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Appraisal of Heterosis for Yield and Yield Attributing Components in Maize (*Zea Mays* L.)

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ABSTRACT

Estimation of heterosis for yield and yield attributing components in maize was carried out involving 45 crosses developed by including 15 lines, 3 testers along with 3 checks and sown in a Randomized Block Design with three replications. The phenomenon of heterosis was of general occurrence for most of the characters under study. Crosses L_9 x T_1 and L_9 x T_2 elucidated desirable and significant heterosis both over mid parent and better parent. Line L_6, L_7 and tester T_1 proved out to be the best general combiner for maturity traits. Crosses, L_5 x T_3 and L_6 x T_2 were good specific combiner for maturity traits. Line L_6, L_2 and tester T_3 were good general combiners and among the crosses L_{10} x T_1 and L_5 x T_3 proved, the best specific combiners for plant height. The superior crosses and lines can be used in future breeding programmes to develop synthetic/hybrid varieties.

Key words : characterization, dominance, heterosis, maize, yield components.

INTRODUCTION

Maize is one of the important cereal crop in world agricultural economy as food (Morris *et al*., 1999) for humans, feed for animals and also a crop of industrial utilization (White and Johnson, 2003). It is also known as miracle crop. It has very high yield potential as compared to other cereals and, that is why referred to as ‘queen of cereals’. In India, it is grown in an area of about 8.17 mha with an overall production of 19.73 mt and productivity of 2415 kg / ha (Agriculture Annual Report, 2008-09). Among the major producing states in India, Andhra Pradesh ranks first; others are Rajasthan, Madhya Pradesh, Bihar, Uttar Pradesh, Karnataka and Gujarat.

Visual selection as well as that based on test-cross performance during inbreeding helps to eliminate many inbreds showing poor performance. Maize being a cross pollinated crop, is endowed with significant amounts of heterosis for grain yield and other agronomic traits. With the introduction of heterosis concepts in maize there has been a breakthrough in yield of this crop. Hence, it may be viewed that there is a wider scope for further improvement of yield through appropriate genetic manipulations.

One of the top priorities in breeding of this crop is to exploit the heterosis partially or fully by developing synthetics/composites or hybrids. The performance of hybrid depends on the genetic makeup of the parents used. The selection of parents is one of the crucial tasks. Further, certain cross combinations produce desirable off springs, whereas, other involving equally promising parents produce poor progeny

(Allard, 1960). Therefore, selection should be based on the sound consideration of combining ability of parents so that only the most desirable and high yielding cross combinations could be combed out from a large number of combinations.

MATERIAL AND METHODS

The present investigation was carried out during the *Rabi* season of 2008-2009 at Crop Research Centre of Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U. P., India. The parental material for present investigation comprised of 15 inbred lines, 3 testers and 3 checks. These were selected on the basis of wide diversity for different metric traits. The inbred lines were developed and maintained at the centre of AICMIP, B.H.U., Varanasi, whereas, testers for investigation *viz.*, CM-119 were collected from maize research stations at Hyderabad, HKI-1105 and HKI-323 from Karnal.

The experimental material consisted of 45 crosses made during *Kharif* 2008, involving 15 lines, 3 testers along with 3 checks sown in a Randomized Block Design with three replications in *Rabi* 2008-2009. Each genotype was planted in a single row plot of 4 m length having a uniform inter and intra row spacing of 60 cms and 20 cms respectively. Two seeds per hill was planted and later on one plant was thinned (if necessary) from each hill to maintain the optimum plant population. Border rows were planted to avoid border effect.

Prior to tasseling, five plants in each plot was randomly selected and tagged to record observations for height and yield traits. However, data on days to 50% tasseling, days to 50% silking and grain yield / plot was recorded on plot basis. The pre-harvest observations recorded were days to tasseling (50%), days to silking (50%), plant height (cm) and ear height (cm), and the post-harvest observations taken were ear length (cm), ear diameter (cm), number of kernels / row, number of kernel rows / ear, 100 kernel weight (g), grain yield / plant (g) and grain yield / plot (kg). The data was subjected to the estimation of heterosis over better parent and standard variety (Fonseca and Patterson, 1968).

RESULTS AND DISCUSSION

Heterosis is a complex biological phenomenon manifested in the superiority of hybrids over parents. The phenomenon of heterosis was of general occurrence for most of the characters under study. The detailed description and the mean performance of inbred lines and testers are presented in Tables 1 and 2 respectively.

In the present investigation, heterosis over mid parent (average heterosis), better parent (heterobeltiosis) and best check hybrid (standard heterosis) for all the characters have been estimated and presented in Table 3, 4 and 5 respectively.

