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Heterosis for yield and its components traits of rice (*Oryza sativa* L.) in aerobic condition

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Abstract
A study was conducted to estimate the extent of relative heterosis and heterobeltiosis for various quantitative and qualitative traits using diallel analysis excluding reciprocal crosses in aerobic condition. Among parents, IET-24021, IET-23998 and IET-24025 were found superior for grain yield and most of its yield attributing traits. High magnitude of relative heterosis and heterobeltiosis were observed for grain yield per plant, days to 50 per cent flowering, number of productive tillers per plant, straw yield per plant, grains per panicle, test weight, protein content and amylose content. The cross combination IET-24001 × GNR-3, IET-24001 × IR-28 and IET-24002 × GNR-3 exhibited highly significant heterosis in desired direction for grain yield and its yield attributing traits. The cross combination IET-24001 × GNR-3, IET-24001 × IR-28 and IET-24002 × GNR-3 were identified as the best combinations for aerobic conditions on the basis of high per se performance and high heterobeltiosis.

Keywords: Aerobic rice, diallel analysis, relative heterosis and heterobeltiosis

Introduction
Rice (*Oryza sativa* L., 2n = 2x = 24) is second most widely grown cereal crop and the staple food for more than half of world's population, providing two thirds of calorie intake for more than three billion people in Asia and one-third of calorie intake of nearly 1.5 billion people in Africa and Latin America. Global production of rice (Paddy) is 685 million tons from 158 million hectares area and its productivity is 4.3 t/ha. In India, rice is cultivated in 44.13 million hectares during 2015 with production of 106.19 million tones and productivity of 2416 kg per hectare (Anon., 2015) [1]. In Gujarat, rice is cultivated in 7.88 lakh hectares with production of 16.36 lakh tones and productivity of 2076 kg per hectare (Anon., 2015) [1].
The heterosis expresses the superiority of F_1 hybrids over its parents in term of yield and other traits. On the other hand, the inbreeding depression reflects on reduction or loss in vigour, fertility and yield as a result of inbreeding. The magnitude of heterosis helps in the identification of potential cross combinations to be used in conventional breeding programme to enable create wide array of variability in segregating generations. The knowledge of heterosis accompanied by the extent of inbreeding depression in subsequent generations is essential for maximum exploitation of such heterosis by adopting appropriate breeding methodology.

Materials and method
The experimental material consisted of 10 parents and 45 hybrids derived through diallel mating design excluding reciprocal crosses were grown in a randomized block design with three replications at the Main Rice Research Centre, Navsari Agricultural University, Navsari during *Kharif* – 2015 for generating data pertaining to various quantitative and qualitative traits. Each entry was grown in a single row consist of 10 plant in each row with a spacing 30 × 10 cm. Observations were recorded from five randomly selected plants in each line for eleven characters *viz.*, Days to 50 per cent flowering, number of productive tillers per plant, plant height (cm), panicle length (cm), grains per panicle, grain yield per plant (gm), straw yield per plant (gm), test weight (gm), protein content (%), amylose content (%) and harvest index (%). The replication wise mean values obtained for each character were analyzed by the usual standard statistical procedure (Panse and Sukhatme, 1978) [2].

Statistical analysis
Heterosis: Heterosis, expressed as per cent increase or decrease in the mean value of F_1 hybrid over the mid and better parent (heterobeltiosis) was computed for

Heterosis (H_1) (%) = {(F_1 – MP)/ MP} x 100
Where, F1 = Mean performance of hybrid, MP = Mean performance of mid parent

Heterosis (H_2) (%) = {(F_1 – BP)/ BP} x 100
Where, F_1 = Mean performance of hybrid, BP = Mean variance of better parents (P_1 or P_2) of hybrid.

