1: Mean squares for grain yield and yield related traits in 64 test crosses and 2 checks evaluated at Hawassa, 2015.

Source Variation	df.	DA (days)	DS (days)	DM (days)	ASI (days)	PH (cm)	EH (cm)	EP (no)	EL (cm)
Replication	1	1.09 ns	0.61ns	3.66 ns	0.27 ns	1.94	303.03*	0.018 ns	1.91ns
Incomplete block (blk/R)	5	9.10**	10.5**	14.8**	0.14 ns	813.9**	376.5**	0.004**	9.87**
Genotypes	65	6.05**	6.00**	14.96**	0.27 ns	442.11*	115.2**	0.001 ns	5.91**
Crosses	63	6.09*	6.01**	15.4**	0.27 ns	441.3 ns	115.5 ns	0.001 ns	5.67*
Error	60	3.12	2.73	3.82	0.27	290.34	73.43	0.001	3.01
CV (%)	-	2.931	2.803	2.005	23.628	9.44	9.43	7.09	12.53
		NRPC(no)	NCPR (no)	ED (cm)	TSW (g)	GY (t/ha)	CPP	BY (t/ha)	HI
Replication	1	0.02ns	17.89ns	0.03 ns	37.12 ns	0.69 ns	0.08 ns	1.08 ns	0.008 ns
Incomplete block (blk/R)	5	0.60 ns	9.81ns	0.17 ns	4687 ns	3.02*	0.04 ns	4.47**	0.017**
Genotypes	65	0.54*	13.52*	0.13**	4824**	2.94**	0.09	3.58**	0.011**
Crosses	63	0.54*	13.9*	0.13 ns	4579**	3.00**	0.10 ns	3.44**	0.011**
Error	60	0.32	8.55	0.09	50.0	1.5882.8	0.1	1.42	0.004
CV (%)	-	5.5	9.17	7.33	20.34	27.02	22.01	27.2	20.7

Note: DA=days to anthesis, DS=days to silking, DM=days to maturity, ASI=anthesis silking interval, PH=plant eight, EH=ear height, EP=ear position, EL=ear length, NRPC=number of row per cob, NCPR=number of kernel per cob, ED= ear diameter, TSW= thousand kernel weight, GY=grain yield, BY=biological yield, CPP=cob per plant, HI=harvest index. *and** significant at P<0.05 and P<0.01 respectively ns=non significance.

Table 2: Maximum, minimum and mean values of grain yield and yield related traits evaluated at Hawassa 2015.

Traits	Maximum	Minimum	Mean	Standard deviation	Standard error
DA (days)	78	71.50	74.67	2.19	0.191
DS (days)	80	73.50	76.84	2.15	0.187
DM (days)	166	149.5	155.86	3.13	0.27
ASI	3	0.12	2.17	0.51	0.05
PH (cm)	254	165	207.49	19.58	1.70
EH(cm)	134	95	110	10.37	0.90
EP	0.65	0.43	0.53	0.04	0.003
EL(cm)	21.50	12.50	17.30	2.17	0.19
NRPC	15.40	12.80	13.86	0.76	0.07
NKPR	43.10	30	36.38	3.34	0.29
ED(cm)	5.22	4.13	4.63	0.34	0.03
TKW	448	200	299.77	61.02	5.31
GY(ton/ha)	8.71	2.92	5.55	1.50	1.30
BY(ton/ha)	9.64	4.91	7.32	1.61	1.40
CPP	2.71	0.41	1.13	0.31	0.03
HI	0.58	0.21	0.43	0.08	0.01

Table 3: List of potential crosses identified based on grain yield crosses evaluated at Hawassa in 2015.

