Nature and magnitude of heterosis for yield and related traits in rice (*Oryza sativa* L.)

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ABSTRACT: Heterosis was studied for 12 characters in 60 crosses developed by crossing 20 lines and tree testers (2 CMS & 1 TGMS) a line x tester mating design. Promising hybrids expressed highest SCA effects for grain yield were obtained with general combiners involved into different parental combinations of UPR 3403-4-1-1 x UPRI 95-167 (L_1 x T_1), UPRI 2008-62 x UPRI 95-17A (L_{20} x T_2) and UPR 3428-4-1-1 x UPRI 95-17A(L_{11} x T_2). The per cent estimate for standard heterosis for grain yield was recorded highest for UPRI 2008-39 x PUSA 6A (L_{19} x T_3) followed by UPR 3403-4-1-1 x UPRI 95-17A (L_1 x T_1) and UPRI 2008-62 x PUSA 6A (L_{20} x T_3). These identified hybrids have potential and can be channelized in rice hybrid development programme after further testing in station/multiplications trials.

Key words: *CMS lines,* heterosis, rice, TGMS

Rice (*Oryza sativa* L.) is the major food crop of more than half of the global population and will continue to occupy the pivotal place in global food and livelihood security systems. Heterosis in rice was first reported by Jones (1926) who observed a marked increase in culm number and grain yield in some F_1 hybrids in comparison to their parents. Heterosis can be quantitatively defined as an upward deviation of the mid parent, based on the average of the values of two parents. Both positive and negative heterosis is useful in crop improvement, depending on the breeding objectives. The use of heterosis in rice increases the yield upto 20% over the improved inbred rice varieties to meet the demand of increasing populations. Hybrid rice includes three line and two-line hybrid rice that is developed via cytoplasmic male sterility and photo/thermo sensitive male sterility respectively (Yuan and Peng, 2005). In crop breeding, although the use of heterosis in first-generation seeds (F_1) is well-known, its application in rice is limited because of the self-pollination character of that crop. In 1974, Chinese scientist successfully transferred the male sterility gene from wild rice to create the CMS line and hybrid combination (FAO org., 2004). The present study was based on the estimation of magnitude and direction of standard heterosis in F_1 hybrid combination of 60 crosses by combining two CMS, one TGMS testers and 20 lines. Nature and magnitude of heterosis would help to identify specific parents and crosses for further exploitation in hybrid breeding programme.

MATERIALS AND METHODS

Two CMS testers (UPRI 95-17A & PUSA 6A) and one TGMS tester (UPRI 95-167) were crossed with 20 well adopted elite lines in line x tester design (Kempthorne, 1957) to generate 60 F_1 combinations. In this paper the agronomic traits *viz.* days to 50% flowering, plant height (cm), number of tillers per plant, number of panicles per plant, panicle length (cm), panicle weight (g), number of grains per panicle, number of spikelets per panicle, fertility percentage, 1000-grain weight (g), harvest index and yield per plant (g) are discussed.

Table1: List of genotypes used in experiment

S.No.	Code	Genotypes
1	T_1	UPRI 95-167
2	T_2	UPRI 95-17A
3	T_3	Pusa 6A
4	L_1	UPR 3403-4-1-1
5	L_2	UPR 3403-11-1-2
6	L_3	UPR 3403-3-1-2
7	L_4	UPR 3406-7-2-1
8	L_5	UPR 3406-7-2-2
9	L_6	UPR 3406-8-1-1
10	L_7	UPR 3411-1-1-1
11	L_8	UPR 3413-8-2-1
12	L_9	UPR 3413-8-3-1
13	L_{10}	UPR 3425-11-1-1
14	L_{11}	UPR 3428-4-1-1
15	L_{12}	UPR 3434-1-1-2
16	L_{13}	UPR 3443-1-3-1
17	L_{14}	UPR 3456-4-2-2
18	L_{15}	UPR 3480-1-1-1
19	L_{16}	UPR 3480-9-1-1
20	L_{17}	UPR 3430-9-2-1
21	L_{18}	UPR 3469-13-1-1
22	L_{19}	UPRI 2008-39
23	L_{20}	UPRI 2008-62

The F_1's and parents were grown with one standard check Pant Dhan 12 at Norman E. Borlaug Crop Research Centre of GBPUA&T, Pantnagar during 2010 WS in RBD with two replications. All the recommended cultural practices were followed to obtain normal growth of the crop. The observations were recorded on five randomly selected plants from each replication for 12 traits.