Results and Discussion

As regard to heterosis over mid parent and better parent a good number of hybrids registered significant heterosis in desired direction for different traits like, for days to 50 per cent flowering in 5 and 10 hybrids, plant height in 5 and 12 hybrids, straw yield per plant in 11 and 9 hybrids, grain yield per plant in 18 and 15 hybrids, number of productive tillers per plant in 11 and 4 hybrids, panicle length for 16 and 11 hybrids, grains per panicle for 31 and 27 hybrids, test weight in 3 and 3 hybrids, protein content in 25 and 14 hybrids, amylose content in 19 and 12 hybrids and harvest index in 2 and 1 hybrids, respectively.

With regard to days to 50 per cent flowering, 5 hybrids showed significant negative relative heterosis for earliness. The hybrid NAUR-1 × GNR-3 manifested numerically higher significant negative relative heterosis. 10 hybrids showed highly significant negative heterobeltiosis in desired direction for earliness. Negative heterosis indicated earliness compared to better parent. The hybrid, NAUR-1 × GNR-3 was manifested numerically higher negative heterosis over better parent (Table 1). The results were in accordance with findings of Roy *et al.* (2009) [12], Bagheri (2010) [4], Patil *et al.* (2012) [9] and Reddy *et al.* (2012) [11] as they reported high degree of heterosis for earliness in desired direction.

Table 1: Estimation of relative heterosis and heterobeltiosis for days to 50 per cent flowering, number of productive tillers per plant, plant height, panicle length and grains per panicle in rice

Crosses	Days to 50 per cent flowering		Number of productive tillers per plant		Plant height (cm)		Panicle length (cm)		Grains per panicle	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
IET 23998 X IET 24001	4.53 **	2.63 *	-22.23 **	-22.33 **	13.74	6.69	-3.25	-3.31	26.61 **	26.54 **
IET 23998 X IET 24002	-2.85 *	-4.02 **	-0.68	-24.67 **	8.35	2.22	-9.62	-12.74	4.05	-4.77 *
IET 23998 X IET 24021	0.79	0.59	-32.09 **	-38.44 **	-0.65	-7.32	4.05	-2.34	23.16 **	12.22 **
IET 23998 X IET 23448	5.39 **	3.04 **	4.82	-26.43 **	-13.66	-16.99 **	-2.08	-4.43	16.59 **	9.40 **
IET 23998 X IET 24025	11.67 **	8.94 **	-50.42 **	-50.72 **	19.57 **	13.78 *	-23.44 *	-34.58 **	-7.36 **	-9.19 **
IET 23998 X GR-7	26.45 **	23.89 **	-24.89 **	-36.02 **	-0.52	-5.92	14.69	-18.50 *	3.87	1.5
IET 23998 X NAUR-1	2.38 *	1.18	-23.99 **	-37.08 **	2.57	1.08	-15.48	-28.79 **	0.48	-3.05
IET 23998 X GNR-3	2.78 *	1.57	28.52 *	-27.14 **	-14.63 *	-15.36 *	42.69 **	11.57	24.61 **	20.00 **
IET 23998 X IR-28	2.54 *	-0.82	-30.12 **	-30.25 **	17.71 *	8.9	-1.12	-3.11	41.05 **	33.01 **
IET 24001 X IET 24002	5.76 **	5.11 **	14.92	-12.98 *	17.24 *	3.39	4.5	0.82	22.19 **	11.90 **
IET 24001 X IET 24021	6.17 **	4.03 **	-15.20 *	-23.25 **	-19.89 **	-20.31 **	5.58	-0.97	24.65 **	13.64 **
IET 24001 X IET 23448	12.86 **	12.40 **	-0.72	-30.43 **	12.28	1.03	-39.19 **	-40.69 **	-2.24	-8.21 **
IET 24001 X IET 24025	8.75 **	8.07 **	0.94	0.19	-16.08 *	-17.21 **	4.09	-11.12	40.40 **	37.70 **
IET 24001 X GR-7	-0.83	-1.03	-26.73 **	-37.69 **	5.68	-6.56	7.65	-23.58 **	3.02	0.73
IET 24001 X NAUR-1	3.29 **	0.2	-12.14	-27.38 **	-14.11 *	-18.18 **	37.75 **	15.97 *	15.06 **	11.07 **
IET 24001 X GNR-3	0.41	-2.59 *	150.78 **	41.90 **	6.33	0.66	31.39 **	2.65	33.53 **	28.67 **
IET 24001 X IR-28	4.24 **	2.71 *	-3.86	-4.17	18.22 *	2.13	4.92	2.73	44.75 **	36.42 **
IET 24002 X IET 24021	2.85 *	1.4	46.41 **	24.25 **	23.31 **	8.1	10.27	7.31	7.30 **	6.85 **
IET 24002 X IET 23448	5.39 **	4.31 **	14.76	7.76	14.45	12.37	0.05	-1	-7.40 **	-9.55 **
IET 24002 X IET 24025	6.25 **	4.94 **	-19.19 *	-38.24 **	28.47 **	15.02 *	-22.32 *	-30.98 **	-9.76 **	-15.63 **
IET 24002 X GR-7	-3.72 **	-4.51 **	-6.47	-15.52 *	8.26	8.01	40.91 **	4.63	10.64 **	3.77
IET 24002 X NAUR-1	2.03	-0.4	-13.61	-19.86 **	2.2	-5.07	-18.52	-28.58 **	-11.25 **	-15.66 **
IET 24002 X GNR-3	3.25 **	0.79	132.51 **	82.76 **	14.54	7.07	56.22 **	27.33 **	18.58 **	12.90 **
IET 24002 X IR-28	0.85	-1.24	-6.72	-29.08 **	10.33	8.31	-9.62	-10.92	39.60 **	19.92 **