The scope for exploitation of hybrid vigour is dependent upon the magnitude of heterosis, biological feasibility, genetic divergence and the type of gene action i.e. additive, dominance, additive x additive, dominance x dominance effect which are the components that determines heterosis.

The crosses L_9 x T_1 and L_9 x T_2 showed desirable and significant heterosis both over mid parent and better parent, crosses L_6 xT_2 and L_7 x T_1 showed heterosis over standard check for days to 50% tasseling & silking. Cross L_6 x T_2 exhibited negative and significant heterosis over standard check. For the trait ear length, crosses L_3 x T_2, L_{12} x T_2 exhibited heterosis over mid parent and better parent, whereas, standard heterosis was showed by L_5 x T_2 and L_2 x T_1 for the same.

Crosses L_2 x T_3 and L_1 x T_3 showed heterosis over mid parent and better parent and L_{14} x T_2, L_{10} x T_2 exhibited standard heterosis for ear diameter. For the trait number of rows / ear, L_{12} x T_3 and L_{12} x T_2 showed heterosis over better parent, mid parent and standard check, whereas, crosses L_{13} x T_3, L_{13} x T_2 showed mid parent, L_{10} x T_3, L_2 x T_3 showed heterobeltiosis and L_{12} x T_2, L_{10} x T_3 exhibited standard heterosis. Among the lines L_6 and tester T_1 showed lowest mean

Table 1. Description of Maize Genotypes involved in experiment

S. No.	Genotypes	Source/Pedigree	Duration	Plant Height	Kernel Type	Kernel colour
1.	HUZM-55	ISO2 × 1381WA-4K	Late	Medium	Flint	Yellow
2.	HUZM-68	DMRWN3 ## -1	Late	Dwarf	Flint	Yellow
3.	HUZM-69	DMRWN-3	Late	Medium	Flint	Yellow
4.	HUZM-70-1	DMRWN-4 (TUXPENO POOL C7)	Late	Dwarf	Semi flint	Yellow
5.	HUZM-77	DMRWN-8 × LOCAL	Late	Medium	Flint	Yellow
6.	HUZM-78	DMRWN-8 × LOCAL	Late	Medium	Flint	Yellow
7.	HUZM-79	DMRWN-8 × LOCAL	Late	Medium	Dent	Yellow
8.	HUZM-91-1	DEWAKI × VC2	Late	Medium	Flint	White
9.	HUZM-175-2	BIO-9681	Late	Medium	Semi flint	Yellow
10.	HUZM-210-2	R-9702	Late	Medium	Semi flint	Yellow
11.	HUZM-211-1	R-9702	Late	Medium	Semi flint	Yellow
12.	HUZM-217	KH-510	Early	Dwarf	Flint	Yellow
13.	HUZM-221	JKMH-168	Medium	Dwarf	Flint	Yellow
14.	HUZM-227-1-1	X-3342	Late	Tall	Semi flint	Yellow
15.	HUZM-329	VIPL - 1806	Late	Medium	Semi flint	Yellow
16.	CM-119	R-109	Early	Tall	Flint	Yellow
17.	HKI-1105	CARGIL - 633	Medium	Medium	Flint	Yellow
18.	HKI-323	POOL-28	Medium	Medium	Flint	Yellow