Heterosis expressed as per cent increase or decrease in the performance of F_1 hybrid over the mid parent (average or relative heterosis), better parent (heterobeltiosis) and check variety (standard heterosis) was computed for each character and statistical significance was determined.

$$\text{(Relative heterosis)} \quad \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{Heterobeltiosis} \quad \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Standard heterosis} \quad \frac{\overline{F_1} - \overline{SV}}{\overline{SV}} \times 100$$

Using the following formula:
Where,
F_1= mean value of F_1 hybrid
MP= mean value of two parents
BP= mean value of better parents
SV= mean value of standard variety

RESULTS AND DISCUSSION

The analysis of variance revealed significant variation due to parents for all the characters and indicates suitability of materials for the investigation. The significant variance due to parent vs crosses indicated prevalence of heterosis for all the characters except panicle number per plant, tillers per plant and harvest index (Table 2).

The significance of variance due to L x T for all the characters provided a direct test indicating that dominance or no-additive variance was important for all characters. The SCA variances were higher than GCA variances for all the traits suggesting preponderance of non-additive gene action in determination of grain yield and its components (Table 2).Similar observations have also been reported earlier by Satyanarayna *et al*. (2000); Venkatesan *et al*. (2007); Dalvi and Patel (2009).

SCA effects for grain yield per plant were significant for the crosses UPR 3403-4-1-1 x UPRI 95-167 (L_1 xT_1), UPRI 2008-62 x UPRI 95-17A (L_{20}x T_2) and UPR 3428-4-1-1 x UPRI 95-17A (L_{11} x T_2) (Table 3).

Grain Yield per plant is a complex trait. It is multiplicative product of several basic component trait of yield. In the present study, out of 60 hybrids, 3 hybrids manifested significant and positive estimates of standard heterosis. The per cent estimate of maximum standard heterosis for grain yield was also reported by Pandey *et al*., (1995); Panwar *et al*., (1998) and Rashid *et al*. (2007). Top

Table 2: Analysis of variance for different characters in rice

Source of variation	d.f.	Mean square											
		Days of 50% flowering	Plant height	Panicle Length	Panicle number per plant	Tiller per plant	Panicle weight	1000 grain weight	Spikelet number per panicle	Grain number per panicle	% spikelet fertility	Harvest Index	Grain yield per plant
Replication	1	0.096ns	2.31ns	1.79ns	30.36**	20.96**	0.012ns	0.277ns	11.18ns	0.57ns	2.12ns	21.18ns	3.79*
Treatment	82	79.13**	303.28**	16.47**	12.45**	12.68**	1.26**	28.45**	2079.64**	2397.26**	708.09**	155.98**	74.13**
Parents	22	52.13**	503.10**	25.61**	9.81**	10.35**	1.48**	50.99**	1885.89**	1535.40**	276.39**	127.95**	33.90**
Lines	19	60.18**	280.38**	10.25**	11.06**	11.73**	1.26**	38.42**	1818.95**	1298.67**	75.76**	42.83**	21.93**
Tester	2	0.166ns	87.76**	13.82**	2.67ns	1.50ns	1.87**	34.93**	3375.5**	524.66**	205.07**	112.68**	23.88**
Line × Tester	38	55.40**	173.13**	3.83**	15.18**	15.42**	1.09**	10.09**	2227.38**	2832.53**	808.28**	234.99**	123.97**
Parents vs. crosses	1	2092.9**	1719.5**	419.25**	0.85ns	0.063ns	1.44**	27.88**	3089.0**	91.50**	830.65**	6.51ns	157.91**
Error	82	2.84	2.37	1.32	0.86	0.93	0.031	0.60	5.46	12.09	5.12	11.19	0.89
σ^2gca		-3.53	-0.63	0.15	-1.80	-1.80	-0.05	-2.35	-40.24	-132.02	-14.91	-3.76	-0.42
σ^2sca		29.78	104.52	2.65	8.32	8.42	0.63	12.34	1122.11	1185.39	263.19	72.07	41.52
σ^2gca/σ^2sca		0.12	-0.006	0.056	-0.25	-0.22	-0.08	-0.19	-0.04	-0.11	-0.06	0.52	-0.01
σ^2A		-0.68	-5.64	-0.12	-1.06	-1.16	0.01	-1.01	-55.63	132.92	58.39	21.25	5.83
σ^2D		29.78	104.52	2.65	8.32	8.42	0.63	12.34	1122.11	1185.39	263.19	72.07	41.52