		Grain yield			Days to maturity		
	Crosses	ton/ha	Heterosis over BH QPY-545	Heterosis over BH-546	Days taken to mature	Heterosis over BH QPY-545	Heterosis over BH- 546
1	L31XT2	8.68	97.73**	102.33**	155	0.00	0.00
2	L8XT1	8.25	88.64**	93.02**	157.5	1.61	1.61
3	L26XT1	7.70	75.00**	79.07**	153.5	-0.97	-0.97
4	L23XT2	7.56	72.73**	76.74**	155.5	0.32	0.32
5	L12XT2	7.04	59.09*	62.79*	149.5	-3.55*	-3.55*
6	L16XT1	7.00	59.09*	62.79*	155.5	0.32	0.32
7	L23XT1	7.00	59.09*	62.79*	152	-1.94	-1.94
8	L21XT1	6.93	56.82*	60.47*	150.5	-2.90	-2.90
9	L21XT2	6.91	56.82*	60.47*	154.5	-0.32	-0.32
10	L8XT2	6.82	54.55*	58.14*	158	1.94	1.94
	Checks						
1	BHQPY-545	4.4			155		
2	BH-546	4.3			155		

Table 4: The magnitude of standard heterosis for 64 hybrids over BHQPY-545 and BH-546 for grain yield and related traits evaluated at Hawassa, 2015.