Table 2. Mean performance of inbred lines and testers for quantitative traits

S. No.	Genotypes		Days to 50% Tassel	Days to 50% Silk	Plant Height (cm)	Ear Height (cm)	Ear Length (cm)	Ear Diameter (cm)	Number of Rows/ ear	Number of Kernel/ row	100 kernels Weight (g)	Yield/ plant (g)	Yield/ plot (Kg)
1	HUZM-55	L_1	98.667	107.000	106.000	38.000	10.200	3.550	14.200	16.900	20.600	44.640	0.444
2	HUZM-68	L_2	97.000	105.000	88.000	37.500	12.700	3.700	14.200	23.700	15.800	51.950	0.616
3	HUZM-69	L_3	95.000	103.667	128.500	32.500	10.750	3.600	11.800	21.200	20.000	26.010	0.182
4	HUZM-70-1	L_4	103.667	105.000	111.000	50.500	13.500	4.000	12.000	22.400	21.100	69.403	0.887
5	HUZM-77	L_5	97.667	107.000	104.000	48.000	14.300	3.450	9.800	15.500	27.500	48.793	0.390
6	HUZM-78	L_6	94.006	100.667	110.300	35.000	13.900	3.150	11.200	19.000	15.200	48.500	0.347
7	HUZM-79	L_7	95.667	102.667	128.500	50.000	13.400	4.150	13.800	29.500	18.600	72.840	1.385
8	HUZM-91-1	L_8	97.000	103.000	135.500	62.500	15.800	4.500	12.750	16.333	28.600	47.323	0.467
9	HUZM-175-2	L_9	106.667	113.000	133.500	63.000	15.400	3.750	13.400	20.500	18.033	48.020	0.618
10	HUZM-210-2	L_{10}	99.000	103.000	125.500	41.500	12.300	3.950	15.600	21.200	18.750	59.690	0.925
11	HUZM-211-1	L_{11}	103.667	106.667	145.000	77.500	13.033	4.550	14.800	21.300	23.900	80.073	1.613
12	HUZM-217	L_{12}	104.000	112.000	118.500	61.500	12.800	3.550	13.600	18.000	12.800	38.723	0.489
13	HUZM-221	L_{13}	99.667	112.667	98.500	35.500	11.300	3.600	9.800	16.000	25.500	37.253	0.284
14	HUZM-227-1-1	L_{14}	97.667	102.667	111.700	49.500	14.600	4.550	13.600	23.700	22.600	92.563	1.603
15	HUZM-329	L_{15}	102.000	108.000	100.500	49.500	13.000	4.150	13.600	20.800	23.500	72.213	0.967
Mean performance of testers													
1	CM-119	T_1	96.667	101.000	152.200	74.000	15.400	4.130	13.400	34.100	22.867	101.130	1.807
2	HKI-1105	T_2	98.000	102.667	126.700	63.500	15.000	4.150	13.200	27.900	23.600	92.680	1.523
3	HKI-323	T_3	97.667	103.222	108.500	51.500	14.300	4.050	13.400	24.500	19.000	79.290	1.300

value for days to 50% tasseling and silking. Line L_6, L_7 and tester T_1 proved out to be the best general combiner for maturity traits. Crosses, L_5 x T_3 and L_6 x T_2 were good specific combiner for maturity traits. Line L_6, L_2 and tester T_3 were good general combiner and among the crosses L_{10} x T_1 and L_5 x T_3 proved to be best specific combiner for plant height.

The expression and magnitude of heterosis however, varied for different character in same crosses and even for same character among the crosses. It was seen that the cross combinations L_{11} x T_2 (39.51) and L_{10} x T_3 (38.49) exhibited highest heterosis for yield / plot over the best check hybrid (Table 6). These results were in consonance with the findings of several workers *viz.*, Singh *et al.* (2004), Sandhu *et al.* (2006),

Table 3. Heterosis in 'F_1' hybrids over mid parental value for quantitative traits studied