*, ** significant at 5 and 1 per cent probability level, respectively

Table 3: Estimates of specific combining ability effects of crosses

Cross	Days to 50% flowering	Plant height	Panicle Length	Panicle number per plant	Tillers per plant	Panicle weight	1000 grain weight	Spikelet number per panicle	Grain number per panicle	% spikelet fertility	Harvest Index	Grain yield per plant
$L_1 \times T_1$	5.99**	-2.63**	0.56	0.04	-0.12ns	1.18**	3.21**	38.18**	41.60**	5.57**	3.84*	12.19**
$L_1 \times T_2$	4.33**	-11.09**	-0.80	-2.29**	-1.62**	0.66**	-0.41	54.51**	33.93**	-5.67**	0.40	0.70
$L_1 \times T_3$	-5.67**	-10.71**	-2.18**	-1.29**	-1.12**	-0.42**	-4.29**	-13.16**	-13.23**	-1.76ns	3.83*	-3.19**
$L_2 \times T_1$	-3.01**	-5.09**	-3.11**	-0.29	-1.12**	-0.67**	0.74**	-53.66**	-41.40**	5.73**	-4.61*	-0.09
$L_2 \times T_2$	-6.67**	1.58**	1.43**	1.21*	1.04*	0.49**	-1.44**	13.84**	41.27**	24.02**	9.55**	7.16**
$L_2 \times T_3$	-3.34**	-4.21**	2.17**	-1.79**	-2.62**	-0.37	-0.32	-31.66**	-10.90**	8.78**	0.33	-2.72**
$L_3 \times T_1$	4.16**	-5.34**	0.15	3.38**	3.38**	0.62**	-2.11**	63.01**	47.43**	-5.34**	0.27	4.43**
$L_3 \times T_2$	4.33**	10.70**	-0.74	-1.46**	-1.79**	0.39**	2.48**	9.18**	11.10**	8.37**	-0.60	-0.16
$L_3 \times T_3$	-3.17**	-0.84	-0.72	-0.96*	-0.46	-0.56**	-2.40**	-18.66**	-20.23**	-5.45**	0.50	-4.91**
$L_4 \times T_1$	-1.67*	-1.38*	0.36	-2.63**	-2.79**	0.38**	4.02**	-11.49**	-12.23**	-3.17**	4.02*	1.25**
$L_4 \times T_2$	-1.01	-2.75**	-0.72ns	5.54**	6.04**	0.29**	-3.55**	18.68**	16.93**	1.38ns	6.57**	-4.42**
$L_4 \times T_3$	0.33	-7.13**	-1.57**	-0.13	0.21	-0.39**	-1.95**	-8.49**	0.27ns	4.41**	-9.97**	-3.08**
$L_5 \times T_1$	3.83**	10.91**	0.47	2.38**	2.54**	-0.70**	-2.17**	-38.99**	-35.23**	-7.58**	-4.96**	-3.04**
$L_5 \times T_2$	-1.84*	2.95**	1.08*	-1.13*	-2.12**	-0.53**	0.39	-31.66**	-31.90**	-2.07ns	-0.62	-6.70**
$L_5 \times T_3$	-0.67	-13.46**	-2.19**	1.37**	2.21**	-1.33**	-5.78**	33.18**	2.93ns	-14.46**	-16.98**	-4.80**
$L_6 \times T_1$	0.16	-2.38**	1.73**	3.04**	2.88**	-0.11**	-1.02**	-28.32**	-33.23**	-10.60**	-9.42**	0.64
$L_6 \times T_2$	-2.84**	9.37**	0.43	-0.96*	-0.29	0.63**	4.32**	6.68**	6.27**	4.51**	12.94**	5.53**
$L_6 \times T_3$	-1.17	6.20**	-0.57	-2.79**	-2.79**	-0.76**	3.34**	-25.82**	-46.57**	-23.88**	-6.58**	-2.08**