	DA		DS		DM		PH		EH		EL	
Crosses	BHQPY-545	BH-546	BHQPY-545	BH-546	BHQPY-545	BH-546	BHQPY-545	BH-546	BHQPY-545	BH-546	BHQPY-545	BH-546
L1xT1	6.90**	4.03*	6.71**	3.25	0.97	0.97	-7.93	-3.24	-6.67	0.00	-14.7	7.9
L1xT2	2.76	0.00	3.36	0.00	-0.32	-0.32	-14.5	-10.2	-16.6*	-10.7	-23.5**	-3.3
L2xT1	4.14*	1.34	4.70**	1.30	1.94	1.94	-27.3	-23.6	-20.8**	-15.2*	-29.9**	-11.3
L2xT2	0.69	-2.01	0.67	-2.60	2.26	2.26	-1.32	3.70	0.00	7.14	-16.3*	5.8
L3XT1	6.21**	3.36	7.38**	3.90*	0.97	0.97	-14.9	-10.6	-14.2*	-8.04	-18.8*	2.7
L3XT2	0.69	-2.01	0.67	-2.60	1.61	1.61	-14.1	-9.72	-9.17	-2.68	-22.2*	-1.58
L4XT1	-0.69	-3.36	0.00	-3.25	1.29	1.29	-7.93	-3.24	-5.83	0.89	-15.9	6.25
L4XT2	4.83*	2.01	4.70**	1.30	-0.97	-0.97	-11.5	-6.94	-10.00	-3.57	-15.9	6.3
L5XT1	1.38	-1.34	0.67	-2.60	-0.32	-0.32	-5.29	-0.46	-5.83	0.89	-21.0*	-0.12
L5XT2	1.38	-1.34	1.34	-1.95	1.29	1.29	8.37	13.89	0.83	8.04	-5.8	19.2*
L6XT1	5.52**	2.68	5.37**	1.95	2.58	2.58	-8.81	-4.17	-5.83	0.89	-25.7**	-6.1
L6XT2	6.90**	4.03*	6.71**	3.25	0.97	0.97	-15.9	-11.6	-17.5*	-11.6	-40.1**	-24.2**
L7XT1	2.07	-0.67	2.68	-0.65	0.00	0.00	-15.4	-11.1	-15.8*	-9.82	-22.8**	-2.37
L7XT2	6.21*	3.36	6.04**	2.60	0.97	0.97	-7.05	-2.31	-20.8**	-15.2**	-15.6	6.7
L8XT1	4.83**	2.01	5.37**	1.95	1.61	1.61	3.52	8.80	2.50	9.82	16.4*	18.3*
L8XT2	0.69	-2.01	0.67	-2.60	1.94	1.94	-6.17	-1.39	-5.83	0.89	-6.04	18.8*
L9XT1	3.45	0.67	3.36	0.00	2.26	2.26	-10.6	-6.02	-16.7*	-10.7**	-23.0**	-2.7
L9XT2	6.21**	3.36	5.37**	1.95	-0.32	-0.32	-16.7	-12.5	-5.83	0.89	-27.7**	-8.6
L10XT1	4.14*	1.34	4.70**	1.30	5.81**	5.81**	-11.0	-6.5	-9.17	-2.68	-16.6*	5.5
L10XT2	2.76	0.00	2.68	-0.65	-0.97	-0.97	-12.8	-8.3	-13.3	-7.14	-15.4	7.0
L11XT1	7.59**	4.70*	7.38**	3.90*	7.10**	7.10**	-15.4	-11.1	-17.5*	-11.6	-22.3**	-1.70
L11XT2	4.14*	1.34	4.03*	0.65	0.65	0.65	-18.5	-14.35	-15.0	-8.93	-32.6**	-14.7
L12XT1	2.76	0.00	2.68	-0.65	1.61	1.61	-0.88	4.17	-0.83	6.25	22.9**	20.1*
L12XT2	3.45	0.67	3.36*	0.00	-3.55	-3.55	-2.20	2.78	-2.50	4.46	-10.1	13.7
L13XT1	-1.38	-4.03*	-0.67	-3.90*	1.94	1.94	-12.33	-7.87	-9.17	-2.68	-20.1*	0.97
L13XT2	0.69	-2.01	0.67	-2.60	-1.94	-1.94	-5.29	-0.46	-5.00	1.79	-11.9	11.3
L14XT1	4.14*	1.34	4.70**	1.30	1.94	1.94	-1.32	3.70	-10.0	-3.57	-17.8*	4.0
L14XT2	6.21**	3.36	6.04**	2.60	1.29	1.29	-13.22	-8.80	-5.83	0.89	-30.1**	-11.6
L15XT1	-1.38	-4.03*	-0.67	-3.90*	-1.94	-1.94	-11.45	-6.94	-13.3	-7.14	-21.8**	-1.15
L15XT2	4.14*	1.34	5.37**	1.95	0.00	0.00	-3.08	1.85	-3.33	3.57	-15.3	7.2
L16XT1	0.00	-2.68	3.36*	0.00	0.32	0.32	-12.33	-7.87	-12.5	-6.25	-10.2	13.5
L16XT2	3.45	0.67	3.36*	0.00	-0.65	-0.65	-7.05	-2.31	-0.83	6.25	-18.0*	3.6