Conti... Table 1

Crosses	Days to 50 per cent flowering		Number of productive tillers per plant		Plant height (cm)		Panicle length (cm)		Grains per panicle	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
IET 24021 X IET 23448	4.15 **	1.62	3.3	-18.44 **	20.22 *	-2.7	5.32	1.38	10.33 **	7.31 **

IET 24021 X IET 24025	4.17 **	1.42	-32.02 **	-37.98 **	-13.40 *	-16.60 **	20.30 *	10.09	18.98 **	10.74 **
IET 24021 X GR-7	2.07	-0.2	-12.91	-17.74 **	28.37 **	0.66	66.05 **	27.49 **	18.93 **	11.06 **
IET 24021 X NAUR-1	-2.77 *	-3.72 **	-8.59	-15.90 **	-2.64	-12.38	28.97 **	16.47 *	17.08 **	10.78 **
IET 24021 X GNR-3	-4.35 **	-5.28 **	60.38 **	3.63	-4.74	-15.29 *	28.96 *	8.47	7.50 **	1.9
IET 24021 X IR-28	2.12	-1.43	-15.79 *	-23.51 **	22.92 **	-7.52	-5.23	-9.14	11.90 **	-4.33 *
IET 23448 X IET 24025	9.17 **	8.94 **	29.47 **	-8.41	-3.37	-18.80 **	-3.11	-14.92	19.08 **	14.09 **
IET 23448 X GR-7	4.56 **	4.35 **	23.50 *	4.13	11.69	8.22	63.34 **	19.69 *	19.17 **	14.54 **
IET 23448 X NAUR-1	0.41	-3.01 **	24.69 *	8.14	4.2	-6.31	25.88 *	9.04	16.87 **	13.77 **
IET 23448 X GNR-3	4.56 **	1	17.62	-0.61	9.72	-0.16	-13.05	-30.01 **	-28.39 **	-30.16 **
IET 23448 X IR-28	10.17 **	9.01 **	48.33 **	4.37	3.61	-3.67	1.87	1.47	41.97 **	25.19 **
IET 24025 X GR-7	-0.83	-1.24	-33.41 **	-42.89 **	2.92	-16.20 *	4.32	-11.36	-9.77 **	-10.04 **
IET 24025 X NAUR-1	5.83 **	2.01	-0.8	-17.30 **	-1.15	-7.62	20.21	18.75 *	-11.30 **	-12.67 **
IET 24025 X GNR-3	0.42	-3.21 **	19.65	-31.58 **	11.55	3.01	31.09 **	21.26 *	8.37 **	6.50 **
IET 24025 X IR-28	2.54 *	1.68	-29.12 **	-29.41 **	8.24	-15.43 *	6.68	-6.73	16.59 **	7.65 **
GR-7 X NAUR-1	0	-3.20 **	-15.06 *	-17.15 **	-2.53	-15.08 *	60.90 **	38.64 **	18.64 **	17.18 **
GR-7 X GNR-3	1.24	-2	49.67 **	4.11	17.26 *	3.39	39.41 **	28.79 **	17.96 **	16.29 **
GR-7 X IR-28	-1.27	-2.51 *	-33.38 **	-43.13 **	9.7	5.26	2.26	-25.44 **	3.94	-4.34
NAUR-1 X GNR-3	-6.59 **	-6.59 **	65.99 **	19.19 *	-4.8	-5.94	42.73 **	33.76 **	-7.38 **	-7.55 **
NAUR-1 X IR-28	2.54 *	-2.02	-1.9	-18.61 **	21.05 *	1.19	21.79 *	5.03	19.86 **	8.84 **
GNR-3 X IR-28	8.47 **	3.64 **	124.09 **	27.38 **	10.82	-6.24	51.33 **	21.25 *	42.18 **	28.86 **