$L_7 \times T_1$	9.66**	11.66**	2.37**	0.54	0.38	0.53**	1.86**	27.18**	10.27**	-7.12**	2.05	-6.59**
$L_7 \times T_2$	-1.67*	13.62**	1.87**	1.79**	-1.79**	0.70**	4.20**	-0.99	32.93**	24.33**	9.43**	0.24
$L_7 \times T_3$	-4.63**	4.14**	0.99**	0.67	0.25	-0.18**	-1.75**	-3.35**	0.65ns	4.25**	5.16**	-1.98**
$L_8 \times T_1$	-3.80**	10.06**	0.73	0.33	-0.25	-0.77**	1.76**	-56.52**	-31.52**	10.17**	-0.41	-4.16**
$L_8 \times T_2$	-5.80**	3.31**	0.22	3.83**	3.25**	-0.21**	2.37**	-19.18**	-2.68ns	11.95**	-4.54*	-0.40
$L_8 \times T_3$	-3.63**	0.68	1.42**	-3.67**	-3.75**	0.55**	-0.04	39.82**	22.15**	-7.92**	-0.64	-4.42**
$L_9 \times T_1$	3.70**	1.10*	-2.51**	-1.17*	-0.58	-1.08**	0.92**	-19.68**	-63.68**	-39.01**	-16.14**	-9.46**
$L_9 \times T_2$	1.53*	3.31**	-2.96**	-4.17**	-2.25**	0.87**	1.74**	18.32**	36.65**	16.43**	11.83**	5.86**
$L_9 \times T_3$	4.03**	2.56**	0.56	-2.50**	-2.25**	0.40**	3.97**	-48.52**	-33.02**	6.59**	4.45**	1.40**
$L_{10} \times T_1$	0.20	-3.53**	1.92**	0.17	-0.42	-1.08**	-2.32**	-33.85**	-51.85**	-26.32**	-2.59	-0.69
$L_{10} \times T_2$	0.70	0.06	-0.57	0.67	0.92*	0.42**	-4.07**	15.32**	34.82**	18.91**	-2.47	-0.71
$L_{10} \times T_3$	7.70**	-5.11**	-0.48	0.50	-0.42	-0.88**	-3.34**	16.48**	7.82**	-1.34ns	-8.25**	-5.40**
$L_{11} \times T_1$	7.87**	0.26	1.25**	-3.33**	-3.58**	0.20**	3.47**	5.15**	4.98**	0.97ns	-2.50	-3.03**
$L_{11} \times T_2$	-2.80**	1.51**	0.02	2.00**	2.08**	0.09**	0.65**	-0.52ns	4.82**	4.25**	9.76**	8.31**
$L_{11} \times T_3$	1.70*	-27.57**	1.65**	0.50	0.92*	1.07**	5.65**	34.98**	18.32**	-3.58**	7.84**	8.29**
$L_{12} \times T_1$	0.03	10.60**	0.69	4.00**	5.25**	0.24**	1.48**	12.32**	11.15**	2.10ns	5.61**	4.66**
$L_{12} \times T_2$	-3.30**	11.43**	0.80	-1.50**	-1.92**	0.89**	0.19	-25.35**	11.48**	23.13**	15.05**	6.84**
$L_{12} \times T_3$	1.03	-3.36**	-0.31	-0.83	-0.75	0.54**	2.48**	54.15**	54.82**	9.24**	9.85**	6.92**
$L_{13} \times T_1$	6.53**	-14.11**	0.76	-0.83	-1.42**	-0.21**	-1.82**	-21.35**	-23.18**	-12.83**	-13.49**	-3.08**
$L_{13} \times T_2$	-3.80**	-0.53	1.39**	5.33**	4.58**	0.70**	-5.76**	25.15**	37.48**	15.79**	-2.36	3.69**
$L_{13} \times T_3$	-7.97**	-1.32*	-1.63**	-1.33**	-1.25**	-0.12**	-1.46**	10.65**	10.32**	1.00ns	-0.95	-4.34**