L17XT1	4.14*	1.34	4.70**	1.30	1.61	1.61	-3.52	1.39	-4.17	2.68	-6.0	18.9*
L17XT2	3.45	0.67	4.03*	0.65	0.65	0.65	-10.13	-5.56	-0.83	6.25	-17.3*	4.6
L18XT1	0.00	-2.68	0.67	-2.60	-1.94	-1.94	-6.61	-1.85	-7.50	-0.89	-15.4	6.9
L18XT2	0.00	-2.68	0.00	-3.25	2.26	2.26	-4.41	0.46	-10.0	-3.57	-16.8*	5.2
L19XT1	3.45	0.67	4.70**	1.30	0.65	0.65	-14.10	-9.72	-15.8	-9.82	-24.3**	-4.2
L19XT2	3.45	0.67	4.03*	0.65	0.32	0.32	-1.32	3.70	11.7	19.6*	-26.0**	-6.4
L20XT1	0.00	-2.68	0.00	-3.25	1.61	1.61	-6.17	-1.39	-8.33	-1.79	-11.9	11.3
L20XT2	5.52**	2.68	6.04**	2.60	0.00	0.00	-13.22	-8.80	-10.00	-3.57	-24.5**	-4.5
L21XT1	2.07	-0.67	2.01	-1.30	-2.90	-2.90	-10.13	-5.56	-7.50	-0.89	-11.8	11.6
L21XT2	1.38	-1.34	2.01	-1.30	-0.32	-0.32	-6.17	-1.39	-17.5*	-11.6	0.67	27.3*
L22XT1	4.14*	1.34	4.03*	0.65	0.00	0.00	-8.37	-3.70	-4.17	2.68	-6.5	18.3*
L22XT2	6.21**	3.36	5.37**	1.95	0.32	0.32	-11.01	-6.48	-4.17	2.68	-20.9*	-0.06
L23XT1	1.38	-1.34	0.67	-2.60	-1.94	-1.94	-2.64	2.31	-7.50	-0.89	-9.6	14.3
L23XT2	4.14*	1.34	4.03*	0.65	0.32	0.32	-5.29	-0.46	-8.33	-1.79	22.9	30.1**
L24XT1	-1.38	-4.03*	-0.67	-3.90*	-0.97	-0.97	-11.89	-7.41	-5.00	1.79	-21.9	-1.33
L24XT2	2.76	0.00	3.36*	0.00	1.61	1.61	-14.10	-9.72	-7.50	-0.89	-16.9*	5.1
L25XT1	2.76	0.00	3.36*	0.00	1.94	1.94	-12.33	-7.87	-11.7	-5.36	-26.2**	-6.7
L25XT2	3.45	0.67	3.36*	0.00	-0.65	-0.65	-8.81	-4.17	-8.33	-1.79	-10.6	13.1
L26XT1	1.38	-1.34	1.34	-1.95	-0.97	-0.97	5.73	11.11	-2.50	4.46	23.3**	22.3**
L26XT2	2.76	0.00	2.68	-0.65	1.94	1.94	-18.06	-13.89	-15.0	-8.93	-12.9	10.2
L27XT1	-0.69	-3.36	-0.67	-3.90	1.29	1.29	-5.29	-0.46	-9.17	-2.68	-19.7*	1.58
L27XT2	-1.38	-4.03*	-1.34	-4.55**	-2.90	-2.90	-13.66	-9.26	-13.3	-7.14	-17.6*	4.0
L28XT1	3.45	0.67	3.36*	0.00	-0.65	-0.65	-5.29	-0.46	-5.00	1.79	-7.2	17.3*
L28XT2	1.38	-1.34	1.34	-1.95	0.97	0.97	-9.25	-4.63	-10.8	-4.46	-22.1**	-1.46
L29XT1	2.76	0.00	3.36	0.00	-0.32	-0.32	-10.13	-5.56	-13.3	-7.14	-21.2*	-0.36
L29XT2	6.90**	4.03*	6.71**	3.25	0.32	0.32	-9.25	-4.63	-8.33	-1.79	-24.2**	-4.1
L30XT1	4.14*	1.34	4.03*	0.65	1.29	1.29	-12.33	-7.87	-19.2*	-13.4	-13.4	9.5
L30XT2	6.90**	4.03*	6.71**	3.25	0.32	0.32	-11.01	-6.48	-10.00	-3.57	-23.8**	-3.6
L31XT1	4.14*	1.34	4.03*	0.65	2.90	2.90	-8.37	-3.70	-10.00	-3.57	-17.3*	4.6
L31XT2	5.52**	2.68	5.37**	1.95	0.00	0.00	11.89	17.59	5.83	13.4	28.6	25.5
L32XT1	4.83**	2.01	4.70**	1.30	0.97	0.97	-17.18	-12.96	-1.67	5.36	-28.4**	-9.5
L32XT2	1.38	-1.34	1.34	-1.95	0.00	0.00	-9.69	-5.09	-11.7	-5.36	-13.4	9.5
SE(m±)	3.12		2.73		3.82		290.34		73.43		3.01	
CD 0.05	3.53		3.30		3.91		34.06		17.14		3.47	
CD 0.01	4.70		4.40		5.20		45.30		22.79		4.61	