*, ** significant at 5% and 1% levels of probability, respectively. MP = Mid parent, BP = Better parent

With regard to number of productive tillers per plant, 11 hybrids gave significant positive result for relative heterosis. The highest estimate of relative heterosis was observed with hybrid IET-24001 × GNR-3. 4 hybrids gave significant positive results for heterobeltiosis. The hybrids showing highest percentage of heterosis over better parent was IET-24001 × GNR-3 (Table 1). Most of the crosses showed positive and significant estimates. Similar results were also reported by Reddy and Nerkar (1995) [10], Bagheri (2010) [4], Reddy *et al.* (2012) [11], Parihar and Pathak (2008) [8] and Roy *et al.* (2009) [12] in rice.

With regard to plant height, 5 hybrids showed significant negative relative heterosis for dwarfness. The hybrid, IET-24001 × IET-24021 manifested highest significant negative relative heterosis. The results for plant height indicated that 12 hybrids highlighted significant negative heterosis in desired direction over better parent as dwarfness is desirable for this trait. The hybrid, IET-24001 × IET-24021 was showed highest heterobeltiosis in negative direction (Table 1). The similar results were also reported by Venkatesan *et al.* (2008) [16] and Roy *et al.* (2009) [12].

With regard to panicle length, 16 hybrids showed significant positive relative heterosis. IET-24021 × GR-7 manifested significant positive relative heterosis. 11 hybrids expressed significant positive heterosis over better parent. The hybrid, GR-7 × NAUR-1 was exhibited highest heterobeltiosis for this character (Table 1). The similar results were also reported by Singh *et al.* (2007) [14], Roy *et al.* (2009) [12] and Bagheri (2010) [4].

With respect to grains per panicle, 31 hybrids showed significant positive heterosis over mid parent. IET-24001 × IR-28 was top ranking hybrid showing highly significant positive relative heterosis. 27 hybrids showed significant positive heterosis over better parent. IET-24001 × IET-24025 was top ranking hybrid showing highly significant positive heterobeltiosis (Table 1). The results were in agreement with the findings of Parihar and Pathak (2008) [8], Venkatesan *et al.* (2008) [16], Veeresha *et al.* (2013) [15] and Saleem *et al.* (2008).