$L_{14} \times T_1$	0.70	6.51**	-1.16**	2.33**	1.58**	-1.41**	-4.12**	-4.02**	-49.52**	-33.78**	-15.24**	-8.31**
$L_{14} \times T_2$	-1.36	-1.51**	-1.55**	-0.71	-0.12	-1.00**	-1.45**	-34.82**	-42.25**	-9.82**	-9.01**	-10.21**
$L_{14} \times T_3$	-0.53	1.03	0.07	1.96**	1.88**	0.11**	-1.35**	2.01*	-2.42ns	-4.50**	0.00	3.47**
$L_{15} \times T_1$	11.47**	7.41**	1.96**	-2.54**	-2.12**	0.63**	1.93**	32.34**	15.92**	-10.19**	0.70	3.59**
$L_{15} \times T_2$	6.64**	4.41**	1.70**	3.96**	4.88**	0.12**	-0.70**	13.84**	19.25**	2.19ns	9.25**	4.51**
$L_{15} \times T_3$	2.97**	-2.68**	1.08*	-0.04	-0.46	0.58**	0.52*	5.84**	22.42**	15.00**	6.59**	2.30**
$L_{16} \times T_1$	1.81*	0.91	0.79	5.96**	4.88**	-0.50**	-1.42**	13.34**	-25.75**	-25.22**	-12.16**	-3.14**
$L_{16} \times T_2$	-8.19**	2.78**	-0.70	-0.88	-1.12*	-1.01**	-1.87**	-14.49**	-14.42**	-1.24ns	-4.72*	-5.83**
$L_{16} \times T_3$	-4.53**	-7.18**	-1.18**	1.29**	2.21**	0.69**	-0.15	24.68**	40.75**	17.94**	3.19	0.85
$L_{17} \times T_1$	2.47**	0.78	1.29**	0.29	-0.46	0.15**	6.48**	3.34**	-14.58**	-13.46**	1.97	5.62**
$L_{17} \times T_2$	-6.03**	6.49**	0.12	3.12**	3.21**	0.50**	-1.58**	-4.99**	4.42*	4.50**	4.23*	4.15**
$L_{17} \times T_3$	-6.86**	2.49**	-0.53	-2.21**	-2.46**	-0.48**	0.09	-23.82**	-21.92**	-2.35*	-4.07*	-2.21**
$L_{18} \times T_1$	2.47**	5.61**	1.55**	-1.88**	-2.29**	0.31**	1.30**	9.01**	-5.08**	-8.67**	0.21	-5.23**
$L_{18} \times T_2$	-5.53**	16.66**	-2.12**	-2.88**	-3.46**	-0.37**	-3.48**	4.01**	16.92**	11.16**	-2.88	-5.25**
$L_{18} \times T_3$	1.81*	-13.55**	-1.77**	-2.88**	-3.12**	0.29**	-1.87**	20.84**	20.75**	-0.03ns	-4.99**	2.04**
$L_{19} \times T_1$	3.97**	2.03**	1.39**	0.12	-0.29	0.45**	5.60**	-7.82**	-14.42**	-8.67**	1.93	-2.04**
$L_{19} \times T_2$	-1.19	5.74**	-1.42**	-2.21**	-2.12**	-0.43**	-1.46**	-25.82**	-21.58**	1.37ns	-0.43	-7.55**
$L_{19} \times T_3$	-3.69**	4.74**	-1.20**	1.79**	1.71**	-0.42**	-2.50**	14.68**	16.92**	8.32**	0.55	-2.45**
$L_{20} \times T_1$	4.97**	-5.68**	1.95**	-2.54**	-1.79**	0.07**	2.42**	0.68**	9.08**	8.09**	8.94**	-1.61**
$L_{20} \times T_2$	-1.69*	-10.34**	-0.74	0.79	0.88*	-0.41**	-0.40	37.82**	-20.58**	6.12**	-1.11	10.93**
$L_{20} \times T_3$	0.97	-20.14**	-0.71**	-0.54	0.21	0.72**	-0.09	5.01**	16.58**	9.45**	5.81**	8.08**
SE crosses	0.70	0.53	0.42	0.46	0.46	0.03	0.23	0.90	1.80	1.15	1.84	0.44