Table 4: Continued

Crosses	NRPC		NCPR		TSW		GY		BY		HI	
	BHQPY-545	BH-546	BHQPY-545	BH-546	BHQPY-545	BH-546	BHQPY-545	BH-546	BHQPY-545	BH-546	BHQPY-545	BH-546
L1xT1	7.6	1.4	-5.12	-3.83	-25.3**	15.2**	29.5	32.6	-17.66	-20.93	16.00	7.41
L1xT2	16.7**	10.0*	-2.43	-1.09	-28.4**	10.5**	18.2	20.9	-14.15	-17.56	6.67	-1.23
L2xT1	0.00	-5.7	-10.2	-9.0	-27.7**	11.4**	2.3	4.7	0.74	-3.26	-13.33	-19.75
L2xT2	6.06	0.00	-3.23	-1.91	-25.3**	15.2**	-4.5	-2.3	-18.20	-21.45	-2.67	-9.88
L3XT1	6.06	0.00	1.35	2.73	-37.6**	-3.8*	18.2	20.9	-23.3*	-26.37*	13.33	4.94
L3XT2	7.6	1.4	-1.89	-0.55	-29.6**	8.6**	18.2	20.9	-22.49	-25.57*	22.67	13.58
L4XT1	5.3	-0.71	2.43	3.83	-27.2**	12.4**	27.3	30.2	-2.70	-6.57	1.33	-6.17
L4XT2	5.3	-0.71	4.31	5.74	-29.6**	8.6**	29.5	32.6	-28.17*	-31.02*	25.33	16.05
L5XT1	5.3	-0.71	-4.85	-3.55	-29.0**	9.5**	38.6	41.9	-41.7**	-44.1**	44.0**	33.33*
L5XT2	1.5	-4.3	-4.31	-3.01	-12.96	34.3**	38.6	41.9	-31.62*	-34.34*	32.0*	22.22
L6XT1	3.0	-2.9	-8.63	-7.38	-36.4**	-1.90	47.7	51.2	-2.41	-6.29	13.33	4.94
L6XT2	3.0	-2.9	-10.5	-9.29	-48.7**	-21.0**	-18.2	-16.3	-1.73	-5.64	-20.00	-25.93
L7XT1	-3.0	-8.6	-16.2**	-15.0**	-35.2**	0.00	0.0	2.3	-13.91	-17.33	-4.00	-11.11
L7XT2	10.6*	4.3	2.16	3.55	-27.8**	11.4**	29.5	32.6	-10.14	-13.71	9.33	1.23
L8XT1	9.1*	2.9	5.66	7.1	16.05*	16.1**	88.6**	93.0**	-12.05	-15.55	36.0*	25.93
L8XT2	6.1	10.0	0.81	2.19	-16.67	28.6**	54.5*	58.1*	-15.85	-19.19	25.33	16.05
L9XT1	12.9**	6.4	-7.01	-5.74	-24.1**	17.1**	25.0	27.9	-0.74	-4.68	2.67	-4.94
L9XT2	3.0	-2.9	-5.93	-4.64	-43.2**	-12.4**	-9.1	-7.0	-43.2**	-45.4**	16.00	7.41
L10XT1	9.1*	2.9	0.00	1.37	-35.8**	-0.95	0.0	2.3	-4.12	-7.93	-10.67	-17.28
L10XT2	6.1	0.00	1.08	2.46	-30.9**	6.7**	34.1	37.2	-34.2**	-36.9**	33.3*	23.46
L11XT1	1.5	-4.3	-4.58	-3.28	-18.5*	25.7**	34.1	37.2	-36.4**	-38.9**	34.7*	24.69
L11XT2	9.1*	2.9	-7.28	-6.01	-50.6**	-23.8**	-13.6	-11.6	-3.54	-7.38	-24.00	-29.63
L12XT1	6.1	0.00	-2.70	-1.37	-15.4*	30.5**	50.0	53.5*	-8.02	-11.68	17.33	8.64
L12XT2	5.3	-0.71	8.36	9.84	16.7*	28.6**	59.1**	62.8*	-28.72*	-31.6*	37.3**	27.16
L13XT1	10.6*	4.3	0.81	2.19	-22.2**	20.0**	50.0	53.5*	-40.2**	-42.6**	46.7**	35.8*
L13XT2	3.0	-2.9	-0.54	0.82	-5.56	45.7**	18.2	20.9	5.89	1.69	-6.67	-13.58
L14XT1	0.00	-5.7	1.35	2.73	-16.67*	28.6**	25.0	27.9	-21.80	-24.9*	14.67	6.17
L14XT2	5.3	-0.7	-10.5	-9.29	-47.5**	-19.1**	-15.9	-14.0	-24.5*	-27.5*	-2.67	-9.88
L15XT1	10.6*	4.3	-11.6*	-10.4*	-25.3**	15.24**	18.2	20.9	-31.5*	-34.2**	21.33	12.35
L15XT2	4.6	-1.4	5.12	6.56	-22.2**	20**	54.5*	58.1*	-26.19*	-29.13*	34.67*	24.69
L16XT1	4.6	-1.4	0.81	2.19	-11.73	36.2**	59.1*	62.8*	-23.27*	-26.32*	34.67*	24.69
L16XT2	5.3	-0.7	-2.16	-0.82	-37.7**	-3.8*	11.4	14.0	-21.05	-24.2*	13.33	4.94