Among 45 hybrids, 18 hybrids exhibited significant and positive estimates of relative heterosis for grain yield per plant. The best performing hybrid for this trait was IET-24001 × IR-28. 15 hybrids depicted significant positive relative heterosis as well as heterobeltiosis for grain yield per plant (Table 2). The results were in accordance with finding of Reddy and Nerkar (1995) [10], Singh *et al.* (2007) [14], Parihar and Pathak (2008) [8], Venkatesan *et al.* (2008) [16], Roy *et al.* (2009) [12], Bagheri (2010) [4], Reddy *et al.* (2012) [11], Latha *et al.* (2013) [7] and Kumar *et al.* (2010) [6].

For straw yield per plant, 11 hybrids exhibited significant positive relative heterosis. The hybrid IET-24001 × IET-24025 exhibited highest significant positive relative heterosis for this trait. The 9 hybrids showed significant positive heterosis over better parent. The hybrid, IET-24001 × IET-24025 exhibited highest significant positive heterobeltiosis for this trait (Table 2). Similar results have been reported by Aananthi and Jebaraj (2006) [3], Bagheri (2010) [4] and Kumar *et al.* (2010) [6].

For test weight, 3 hybrids exhibited significant and positive heterosis over mid parent. Whereas, hybrid IET-24001 × IET-24025 was recorded maximum heterosis over mid parent. 3 hybrids expressed significant positive heterobeltiosis. The hybrid, IET-24001 × IET-24025 was recorded maximum heterosis over better parent (Table 2). Positive heterosis for test weight was also reported by Singh *et al.* (2007) [14], Roy *et al.* (2009) [12], Patil *et al.* (2012) [9], Jarwar *et al.* (2013) [5], Latha *et al.* (2013) [7], Parihar and Pathak (2008) [8], Singh *et al.* (2007) [14] and Veeresha *et al.* (2013) [15].

For protein content, 25 hybrids showed highly significant heterosis over mid parent. The cross IET-24002 × GR-7 exhibited highest positive relative heterosis for this trait. 14 hybrids showed highly significant heterosis over better parent.

The cross IET-24025 × NAUR-1 exhibited highest positive heterobeltiosis for this trait (Table 2). Similar results were reported by Patil *et al.* (2012) [9].

For amylose content, 19 crosses depicted positive and significant heterosis over mid parent. The highest estimate was observed with hybrid IET-24021 × IR-28. 12 hybrids exhibited for highly significant heterosis over better parent. The hybrid IET-24021 × NAUR-1 was top in highest heterobeltiosis percentage (Table 2). The results were in accordance with Patil *et al.* (2012) [9].

With regards to harvest index, 2 hybrids exhibited significant positive relative heterosis. The hybrid GR-7 × GNR-3 was showed highest relative heterosis. Only one hybrid, GR-7 × GNR-3 was exhibited significant heterosis over better parent (Table 2). Similar results were found by Parihar and Pathak (2008) [8] and Kumar *et al.* (2010) [6].

In present study, the magnitude of the heterosis varied from hybrid to hybrid. The top hybrids *viz.*, IET 24001 × GNR-3, IET 24001 × IR-28 and IET 24002 × GNR-3 showed significant positive heterosis over better parent for grain yield per plant (Table 3). The hybrid IET 24001 × GNR-3 showed significant heterobeltiosis in desired direction for different traits *viz.*, days to 50 per cent flowering, number of productive tillers per plant, grains per panicle, grain yield per plant, straw yield per plant, test weight, protein content and amylose content, while hybrid IET 24001 × IR-28 showed significant heterobeltiosis in desired direction for days to 50 per cent flowering, grains per panicle, grain yield per plant, straw yield per plant and hybrid IET 24002 × GNR-3 was showed significant heterosis in desired direction for number of productive tillers per plant, panicle length, grains per panicle, grain yield per plant, test weight, and protein content (Table 3).

On the whole, considerable relative heterosis and heterobeltiosis observed for grain yield and other associated characters suggested the presence of large genetic diversity among the parents and also the unidirectional distribution of allelic constitution contributing towards desirable heterosis in the present material. The negative heterobeltiosis expressed by a number of crosses for characters such as days to 50 per cent flowering and plant height demonstrated that hybrids were superior to the parents for these traits and heterotic effects were in the desirable direction.