S. No.	Crosses	Days to 50% Tassel	Days to 50% Silk	Plant Height (cm)	Ear Height (cm)	Ear Length (cm)	Ear Diameter (cm)	Number of Rows / ear	Number of Kernels / row	100 kernel Weight (g)	Yield / plant (g)	Yield / plot (Kg)
1	$L_1 X T_1$	-3.07**	-3.85**	19.67**	18.75**	23.44**	18.49**	10.14**	22.35**	11.81**	66.81**	99.02**
2	$L_1 X T_2$	-3.39**	-5.56**	28.15**	25.12**	32.94**	23.38**	16.79**	39.29**	25.79**	89.28**	157.50**
3	$L_1 X T_3$	-0.51	-3.60**	35.38**	31.84**	38.78**	26.32**	15.94**	46.86**	19.70**	136.00**	219.13**
4	$L_2 X T_1$	-2.24**	-3.88**	20.07**	35.43**	41.87**	11.11**	1.45	17.65**	42.76**	80.90**	98.95**
5	$L_2 X T_2$	-1.54**	-4.65**	32.74**	49.50**	41.88**	22.29**	13.87**	27.13**	63.45**	162.50**	180.77**
6	$L_2 X T_3$	-1.37**	-4.27**	45.24**	66.29**	30.37**	26.45**	17.39**	31.95**	53.83**	147.73**	210.37**
7	$L_3 X T_1$	-2.96**	-4.56**	13.50**	42.72**	32.70**	15.14**	4.76	20.43**	20.37**	127.42**	168.86**
8	$L_3 X T_2$	-1.55**	-4.04**	10.50**	7.29	47.83**	22.58**	7.20*	38.90**	27.29**	162.25**	223.30**
9	$L_3 X T_3$	-0.35	-3.02**	21.52**	52.38**	40.12**	21.05**	11.11**	38.73**	40.00**	182.48**	239.18**
10	$L_4 X T_1$	-3.49**	-3.24**	22.11**	30.92**	15.22**	10.70**	5.51	12.57**	30.78**	56.65**	72.23**
11	$L_4 X T_2$	-1.82**	-1.77**	28.99**	49.12**	28.77**	20.82**	7.94*	35.59**	33.78**	105.49**	140.60**
12	$L_4 X T_3$	-2.98**	-4.27**	36.22**	60.78**	26.26**	13.04**	7.09*	38.17**	18.20**	117.72**	160.59**
13	$L_5 X T_1$	-2.23**	-5.77**	29.98**	47.54**	27.95**	15.39**	-10.34**	36.29**	31.17**	81.29**	136.76**
14	$L_5 X T_2$	-2.21**	-5.56**	36.11**	45.29**	41.30**	13.16**	-6.09	68.66**	18.40**	119.97**	174.96**
15	$L_5 X T_3$	-4.78**	-7.98**	38.35**	35.68**	26.92**	18.67**	5.17	61.00**	27.46**	113.56**	173.43**
16	$L_6 X T_1$	-1.75**	-3.14**	20.76**	42.51**	21.84**	22.25**	-2.44	31.45**	61.82**	87.90**	148.30**
17	$L_6 X T_2$	-4.51**	-4.59**	11.39**	4.57	19.03**	16.44**	6.56*	22.39**	40.72**	47.59**	113.90**
18	$L_6 X T_3$	-4.00**	-6.13**	23.40**	34.10**	17.73**	16.67**	10.57**	32.41**	47.08**	69.36**	122.27**
19	$L_7 X T_1$	-4.68**	-4.09**	14.00**	22.58**	26.04**	12.32**	0.00	15.41**	29.26**	65.60**	44.75**
20	$L_7 X T_2$	-3.27**	-4.55**	20.30**	11.89*	14.08**	3.86	-3.70	10.45*	18.48**	46.42**	58.85**
21	$L_7 X T_3$	-4.83**	-5.11**	22.53**	26.11**	11.91*	3.66	-1.47	12.96**	51.06**	46.73**	73.56**
22	$L_8 X T_1$	-3.27**	-3.27**	12.96**	25.27**	7.05	5.21	-8.22**	21.35**	16.00**	94.65**	135.78**
23	$L_8 X T_2$	-4.62**	-5.02**	22.43**	25.40**	12.99**	11.68**	-1.35	49.66**	23.75**	141.27**	110.39**
24	$L_8 X T_3$	-4.45**	-6.22**	30.74**	30.70**	6.53	12.98**	-2.10	44.49**	26.19**	120.32**	166.42**
25	$L_9 X T_1$	-6.89**	-6.85**	18.31**	31.39**	18.83**	10.41**	5.97*	37.73**	25.92**	87.00**	114.74**
26	$L_9 X T_2$	-6.19**	-7.26**	21.06**	23.32**	19.74**	13.92**	9.77**	45.87**	17.69**	100.60**	153.11**
27	$L_9 X T_3$	-4.40**	-6.85**	28.51**	41.48**	19.87**	11.28**	17.91**	42.22**	26.10**	128.66**	175.63**
28	$L_{10} X T_1$	-2.90**	-3.27**	26.76**	41.13**	14.80**	10.97**	13.10**	16.09**	17.50**	59.29**	95.49**
29	$L_{10} X T_2$	-2.88**	-4.70**	45.52**	69.52**	24.79**	22.22**	20.83**	29.94**	19.48**	93.18**	137.17**
30	$L_{10} X T_3$	-2.71**	-5.58**	47.44**	70.97**	30.08**	17.50**	18.62**	48.80**	22.65**	111.82**	186.74**
31	$L_{11} X T_1$	-3.49**	-3.05**	25.17**	35.31**	25.21**	12.90**	12.06**	16.61**	27.23**	87.03**	72.51**
32	$L_{11} X T_2$	-3.14**	-2.55**	22.56**	21.28**	27.35**	9.20**	11.43**	32.52**	26.74**	99.58**	104.89**
33	$L_{11} X T_3$	-2.65**	-4.08**	34.52**	45.74**	35.00**	12.33**	7.80**	49.78**	32.17**	107.21**	106.64**
34	$L_{12} X T_1$	-4.32**	-4.23**	31.88**	36.53**	17.02**	8.07**	2.22	34.36**	21.68**	57.91**	112.61**
35	$L_{12} X T_2$	-2.97**	-4.97**	36.22**	45.60**	42.45**	15.58**	2.99	73.86**	17.03**	136.22**	201.52**
36	$L_{12} X T_3$	-4.13**	-6.42**	50.40**	68.14**	32.10**	11.84**	2.22	75.06**	26.42**	129.53**	190.72**
37	$L_{13} X T_1$	-1.53**	-6.40**	38.97**	65.30**	23.60**	12.55**	18.97**	35.33**	6.48*	82.35**	138.56**
38	$L_{13} X T_2$	-1.18*	-6.50**	50.53**	73.74**	42.21**	15.10**	21.74**	57.63**	-2.44	132.31**	230.20**
39	$L_{13} X T_3$	-2.03**	-7.01**	58.65**	90.80**	39.06**	16.34**	29.31**	66.91**	35.96**	148.72**	264.98**
40	$L_{14} X T_1$	-4.29**	-4.75**	23.53**	33.60**	2.00	7.14**	-0.74	4.15	24.27**	21.92*	43.50**
41	$L_{14} X T_2$	-3.24**	-4.55**	29.61**	38.94**	22.97**	19.08**	10.45**	24.42**	32.68**	88.95**	92.75**
42	$L_{14} X T_3$	-2.73**	-3.19**	34.88**	50.50**	4.50	6.51*	3.70	24.07**	29.57**	49.03**	51.78**
43	$L_{15} X T_1$	-4.36**	-6.22**	25.45**	36.84**	14.79**	5.80*	-5.19	22.40**	8.27**	54.54**	81.21**
44	$L_{15} X T_2$	-5.33**	-5.38**	37.32**	46.90**	35.00**	7.23*	0.00	49.08**	3.61	95.79**	109.05**
45	$L_{15} X T_3$	-4.84**	-5.92**	38.28**	55.45**	20.15**	13.41**	0.74	32.01**	43.76**	66.39**	136.70**