*, ** significant at 5 and 1 per cent probability level, respectively

Table 4: Per cent average heterosis, heterobeltiosis and standard heterosis in rice

Cross	Grain yield/plant		
	Heterobeltiosis	Mid-parent heterosis	Standard heterosis
$L_1 \times T_1$	121.415**	198.728**	62.915**
$L_1 \times T_2$	29.048ns	37.595ns	-5.048ns
$L_1 \times T_3$	5.346ns	37.266ns	-22.487ns
$L_2 \times T_1$	36.504ns	84.205**	0.500ns
$L_2 \times T_2$	1.699ns	8.465ns	-25.125ns
$L_2 \times T_3$	75.973**	129.342**	29.559ns
$L_3 \times T_1$	-24.173ns	-1.760ns	-50.500**
$L_3 \times T_2$	-10.101ns	-9.518ns	-41.314*
$L_3 \times T_3$	48.311ns	85.050**	-3.183ns
$L_4 \times T_1$	4.071ns	38.731ns	-26.171ns
$L_4 \times T_2$	-28.622ns	-25.193ns	-49.363**
$L_4 \times T_3$	56.795*	101.690**	11.232ns
$L_5 \times T_1$	24.966ns	76.126**	5.844ns
$L_5 \times T_2$	-68.430**	-64.141**	-73.261**
$L_5 \times T_3$	18.282ns	61.510*	0.182ns
$L_6 \times T_1$	-24.317ns	4.138ns	-40.769*
$L_6 \times T_2$	21.034ns	32.760ns	-5.275ns
$L_6 \times T_3$	-5.723ns	25.459ns	-26.216ns
$L_7 \times T_1$	34.742ns	82.766**	0.796ns
$L_7 \times T_2$	11.611ns	19.922ns	-16.507ns
$L_7 \times T_3$	-5.623ns	23.681ns	-29.400ns
$L_8 \times T_1$	19.383ns	61.133*	-12.051ns
$L_8 \times T_2$	11.296ns	18.736ns	-18.008ns
$L_8 \times T_3$	47.994*	92.919**	9.027ns
$L_9 \times T_1$	-26.807ns	0.482ns	-43.133*
$L_9 \times T_2$	-6.819ns	1.872ns	-27.603ns
$L_9 \times T_3$	55.985*	107.071**	21.191ns
$L_{10} \times T_1$	-42.002	-11.916ns	-35.039ns
$L_{10} \times T_2$	-72.127**	-64.613**	-68.781**
$L_{10} \times T_3$	-15.510ns	25.041ns	-5.366ns
$L_{11} \times T_1$	-0.834ns	43.410ns	-8.095ns
$L_{11} \times T_2$	-45.191*	-35.340ns	-49.204**
$L_{11} \times T_3$	-19.578ns	12.898ns	-25.466ns
$L_{12} \times T_2$	-21.935ns	13.409ns	-26.444ns
$L_{12} \times T_3$	29.271ns	53.540**	21.805ns
$L_{12} \times T_2$	-14.817ns	20.170ns	-19.736ns
$L_{13} \times T_1$	-29.728ns	-0.242ns	-38.995*
$L_{13} \times T_2$	25.563ns	44.137*	9.004ns
$L_{13} \times T_3$	-22.368ns	6.830ns	-32.606ns
$L_{14} \times T_1$	-38.937*	-7.077ns	-31.037ns
$L_{14} \times T_2$	3.684ns	32.034ns	17.099ns
$L_{14} \times T_3$	10.852ns	64.407**	25.193ns
$L_{15} \times T_1$	-64.247**	-50.493ns	-71.442**
$L_{15} \times T_2$	-2.391ns	8.051ns	-22.033ns
$L_{15} \times T_3$	-27.953ns	-3.471ns	-42.451*
$L_{16} \times T_1$	8.396ns	47.332ns	-18.395ns
$L_{16} \times T_2$	41.649ns	52.644*	6.639ns
$L_{16} \times T_3$	-19.209ns	6.109ns	-39.177*
$L_{17} \times T_1$	39.424ns	83.161**	-5.275ns
$L_{17} \times T_2$	-23.427ns	-21.402ns	-47.976**
$L_{17} \times T_3$	10.241ns	39.606ns	-25.102ns
$L_{18} \times T_1$	36.273ns	7.934*	-16.030ns
$L_{18} \times T_2$	65.596*	69.300**	6.708ns
$L_{18} \times T_3$	66.458*	103.152**	2.569ns
$L_{19} \times T_1$	70.880*	104.228**	-9.936ns
$L_{19} \times T_2$	50.176ns	65.217*	-3.229ns
$L_{19} \times T_3$	253.322**	304.544**	86.221**
$L_{20} \times T_1$	-3.724ns	37.178ns	-15.348ns
$L_{20} \times T_2$	-51.952*	-44.546*	-57.754**
$L_{20} \times T_3$	55.547**	114.898**	36.767*