Table 2: Estimation of relative heterosis and heterobeltiosis for grain yield per plant, straw yield per plant, test weight, protein content, amylose content and harvest index in rice

Crosses	Grain yield per plant (g)		Straw yield per plant (g)		Test weight (g)		Protein content (%)		Amylose content (%)		Harvest index (%)	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
IET 23998 X IET 24001	71.10 **	23.24 *	44.73 **	13.13 *	-1.17	-3.36	1.91	-22.27 **	9.17 *	0.77	0.69	-2.73
IET 23998 X IET 24002	39.76 *	-5.05	24.68 **	10.83 *	-6.90 **	-7.70 **	-2.6	-19.61 **	6.94	6.03	3.29	0.95
IET 23998 X IET 24021	-28.13 **	-31.18 **	-15.52 *	-23.65 **	-4.2	-6.51 **	-17.58 **	-28.53 **	-2.65	-17.63 **	-6.06	-7.86
IET 23998 X IET 23448	9.83	-10.5	-19.26 **	-24.86 **	-6.44 **	-7.06 **	40.54 **	19.23 **	-14.61 **	-18.50 **	-4.25	-4.81
IET 23998 X IET 24025	-44.29 **	-45.48 **	13.54 *	3.88	-6.19 *	-9.85 **	28.05 **	3.22	14.39 **	11.26 **	-6.71	-7.94
IET 23998 X GR-7	-9.03	-27.05 **	7.26	-8.27	-2.04	-6.11 **	27.07 **	-10.16 **	16.59 **	15.58 **	-4.66	-5.38
IET 23998 X NAUR-1	-6.92	-29.61 **	0.25	-17.77 **	-11.24 **	-11.30 **	44.09 **	5.17 **	-24.02 **	-26.12 **	-5.14	-7.23
IET 23998 X GNR-3	2.82	-8.09	-2.16	-11.70 *	-1.26	-4.43 *	-35.61 **	-41.53 **	-15.83 **	-21.69 **	2.15	-4.25
IET 23998 X IR-28	85.38 **	26.29 **	26.78 **	11.16 *	-4.72 *	-5.26 **	-9.21 **	-20.70 **	-31.19 **	-35.26 **	-2.65	-5.86
IET 24001 X IET 24002	34.26 *	28.23 *	-9.57	-19.51 **	-3.52	-4.83 *	7.20 **	0.2	6.39	-0.89	8.68	7.45
IET 24001 X IET 24021	21.22	-17.39	10.07	-3.67	-2.82	-3.01	50.71 **	34.47 **	54.02 **	18.89 **	-2.58	-4.03
IET 24001 X IET 23448	0.44	-9.59	8.26	-8.12	-7.36 **	-10.02 **	5.72 *	-3.67	-10.61 **	-13.43 **	-2.47	-6.35
IET 24001 X IET 24025	90.19 **	40.76 **	54.27 **	33.31 **	9.55 **	7.70 **	0.85	-3.74	-7.17	-11.78 **	9.96	4.77
IET 24001 X GR-7	5.77	-3.37	31.44 **	21.45 **	-2.87	-4.76 *	16.32 **	9.36 **	-25.96 **	-32.30 **	-2.28	-4.86
IET 24001 X NAUR-1	26.61	21.72	16.64 *	11.95	-4.22	-6.28 **	-5.53	-8.85 **	16.12 **	4.00	8.03	6.74
IET 24001 X GNR-3	90.61 **	56.51 **	35.47 **	18.75 **	6.77 **	5.71 **	-12.43 **	-40.64 **	-12.19 **	-12.84 **	5.07	2.05
IET 24001 X IR-28	103.69 **	94.96 **	40.66 **	26.91 **	4.53	2.81	15.68 **	2.47	-3.75	-5.48	-3.48	-3.58
IET 24002 X IET 24021	98.68 **	27.49 **	-4.78	-6.21	4.53	2.9	13.07 **	8.24 **	39.24 **	16.66 **	-5.79	-6.12
IET 24002 X IET 23448	53.13 **	31.06 *	-8.29	-12.15 *	-6.39 **	-7.82 **	-18.22 **	-20.15 **	7.18	3.21	7.6	4.53
IET 24002 X IET 24025	3.93	-27.39 **	-14.48 *	-16.73 **	-4.18	-7.11 **	15.09 **	12.80 **	4.04	2.08	-7.93	-11.23 *
IET 24002 X GR-7	22.15	6.16	-7.95	-11.11	0.57	-2.76	61.31 **	41.18 **	15.93 **	13.93 **	5.36	3.78
IET 24002 X NAUR-1	6.9	-2.01	-9.47	-15.81 *	-9.85 **	-10.56 **	-60.38 **	-64.35 **	20.08 **	15.73 **	-8.21	-8.26
IET 24002 X GNR-3	101.40 **	56.67 **	3.61	2.19	6.62 **	4.11 *	14.31 **	-15.68 **	8.00 *	1.41	6.33	2.08
IET 24002 X IR-28	61.10 **	60.76 **	8.12	6.79	-5.09 *	-5.36 **	-10.59 **	-14.99 **	-11.39 **	-15.87 **	-6.61	-7.57
IET 24021 X IET 23448	-1.41	-23.68 **	-18.96 **	-21.15 **	-1.73	-4.75 *	-9.93 **	-11.65 **	47.35 **	18.17 **	9.25	6.52
IET 24021 X IET 24025	-32.17 **	-36.50 **	-15.55 *	-16.50 **	0.35	-1.16	16.12 **	8.85 **	54.28 **	26.44 **	-8.83	-11.78 *
IET 24021 X GR-7	13.5	-13.58	0.86	-4.11	1.12	-0.65	16.32 **	-3.05	39.20 **	18.97 **	7.42	6.18
IET 24021 X NAUR-1	56.17 **	11.91	5.35	-3.6	-1.7	-4.00 *	43.64 **	23.20 **	53.41 **	33.97 **	1.14	0.85
IET 24021 X GNR-3	16.5	-0.74	-8.01	-8.13	-0.4	-1.2	-13.31 **	-32.57 **	26.70 **	-1.3	8.88	4.14
IET 24021 X IR-28	28.62	-17.23	11.28	8.23	-2.7	-4.49 *	-26.62 **	-27.10 **	55.45 **	22.65 **	-0.53	-1.9
IET 23448 X IET 24025	21.12	1.22	16.43 *	14.59 **	0.26	-4.32 *	-18.57 **	-22.11 **	-3.62	-5.37	-7.06	-7.74
IET 23448 X GR-7	-0.02	-1.36	-6.77	-13.87 *	1.23	-3.65	47.21 **	25.44 **	8.11 *	2.25	0.77	-0.59
IET 23448 X NAUR-1	16.46	9.3	-5.5	-16.06 **	-7.20 **	-7.88 **	10.45 **	-3.19	-0.47	-7.75 *	-5.12	-7.77