*** Significant at 5% level of significance; ** Significant at 1% level of significance**

Chattopadhyay and Dhiman (2006), Ali *et al.* (2007), Renuka *et al.* (2008) and Mandal *et al.* (2009) who in their experiments came to the same conclusion as cited above.

CONCLUSION

It was concluded on the basis of mean performance that tester T_1 was found to be superior for maturity traits whereas, line L_3 for

Table 4. Heterosis in ‘F_1’ hybrids over better parent value for quantitative traits studied

S. No.	Crosses	Days to 50% Tassel	Days to 50% Silk	Plant Height (cm)	Ear Height (cm)	Ear Length (cm)	Ear Diameter (cm)	Number of Rows / ear	Number of Kernels / row	100 kernel Weight (g)	Yield / plant (g)	Yield / plot (Kg)
1	L_1 X T_1	-4.05**	-6.54**	1.51	-10.14*	2.60	10.17**	7.04*	-8.50	6.27	20.22*	23.99*
2	L_1 X T_2	-3.72**	-7.48**	17.68**	0.00	11.67*	14.46**	12.68**	11.83*	17.80**	40.22**	66.30**
3	L_1 X T_3	-1.01	-4.05**	33.82**	14.56*	18.88**	18.52**	12.68**	24.08**	15.05**	84.44**	114.10**
4	L_2 X T_1	-2.41**	-5.71**	-5.26	2.3	29.44**	5.33	-1.41	-0.29	20.70**	36.91**	33.39**
5	L_2 X T_2	-2.04**	-5.71**	12.47**	18.90**	31.00**	15.66**	9.86**	17.56**	36.44**	104.82**	97.16**
6	L_2 X T_3	-1.71**	-4.72**	31.52**	43.69**	23.08**	20.99**	14.08**	29.80**	40.88**	105.02**	128.72**
7	L_3 X T_1	-3.79**	-5.79**	4.66	2.70	12.66*	7.75*	-1.49	-2.35	12.83**	42.96**	47.97**
8	L_3 X T_2	-3.06**	-4.50**	9.73*	18.90**	26.89**	14.46**	1.52	22.22**	17.58**	67.93**	80.96**
9	L_3 X T_3	-1.71**	-4.09**	12.06**	24.27**	22.73**	14.32**	4.48	29.39**	36.50**	87.57**	93.33**
10	L_4 X T_1	-6.75**	-5.08**	5.58	10.14*	8.12	8.96**	0.00	-6.74	25.73**	32.08**	28.41**
11	L_4 X T_2	-4.50**	-2.86**	20.99**	33.86**	22.33**	18.63**	3.03	22.22**	26.69**	79.68**	90.37**
12	L_4 X T_3	-5.79**	-4.72**	34.68**	59.22**	22.73**	12.35**	1.49	32.24**	12.32**	104.15**	119.23**
13	L_5 X T_1	-2.73**	-8.41**	9.40*	21.62**	23.38**	5.89	-22.39**	-0.88	20.12**	34.38**	43.91**
14	L_5 X T_2	-2.38**	-7.48**	23.91**	27.56**	38.00**	3.61	-18.18**	31.18**	10.00**	67.89**	72.65**
15	L_5 X T_3	-4.78**	-8.41**	35.48**	31.07**	26.92**	9.88**	-8.96*	31.43**	7.76**	72.49**	77.69**
16	L_6 X T_1	-3.10**	-3.30**	4.14	4.95	15.91**	7.75*	-10.45**	2.35	34.69**	39.01**	47.97**
17	L_6 X T_2	-6.46**	-5.52**	4.18	-18.90**	14.67**	2.41	-1.52	2.87	15.68**	12.41	31.29**
18	L_6 X T_3	-5.80**	-8.49**	22.39**	12.62	16.08**	3.70	1.49	17.55**	32.37**	36.47**	40.77**
19	L_7 X T_1	-5.17**	-4.87**	5.12	2.70	17.86**	12.05**	-1.45	7.62	17.20**	42.44**	27.86**