L17XT1	10.6*	4.3	4.85	6.28	-8.64	41**	52.3*	55.8*	1.79	-2.26	10.67	2.47
L17XT2	5.3	-0.7	-7.82	-6.56	-31.5**	5.7**	-34.1	-32.6	-20.29	-23.5*	-20.00	-25.93
L18XT1	6.1	0.00	-5.39	-4.10	-25.93	14.3**	25.0	27.9	-39.5**	-41.9**	36.00*	25.93
L18XT2	9.1*	2.9	-12.7*	-11.5*	-16.05*	29.5**	40.9	44.2	-21.98	-25.1*	32.00*	22.22
L19XT1	5.3	-0.7	-8.4	-7.1	-33.95*	1.90	20.5	23.3	-16.67	-19.98	13.33	4.94
L19XT2	0.00	-5.7	-2.43	-1.09	-37.7**	-3.8*	25.0	27.9	-42**	-44.3**	34.67*	24.69
L20XT1	3.03	-2.9	2.70	4.10	-33.3**	2.86	31.8	34.9	-46**	-48.1**	46.67**	35.80*
L20XT2	5.3	-0.7	-2.43	-1.09	-43.8**	-13.3**	-11.4	-9.3	2.20	-1.87	-21.33	-27.16
L21XT1	9.1*	2.9	-2.70	-1.37	-9.26	40.0**	56.8*	60.5*	-40.4**	-42.8**	49.33**	38.27**
L21XT2	4.6	-1.4	4.04	5.46	-18.52*	25.7**	56.8*	60.5*	1.34	-2.69	14.67	6.17
L22XT1	3.0	-2.9	4.58	6.01	-14.20	32.4**	50.0	53.5**	-35.6**	-38.2**	41.33**	30.86*
L22XT2	1.5	-4.3	-8.89	-7.65	-41.98*	-10.5**	2.3	4.7	-31.7*	-34.4**	12.00	3.70
L23XT1	9.1*	2.9	-2.70	-1.37	-5.56	45.7**	59.1*	62.8*	-29.9*	-32.7*	41.33**	30.86*
L23XT2	1.5	-4.3	16.2**	17.8**	10.49	70.4**	72.7**	76.7**	1.75	-2.29	21.33	12.35
L24XT1	1.5	-4.3	-10.5	-9.3	-38.3**	-4.8**	22.7	25.6	-14.68	-18.07	0.00	-7.41
L24XT2	6.1	0.00	-2.16	-0.82	-28.4**	10.5**	52.3*	55.8*	-10.81	-14.35	14.67	6.17
L25XT1	1.5	-4.3	-19.1**	-18.0**	-20.9**	21.9**	-11.4	-9.3	-16.60	-19.92	-9.33	-16.05
L25XT2	-1.5	-7.1	3.77	5.19	-16.67*	28.6**	36.4	39.5	-12.11	-15.60	13.33	4.94
L26XT1	9.1*	2.9	8.89	10.4	6.79	43.8**	75.0**	79.1**	-14.15	-17.56	36.00*	25.93
L26XT2	3.03	-2.9	-6.47	-5.19	-25.3**	15.2**	-13.6	-11.6	-15.85	-19.19	-10.67	-17.28
L27XT1	6.1	0.00	7.28	8.74	-31.5**	5.7**	0.0	2.3	-26.4*	-29.34*	5.33	-2.47
L27XT2	7.6	1.43	14.6*	16.1**	-37.7**	-3.8*	25.0	27.9	-43.5**	-45.8**	37.33*	27.16
L28XT1	6.1	0.00	9.2	10.7	-27.2**	12.4**	40.9	44.2	-43.9**	-46.2**	45.33**	34.57*
L28XT2	14.4*	7.9	-7.55	-6.28	-31.5**	5.7**	13.6	16.3	-14.97	-18.35	9.33	1.23
L29XT1	5.3	-0.7	2.16	3.55	-33.9**	1.9	9.1	11.6	-1.07	-5.00	-12.00	-18.52
L29XT2	5.3	-0.7	-11.6*	-10.4	-30.9**	6.7**	2.3	4.7	2.35	-1.72	-12.00	-18.52
L30XT1	7.6	1.4	-2.16	-0.82	-22.2**	20.0**	52.3*	55.8*	-11.95	-15.45	21.33	12.35
L30XT2	1.5	-4.3	2.16	3.55	-36.4**	-1.90	11.4	14.0	-8.57	-12.20	-1.33	-8.64
L31XT1	-1.5	-7.1	2.70	4.10	-24.8**	16.2**	22.7	25.6	-30.1*	-32.9*	22.67	13.58
L31XT2	12.1*	5.7	8.09	9.56	-13.58	33.3**	97.7**	102.3**	-27.0*	-29.9*	50.67**	39.51**
L32XT1	1.5	-4.3	-13.8*	-12.6*	-40.7**	-8.6**	-22.7	-20.9	-37.6**	-40.1**	-2.67	-9.88
L32XT2	6.1	0.00	-5.66	-4.37	-21.6**	20.9**	6.8	9.3	-34.4**	-37.0**	16.00	7.41
SE(m±)	0.32		8.55		50.0		1.425		1.424		0.004	
CD 0.05	1.13		5.83		14.14		2.39		2.39		0.13	
CD 0.01	1.50		7.76		18.81		3.18		3.17		0.17	