IET 23448 X GNR-3	-24.96 *	-31.00 **	-19.85 **	-22.13 **	-8.06 **	-11.62 **	-23.76 **	-42.07 **	-38.38 **	-39.86 **	16.68 **	8.69
IET 23448 X IR-28	89.94 **	62.96 **	8.21	2.33	-2.03	-3.23	4.61 *	1.93	-0.85	-2.19	-3.62	-7.36
IET 24025 X GR-7	-20.08	-34.26 **	-4.95	-10.7	-3.71	-3.95	53.90 **	37.73 **	3.02	-0.69	-5.53	-7.49
IET 24025 X NAUR-1	56.41 **	21.45 *	2.7	-7.18	-0.82	-4.63 *	113.64 **	96.45 **	6.14	0.3	0.34	-3.2
IET 24025 X GNR-3	-6.8	-14.72	-17.54 **	-18.58 **	1.26	0.55	-19.34 **	-41.99 **	7.69 *	3.14	2.21	-5.53
IET 24025 X IR-28	77.19 **	24.14 *	7.99	3.83	0.34	-3.02	-19.60 **	-25.15 **	0.33	-2.86	-5.38	-9.74
GR-7 X NAUR-1	-0.53	-5.31	11.49	7.49	1.53	-2.63	20.86 **	17.86 **	7.9	5.85	-7.58	-8.91
GR-7 X GNR-3	35.69 **	22.94 *	20.36 **	14.60 *	-3.93	-4.84 *	-45.78 **	-66.10 **	11.93 **	3.18	17.30 **	10.84 *
GR-7 X IR-28	2.5	-10.71	-11.39	-13.33 *	-6.17 *	-9.54 **	8.92 **	-9.91 **	16.72 **	8.81 **	-6.56	-8.93
NAUR-1 X GNR-3	28.07 *	9.97	10.99	1.71	-1.24	-4.34 *	60.45 **	3.77 *	-16.81 **	-24.88 **	5.04	0.78
NAUR-1 X IR-28	25.99	15.75	1.77	-4.11	-7.22 **	-7.69 **	-6.67 *	-20.54 **	21.73 **	11.18 **	2.42	1.31
GNR-3 X IR-28	92.44 **	50.08 **	-2.78	-5.31	3.49	0.75	23.58 **	-3.10 *	2.28	1.21	9.32	6.07