20	L_7 X T_2	-4.42**	-4.55**	19.46**	0.00	8.00	3.86	-5.80	7.46	5.93	30.75**	51.64**
21	L_7 X T_3	-5.80**	-6.60**	13.00**	24.27**	8.39	2.41	-2.90	3.39	49.47**	40.77**	68.23**
22	L_8 X T_1	-3.44**	-4.21**	6.77	15.54**	5.70	0.89	-10.45**	-10.26*	4.37	42.87**	48.34**
23	L_8 X T_2	-5.10**	-5.18**	18.45**	24.41**	10.13*	7.33*	-3.03	18.64**	12.94**	82.23**	37.42**
24	L_8 X T_3	-4.78**	-7.55**	17.71**	19.20**	1.48	7.33*	-4.48	20.41**	5.01	75.91**	81.03**
25	L_9 X T_1	-11.25**	-11.80**	11.04**	21.62**	18.83**	5.33	5.97	10.26*	12.61**	37.90**	44.10**
26	L_9 X T_2	-10.00**	-11.50**	17.98**	22.83**	18.18**	8.43*	8.96*	26.52**	3.81	52.27**	77.90**
27	L_9 X T_3	-8.44**	-3.77**	16.48**	28.57**	15.58**	7.16*	17.91**	30.61**	22.89**	83.57**	103.33**
28	L_{10} X T_1	-4.04**	-2.31**	15.64**	10.14*	3.25	8.56*	5.13	-5.87	6.92*	26.65**	47.79**
29	L_{10} X T_2	-3.37**	-4.55**	44.83**	40.16**	13.56**	19.28**	11.54**	14.34**	7.20*	58.80**	90.59**
30	L_{10} X T_3	-3.37**	-6.92**	37.45**	54.37**	20.98**	16.05**	10.26**	38.78**	21.84**	85.64**	145.38**
31	L_{11} X T_1	-6.75**	-0.33	22.21**	32.26**	15.58**	7.69*	6.76*	-5.28	24.48**	67.56**	63.28**
32	L_{11} X T_2	-5.79**	-0.65	14.83**	10.32*	19.00**	4.40	5.41	16.85**	25.94**	86.01**	99.17**
33	L_{11} X T_3	-5.47**	-3.77**	17.59**	21.29**	29.02**	6.15*	2.70	40.00**	18.62**	106.20**	86.57**
34	L_{12} X T_1	-7.69**	0.99	17.28**	25.00**	7.14	0.48	1.47	2.64	-5.10	9.19	35.06**
35	L_{12} X T_2	-5.77**	-0.65	31.81**	43.31**	32.00**	7.23*	1.47	43.01**	-9.75**	67.46**	99.12**
36	L_{12} X T_3	-7.05**	-3.77	44.05**	54.47**	25.17**	4.94	1.47	51.84**	5.79	70.82**	100.00**
37	L_{13} X T_1	-3.01**	-0.99	14.45**	22.30**	7.14	5.33	2.99	-0.59	0.98	24.76*	38.01**
38	L_{13} X T_2	-2.01**	-1.95**	33.78**	35.43**	24.67**	7.47*	6.06	24.01**	-6.08*	62.84**	95.84**
39	L_{13} X T_3	-3.01**	-4.09**	51.34**	61.17**	24.48**	9.88**	11.94**	37.96**	18.63**	82.79**	122.31**
40	L_{14} X T_1	-4.78**	-3.96**	7.10	11.49*	-0.65	2.20	-1.47	-11.73**	23.54**	16.75	35.42**
41	L_{14} X T_2	-3.40**	-4.55**	21.94**	23.62**	21.33**	13.85**	8.82*	15.05**	29.87**	88.83**	87.94**
42	L_{14} X T_3	-2.73**	-4.72**	32.95**	47.57**	3.42	0.66	2.94	22.04**	19.25**	38.34**	37.42**
43	L_{15} X T_1	-6.86**	-2.97**	4.14	14.19**	5.84	5.54	-5.88	-1.47	6.81*	32.45**	39.11**
44	L_{15} X T_2	-7.19**	-2.92**	23.13**	30.71**	26.00**	7.23*	-1.47	30.11**	3.39	74.17**	70.90**
45	L_{15} X T_3	-6.86**	-5.03**	33.18**	52.43**	14.69**	12.05**	0.00	22.04**	30.00**	58.96**	106.41**