Note: SE (m±) =standard error of a mean, CD =critical difference.

Plant Height: Negative heterosis for plant height is desirable for breeding short statured hybrids and which implying that these hybrids would mature earlier. Percent of standard heterosis over the two standard checks BHQPY-545 and BH-546 for plant height ranged from -27.3 to 11.89 cm and -23.6 to 17.59 cm, respectively.

Ear Height: Negative heterosis for ear height desirable implying that these hybrids could escape drought. Thirteen hybrids showed significant negative standard heterosis for ear height over BHQPY-545 and three hybrids showed significant negative standard heterosis for ear height over BH-546 while one hybrid showed significant positive standard heterosis for ear height over BH-546 (Table 4).

Ear Length: Thirty three hybrids showed significant negative standard heterosis for ear length over BHQPY-545 while none of them showed significant positive heterosis over BHQPY-545. Six crosses showed significant positive standard heterosis for ear height over BH-546 while only one hybrid showed significant positive standard heterosis for ear length over BH-546 (Table 4).

Number of Kernels Row per Cob: Analysis of variance in number of kernels row per cob showed significant (P=0.05) variation among the crosses (Table 1). Fourteen crosses showed significant positive standard heterosis for number of kernels row per cob over BHQPY545 while, none of the crosses showed significant negative standard heterosis. Only two crosses showed significant positive standard heterosis for number of kernel row per cob over BH-546 while none of the crosses showed significant negative standard heterosis. The highest significant positive standard heterosis for kernels row per cob was manifested by L1xT2 (16.7%) followed by L28XT2 (14.4%) (Table 4).

Number of Kernels per Row: Analysis of variance in number of kernels per row revealed significant (P=0.05) variation among the crosses (Table 1). Only two crosses showed significant positive standard heterosis for number of kernels per row over BHQPY-545 while six crosses showed significant negative standard heterosis. Two crosses showed significant positive standard heterosis for number of kernel per row over BH-546 while five crosses showed significant negative standard heterosis. The highest significant positive standard heterosis for number of kernel per row manifested by L23XT2 followed by L28XT2 (16.1%) (Table 4).

Thousand Kernel Weight: Analysis of variance for thousand kernel weight revealed highly significant (P=0.01) variation among the crosses (Table 1). Fifty one hybrids showed significant negative standard heterosis for thousand kernel weights over BHQPY-545 while two hybrids showed significant positive standard heterosis for thousand kernel weights over BHQPY-545 and forty nine hybrids showed significant positive standard heterosis for thousand kernel weights over BH-546 while ten hybrids showed significant negative standard heterosis for thousand kernel weights over BH-546 (Table 4).

Grain Yield: Analysis of variance with reference to grain yield revealed highly significant (P=0.01) variation among the crosses (Table 1). Percent heterosis over standard checks for grain yield was presented in Table 4. For grain yield fourteen hybrids showed significant positive standard heterosis over BHQPY-545 and seventeen hybrids showed significant positive standard heterosis over BH-546. None of hybrids showed significant negative standard heterosis over both BHQPY-545 and BH-546 (Table 4).

Potential Crosses for Future Use: From the current study, eleven potential crosses were identified either for release as hybrids or for further use in maize breeding program after further verification of the results. The yield potential of the crosses ranged from 6.82 to 8.68 ton/ha (Table 3). A cross with higher standard heterosis over standard checks was used for hybrid maize development. The first ten crosses L31XT2, L8XT1, L26XT1, L23XT2, L12XT2, L16XT1, L23XT1, L21XT1, L21XT2 and L8XT2 had high mean performance and standard heterosis over both checks for grain yield and other yield contributing traits like number of kernels per row, 1000 kernel weight, number of kernel rows per ear, ear diameter and ear length.