three hybrids exhibiting higher grain yield recorded for UPRI 2008-39 × PUSA 6A ($L_{19} \times T_3$) followed by UPR 3403-4-1-1× UPRI 95-17 A ($L_1 \times T_1$), UPRI 2008-62 × PUSA 6A ($L_{20} \times T_3$). (Table 4). These crosses can be used directly as two line and three line hybrids and as parents in hybridization program.

Nature and magnitude of better parent heterosis for grain yield per plant plays a major role in development of new hybrids.15 hybrids manifested significant heterosis, of which 10 hybrids had positive estimates. The range of heterosis varied from -72.127 to 253.322 per cent. Promising hybrids were $L_{19} \times T_3$ (253.322), $L_1 \times T_1$ (121.415), $L_2 \times T_3$ (75.973), $L_{19} \times T_1$ (70.880), and $L_{18} \times T_3$ (66.458).For relative heterosis, 26 crosses manifested significant heterosis, of which 23 had positive estimates. The estimates ranged between -64.613 to 304.544 per cent. The hybrids were $L_{19} \times T_3$ (304.544), $L_1 \times T_1$ (198.728), $L_2 \times T_3$ (129.342), $L_{20} \times T_3$ (114.898), and $L_9 \times T_3$ (107.071).Seventeen crosses possessed significant standard heterosis for grain yield/plant, of these only3 crosses had positive estimates. These estimates ranged between -73.261 to 86.221 per cent. Promising hybrids for higher grain yield per plant were $L_{19} \times T_3$ (86.221), $L_1 \times T_1$ (62.915) and $L_{20} \times T_3$ (36.767).

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