Significant at 5% level of significance; ** Significant at 1% level of significance

dwarfness. For yield traits, the line L_{11}, L_{10} and tester T_2 was found to be superior hence, these lines can be used in future breeding programmes to develop synthetic/hybrid varieties. The cross L_{14} x T_2 which was high yielding and at par in maturity may be further tested over locations and years for commercial exploitation. The crossesL_5 x T_3, L_6 x T_2 and L_1 x T_2 were early in maturity whereas, the crosses L_6 x T_1, L_{14} x $T_{2.}$ were high yielding. Therefore, these crosses may be used in hybrid breeding programmes. L_{11} x T_2 and L_{10} x T_3 showed highest heterosis over best check hybrid. Therefore, the crosses may be further evaluated for commercial utilization as hybrid varieties.

Table 5. Heterosis in 'F_1' hybrids over best check hybrid for quantitative traits studied

S. No.	Crosses	Days to 50% Tassel	Days to 50% Silk	Plant Height (cm)	Ear Height (cm)	Ear Length (cm)	Ear Diameter (cm)	Number of Rows / ear	Number of Kernels / row	100 kernel Weight (g)	Yield / plant (g)	Yield / plot (Kg)
1	L_1 X T_1	1.79**	2.04**	7.67*	-6.34	-0.32	1.11	13.43**	-3.41	3.62	4.55	-2.75
2	L_1 X T_2	2.15**	1.02	3.90	-10.56*	5.68	5.56	19.40**	-3.41	18.55**	11.76	9.99
3	L_1 X T_3	5.02**	4.76**	1.18	-16.90**	7.26	6.67*	19.40**	-5.88	1.07	25.76**	20.84**
4	L_2 X T_1	1.79**	1.02	0.49	6.34	25.76**	-3.33	4.48	5.26	17.70**	19.07*	4.63
5	L_2 X T_2	3.23**	1.02	-0.70	6.34	23.97**	6.67*	16.42**	1.55	37.31**	63.24**	30.39**
6	L_2 X T_3	3.23**	3.06**	-0.56	4.23	11.04*	8.89**	20.90**	-1.55	14.14**	39.80**	29.09**
7	L_3 X T_1	0.00	-0.34	11.01**	7.04	9.46	-1.11	-1.49	3.10	10.02**	24.33**	16.06*
8	L_3 X T_2	2.15**	1.02	-1.74	-27.46**	20.08**	5.56	0.00	5.57	18.34**	33.84**	19.68*
9	L_3 X T_3	3.23**	3.74**	0.35	-9.86	10.73*	2.89	4.48	-1.86	16.42**	27.90**	9.12
10	L_4 X T_1	3.94**	1.70*	11.99**	14.79**	5.05	0.00	0.00	-1.55	22.60**	14.87	0.72
11	L_4 X T_2	6.45**	4.08**	6.83	19.72**	15.77**	9.41**	1.49	5.57	27.51**	43.21**	25.90**
12	L_4 X T_3	5.02**	3.06**	4.18	15.49**	10.73*	1.11	1.49	0.31	1.07	39.20**	23.73**
13	L_5 X T_1	2.15**	0.00	16.03**	26.76**	19.87**	-2.81	-22.39**	4.64	40.87**	16.87*	12.88
14	L_5 X T_2	2.87**	1.02	9.41*	14.08**	30.60**	-4.44	-19.40**	13.31**	29.00**	33.81**	14.18
15	L_5 X T_3	0.00	0.00	2.44	-4.93	14.51**	-1.11	-8.96*	-0.31	26.37**	17.62*	0.29
16	L_6 X T_1	0.72	-0.34	10.45**	9.39	12.62*	-1.11	-10.45**	8.05	31.34**	20.89*	16.06*
17	L_6 X T_2	-1.43*	-1.02	-8.01*	-27.46**	8.52	-5.56	-2.99	-11.15*	16.42**	-10.41	-13.17
18	L_6 X T_3	-1.08	-1.02	-5.92	-18.31**	4.73	-6.67*	1.49	-10.84*	7.25*	-6.94	-20.55**
19	L_7 X T_1	-1.43	-0.34	11.50**	7.04	14.51**	3.33	1.49	13.62**	14.29**	23.88**	0.29
20	L_7 X T_2	0.72	0.00	6.97	-10.56*	2.21	-4.22	-2.99	-1.86	6.61*	4.21	0.29
21	L_7 X T_3	-1.08	1.02	1.18	-9.86	-2.21	-5.56	0.00	-5.57	21.11**	-4.02	1.16
22	L_8 X T_1	0.72	0.68	13.24**	20.42**	5.36	0.89	-10.45**	-5.26	27.29**	24.25**	16.35*