*, ** significant at 5% and 1% levels of probability, respectively. MP= Mid parent, BP = Better parent

Table 3: Best crosses on the basis of their *per* se and heterotic performance for grain yield and related parameters

Sr. No.	Promising hybrids	Grain yield per plant (g)	Heterosis (%)		Significant heterosis in other traits in desired direction	
			Relative Heterosis	Heterobeltiosis	Relative Heterosis	Heterobeltiosis
1	IET 24001 X GNR-3	33.2	90.61**	56.51**	PT, PL,GP, TW, SY	DF, PT, GP, SY, TW, PC,AC
2	IET 24001 X IR-28	32.6	103.69**	94.96**	DF, PH, GP, SY, PC	DF, GP, SY
3	IET 24002 X GNR-3	32.1	101.40**	56.67**	DF, PT, PL, GP, TW, PC, AC	PT, PL, GP, TW, PC

*, ** significant at 5% and 1 % levels of probability, respectively

Note:-

DF- Days to 50% flowering	GP- Grains per panicle	PC- Protein content
PH- Plant height	SY- Straw yield per plant	AC- Amylose content
PT- No. of Productive tillers per plant	TW- Test weight	HI- Harvest index
PL- Panicle length		

Conclusion

From present investigation it is concluded that heterosis in both positive and negative direction is important based on character under study. For characters *viz.*, days to 50 per cent flowering and plant height negative heterosis is desirable whereas for characters *viz.*, number of productive tillers per plant, panicle length, grains per panicle, grain yield per plant, straw yield per plant, test weight, protein content, amylose content and harvest index positive heterosis is desirable. All the promising hybrids developed from 10 parents showed positive heterosis over their respective mid and better parents which supporting high relative heterosis and heterobeltiosis for yield and its components in rice.

From the results and discussion, it can be concluded that the highest extent of heterosis for grain yield per plant over mid parent was recorded in the hybrid IET-24001 × IR-28 followed by IET-24002 × GNR-3 and IET-24002 × IET-24021 and over better parent was recorded in the hybrid IET-24001 X IR-28, followed by IET-23448 X IR-28 and IET-24002 X IR-28. The hybrids which registered higher values of various heterotic effects for grain yield also exerted higher amount of heterotic effect for at least two yield contributing component characters, which support the combinational heterosis theory for grain yield in rice. In the present investigation, the expression of heterosis in high heterotic crosses for grain yield could be attributed to combined effect of heterosis for its major component characters.

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