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Selection of best gene pool combination of the basis of heterotic response analysis for grain yield and its contributing traits in Rice (*Oryza sativa* L.)

***Sonu Kumar[1], M. P. Chauhan[1], Amit Tomar[2]**

[1]Department of Genetics and Plant Breeding, N. D. University of Agriculture and Technology, Kumarganj, Ayodhya, U.P., India
[2]Department of Genetics and Plant Breeding, R. L. B. Central Agriculture University, Jhansi, U.P., India
***Corresponding email:** *nagarsonu72@gmail.com*

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Article Authors
Sonu Kumar, M. P. Chauhan, Amit Tomar
Corresponding Author Email
nagarsonu72@gmail.com

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ABSTRACT

The results were indicated that, out of sixty crosses, the most desirable five crosses showing high significant positive heterosis over better parent for grain yield per plant were IR 79156A X NDR 370132 (72.19%), IR 68888A X NDR 370132 (66.69%), IR 68897A X NDR 370131 (43.33%), IR 58025A X CR 2499 (40.71%) and IR 79156A X NDR 2701 (35.80%). Eighteen crosses showed positive and significant heterosis over standard variety and the best five crosses among them were IR 58025A X NDR 1127 (20.78%), IR 79156A X IR 27723 (14.87%), IR 68888A X IR 27723 (14.81%), IR 58025A X Sugandha 5 (12.84%) and IR 68897A X NDR 2701 (12.46%). The cross, IR 58025A X NDR 1127, showed highest mean performance (28.70g), heterobeltiosis (22.48%) and standard heterosis (20.78%) for grain yield per plant while highest yielding parent, NDR-359, produced mean grain yield 23.78 g.

KEYWORDS

Gene Pool Combination, Analysis, Heterosis, Heterobeltiosis, Mean Performance, Crosses, Rice

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Rice (*Oryza sativa* L.) is the most important staple food crop of the world. To focus attention on the importance of rice in global food security and the necessity to increase rice production and productivity, United Nations general assembly in 2002 declared to celebrate the year 2004 as "International year of rice (IYR 2004)" with the theme of "rice is life". Rice belongs to the family of grasses *i.e.*, Gramineae (Poaceae). The cultivated rice belongs to genus *Oryza* and there are about 24 species of rice distributed in tropical, sub-tropical and warm temperate regions of the world. Out of these, most commonly cultivated species are *Oryza sativa* and *Oryza glaberrima*.

The *Oryza sativa* is divided into three sub-species namely *indica*, *japonica* and *javanica*. Rice is rich in genetic diversity, with thousands of varieties grown throughout the world. Rice farming is practiced in several agro-ecological zones in India. No other country in the world has such diversity in rice ecosystems as India. Because cultivation is so widespread, development of four distinct types of ecosystems has occurred in India. These ecosystems are designated as irrigated rice eco system, rainfed upland rice eco system, rainfed lowland rice eco system and flood prone rice eco system. Irrigated ecosystems are the primary type found in East Asia and provide 75% of global rice production.

The exploitation of heterosis for improving yield potential of crop plants has emerged as one of the most outstanding contributions of science of genetics to agriculture. The term heterosis, first coined by (Shull, 1914), denotes superiority of F_1 hybrids over both of its parents in terms of yield or any other character. The assessment of nature and magnitude of heterosis for different characters serves in the identification of potential hybrid combinations for exploitation as hybrid varieties or breeding materials for isolating transgressive segregants for developing high yielding pure line varieties. Hybrid rice technology has also showed increased yield, farmer profitability and better adaptability to stress environments such as water scarce and with high yield potential for aerobic conditions would be one of the exciting research aspects to be carried out to overcome the existing water crisis in India in relation to agricultural production.

Materials and Methods

The experimental materials were consisting four CMS lines having the WA cytoplasmic background *viz*., IR 68885A, IR 58025A, IR 68897A, and IR 79156A used as lines and fifteen promising rice varieties *viz*., NDR 1126,NDR 1127, IR 27723, CR 2499, Sugandha 5, NDR 3112-1, NDR 2701, NDR 2702, NDR 2704, NDR 2706, NDR 370131, NDR 370132, NDR 370133, IR 87651 and NDR 2705 were used as testers, three checks (NDR 2064, NDR 2065 and NDR 359) were the experimental materials of this study. The crosses will be made into “line x tester” mating design (Kempthorne, 1957) to produce 60 crosses.

All the eighty two genotypes were sown in randomized block design (RBD) with three replications at the instructional farm, Department of Genetics and Plant Breeding, N. D. University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) India, during 2013 *kharif* season. A standard spacing of 15cm x 20cm was adopted for planting. Recommended packages of practices were followed during the crop growth period. Observations were recorded for twelve characters *viz*., days to 50% flowering, plant height (cm), panicle length (cm), effective tillers per plant, total no. of spikelets per panicle, total number of filled spikelets per panicle, total number of chaffy spikelets per panicle, spikelet fertility %, 100-grain weight (g), harvest index (%), length of spikelet (cm), breadth of spikelet (cm), grain yield per plant (g), days to 50% flowering, days to maturity, plant height, panicle bearing tillers per plant, panicle length, 1000 grain weight, spikelets per panicle, spikelet fertility (%), harvest-index (%), L/B ratio, grain yield per plant (g) and biological yield per plant (g). The heterosis was computed as per cent increase or decrease of the mean values of crosses (F_1’s) over better-parent (heterobeltiosis) and standard variety (standard heterosis) formula are suggested by (Fonseca and Patterson, 1968).