23	L_8 X T_2	0.00	-0.34	11.85**	11.27*	9.78*	7.33*	-4.48	2.48	37.74**	45.24**	-9.12
24	L_8 X T_3	0.00	0.00	11.15**	4.93	1.16	7.33*	-4.48	-8.67	28.07**	19.95*	2.17
25	L_9 X T_1	1.79**	1.70*	17.77**	26.76**	15.46**	-3.33	5.97	16.41**	9.81**	19.93*	13.02
26	L_9 X T_2	3.23**	2.04**	9.76*	9.86	14.83**	0.00	8.96*	9.29*	4.48	21.36*	17.66*
27	L_9 X T_3	5.02**	4.08**	8.36*	14.08**	12.30*	-3.56	17.91**	-0.93	-0.43	25.17**	14.76
28	L_{10} X T_1	2.15**	0.68	22.65**	14.79**	0.32	-0.37	22.39**	-0.62	4.26	10.15	15.92*
29	L_{10} X T_2	2.87**	0.00	27.87**	25.35**	7.47	10.00**	29.85**	-1.24	7.89*	26.56**	26.05**
30	L_{10} X T_3	2.87**	0.68	20.21**	11.97*	9.15	4.44	28.36**	5.26	-1.28	26.58**	38.49**
31	L_{11} X T_1	3.94**	2.72**	29.62**	44.37**	12.30*	8.89**	17.91**	0.00	26.87**	45.72**	28.08**
32	L_{11} X T_2	5.02**	4.08**	16.03**	20.42**	12.62*	5.56	16.42**	0.93	28.36**	48.25**	39.51**
33	L_{11} X T_3	5.38**	4.08**	18.82**	32.39**	16.40**	7.33*	13.43**	6.19	20.90**	41.99**	30.68**
34	L_{12} X T_1	3.23**	4.08**	24.39**	30.28**	4.10	-7.78*	2.99	8.36	-7.46*	-5.04	5.93
35	L_{12} X T_2	5.38**	4.08**	16.38**	28.17**	24.92**	-1.11	2.99	23.53**	-9.17**	33.47**	31.69**
36	L_{12} X T_3	3.94**	4.08**	18.95**	33.80**	12.93**	-5.56	2.99	15.17**	-14.29**	16.47*	12.88
37	L_{13} X T_1	3.94**	2.4**	21.39**	27.46**	4.10	-3.33	2.99	4.95	9.81**	8.51	8.25
38	L_{13} X T_2	5.02**	2.72**	18.12**	21.13**	17.98**	-0.89	4.48	7.12	2.13	29.79**	29.52**
39	L_{13} X T_3	3.94**	3.74**	14.43**	16.90**	12.30*	-1.11	11.94**	4.64	29.00**	24.64**	25.47**
40	L_{14} X T_1	0.00	-1.02	13.49**	16.20**	-3.47	3.33	0.00	-6.81	20.47**	1.54	6.22
41	L_{14} X T_2	1.79**	0.00	7.67*	10.56*	14.83**	15.11**	10.45**	-0.62	30.70**	50.50**	30.82**
42	L_{14} X T_3	2.15**	3.06**	3.48	7.04	-4.73	1.78	4.48	-7.43	14.93**	10.12	-4.34
43	L_{15} X T_1	2.15**	0.00	10.45**	19.01**	2.84	-2.67	-4.48	4.02	7.04*	15.19	9.12
44	L_{15} X T_2	1.79**	1.70*	8.71*	16.90**	19.24**	-1.11	0.00	12.38**	4.05	38.82**	13.2
45	L_{15} X T_3	2.15**	2.72**	0.70	10.56*	3.47	3.33	1.49	-7.43	30.28**	8.39	16.50*

*** Significant at 5% level of significance; ** Significant at 1% level of significance**

Table 6. Five high yielding crosses showing significant heterosis over check hybrid for yield and some other traits in maize

S. No.	Top ranking crosses	Per se Performance (Kg/plot)	SCA	Heterosis of top ranking crosses for yield over check hybrid (%)	Other trait of ranking crosses show significant heterosis over check
1.	L_{11} x T_2	3.21	0.063	39.51	Ear length, Number of rows/ear, 100 kernel weight
2.	L_{10} x T_3	3.19	0.277	38.49	Number of rows/ear
3.	L_{12} x T_2	3.03	0.249	31.69	Ear length, Number of kernel/rows
4.	L_{14} x T_2	3.01	0.366	30.82	Ear length, ear diameter, Number of rows/ear, 100 kernel weight
5.	L_{11} x T_3	3.01	0.039	30.68	Ear length, ear diameter, Number of rows/ear, 100 kernel weight

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