DISCUSSIONS

Analysis of variance showed significant difference among crosses. This indicates that crosses were sufficiently different from each other and selection is possible to identify the most desirable crosses. In line to these finding also different authors reported significant difference among crosses in yield and yield related traits in different parts of Ethiopia [10, 11, 12].

Percent heterosis over commercial checks was calculated for grain yield and twelve yield related traits (Table 4). Considerable amount of heterosis obtained for yield and yield related traits. [12, 13] observed the varying degree of heterosis for yield and its related traits in maize. Crosses showed heterosis in negative direction is considered to be desirable for days to 50 per cent tasseling, days to 50 per cent silking and days to maturity in developing early maturing varieties while for the crosses shown positive and significant standard heterosis the reverse is true. Earliness is a desirable character as it is useful in multiple cropping and increases water and land use efficiency. Negative standard heterosis is required for traits like plant height, disease and pest reaction, ear height and days to maturity. Crosses that showed negative days to anthesis, silking and days to maturity stands for earliness of the crosses while for crosses shown positive standard heterosis the reverse is true. The current finding is also similar with the findings of [12, 13]. But negative heterosis for plant height and ear height is desirable for breeding short statured hybrids and which implying that these hybrids would mature earlier. Cross L19XT2 (19.6%) had expressed the highest significant positive standard heterosis followed by cross L31XT2 (13.4%) in plant height. [14] also obtained similar results. The highest positive standard heterosis was manifested cross L23xT2 (30.1%) followed by cross L21XT2 (27.3%). These results were comparable with findings of [13, 14]. Number of kernel per row and thousand kernel weights is an important yield factor and is commonly used as selection criteria in maize breeding programs and positively correlate with grain yield. The highest significant positive standard heterosis for kernels row per cob was manifested by L1xT2 (16.7%) followed by L28XT2 (14.4%). [15] found a significant positive standard heterosis over the check. In contrast of current finding, [16] who observed significant posiive and negative standard heterosis for number of rows per cob.

Based on thousand kernel weight, crosses showed positive and negative standard heterosis. Most crosses showed significant standard heterosis over (BHQPY-545). But most crosses showed positive standard heterosis over BH-546. The highest significant positive standard heterosis for thousand kernel weight was manifested by L23XT2 (70.4%) followed by L13XT2 and L23XT1 (45.7%) over BH-546. [15] observed significant positive standard heterosis for thousand-grain weight. Grain yield improvement is one of the most important objectives in maize breeding program and is the main selection criteria in maize. Grain yield improvement is one of the most important objectives in maize breeding program. According to [12] grain yield is the main selection criteria in maize. Crosses showed both positive and negative heterosis in grain yield. The highest significant positive standard heterosis obtained by cross L31XT2 (102.33%) which is followed by cross L8XT1 (93.02%). Our results are also in line with findings of many earlier researchers [10, 12, 14, 15, 17, 18, 19].

CONCLUSIONS

Significant differences observed among crosses for yield and yield related traits indicate presence of genetic variability and high magnitude of standard heterosis over commercial check. In the current finding, considerable amount of heterosis was obtained over best standard check (BHQPY-545) from cross (L31XT2) 97.73% in grain yield. The same cross gives 102.33% yield advantage over BH-546. Top ten yield advantages crosses over both standard checks are L31XT2, L8XT1, L26XT1, L23XT2, L12XT2, L16XT1, L23XT1 and L21XT1in range of 54.55 to 102.33%. Among these ten crosses five of them have negative heterosis of days to maturity over both crosses and crosses L31XT2, L8XT1, L26XT1, L23XT2 and L12XT2 have positive ear length, number of kernel per row, number of rows per cob and thousand kernel weight over standard check. This result indicate that most of cross are earlier than commercial check. Positive standard heterosis is desirable for breeding long statured hybrids and varieties for grain yield. But negative standard heterosis is required for traits like plant height, disease and pest reaction, ear height and days to maturity. Among crosses, L31XT2 was the most prominent combination for grain yield. It is suggested to evaluate these hybrids in multi-environment for years on large scale for adaptation to wider agro-climatic conditions before their commercial cultivation.

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