Results and Discussion

Heterosis was estimated as percent increase or decrease of F_1 value over better parent (BP) and standard variety (SV). NDR 359 was used as standard checks for all the characters. The estimates of heterobeltiosis and standard heterosis for twelve characters of sixty crosses are presented in table 1(a, b, c). Table 1 revealed that, out of sixty, fifty-nine hybrids exhibited negative and highly significant heterosis over BP. The most promising five hybrids showing negative and highly significant heterosis over BP among them were IR 68897A × IR 87651 (38.89) per cent, IR58025A X IR 87651 (37.50) per cent, IR 79156A X IR 87651 (-36.46) per cent, IR 58025A X NDR 2705 (-35.42) per cent and IR 68897A X NDR 370132 (-34.38) per cent. All sixty hybrids showed negative and highly significant heterosis over SV and the best five hybrids were IR 58025A X NDR 2701 (-42.57) per cent, IR 68897A X IR 87651 (-41.91) per cent, IR 79156A X NDR 2706 (-41.58) per cent, IR 58025A X IR 87651 (-40.59) per cent and IR 68888A X NDR 2706 (-40.26) per cent for early flowering. All the sixty hybrids exhibited negative and highly significant heterosis over BP.

The most promising five hybrids showing negative and highly significant heterosis over BP among them were IR 68897A X IR 87651 (-28.84) per cent, IR 58025A X IR 87651 (-28.31) per cent, IR 79156A X IR 87651 (-27.78) per cent, IR 68897A X NDR 370132 (-26.98) per cent and IR 58025A X NDR 2705 (-26.98) per cent. All the sixty hybrids showed negative and highly significant heterosis over SV, the best five hybrids were IR 79156A X NDR 2706 (-32.06) per cent, IR 58025A X NDR 2701 (-32.06) per cent, IR 68897A X IR 87651 (-31.55) per cent, IR 58025A X IR 87651 (-

31.04) per cent and IR 79156A X IR 87651 (-30.53) per cent for early maturity. Similar findings were also observed by (Alam *et al.*, 2004, Alam *et al.,* 2007, Bagheri and Jelodar, 2010, Adilakshmi and Reddy, 2011, Ashfaq *et al.*, 2013). Out of sixty hybrids, fifty-two hybrids exhibited negative and highly significant/significant heterosis over BP. The most promising five hybrids showing negative and significant heterosis over BP were IR 68897A X CR 2499-50 (-22.85) %, IR 68888A X NDR 2702 (-21.62) %, IR 68888A X Sugandha 5 (-11.09) %, IR 58025A X NDR 2705 (-10.45) % and IR 58025A X NDR 2704 (-10.02) %. Three hybrids possessed negative and significant heterosis over SV. The hybrids possessing superior negative heterosis over SV were IR 68897A X CR 2499-50 (-20.79) %, IR 68888A X NDR 2702 (-19.52) % and IR 68897A X NDR 1127 (-7.24) % for dwarf plant height.

The positive and significant value of heterobeltiosis was noted for eight crosses and the best five crosses in this respect were IR 79156A X IR 27723 (33.16) per cent, IR 58025A X NDR 2705 (23.79) per cent, IR 68897A X IR 27723 (20.26) per cent, IR 68897A X IR 87651 (19.58) per cent and IR 68888A X IR 27723 (19.10) per cent. Out of sixty crosses, 33 crosses exhibited significant and positive heterosis over SV. The best five crosses were IR 79156A X NDR 2706 (44.06) per cent, IR 58025A X NDR 1127 (40.90) per cent, IR 68888A X NDR 1126 (37.20) per cent, IR 68888A X NDR 2704 (35.62) per cent and IR 68897A X NDR 2701 (25.36) per cent for panicle bearing tillers per plant. Similar findings were also observed by Janardhanan *et al.*, 2001, Banumathi *et al.*, 2003, Eradasappa *et al.,* 2007, Dwivedi and Pandey, 2012, Gopikamman and Ganesh, 2013).

Three crosses exhibited positive and significant standard heterosis, these were IR 68897A X IR 27723 (14.07) per cent, IR 68888A X NDR 2701 (11.58) per cent and IR 58025A X NDR 370131 (10.21) per cent for panicle length. Highly significant or significant and positive heterosis over BP was shown by eight crosses, the best five crosses were IR 68888A X NDR 2705 (52.85)% , IR 68897A X NDR 370133 (14.82) %, IR 58025A X IR 87651 (14.62) %, IR 79156A X NDR 1126 (12.27) % and IR 58025A X NDR 2701 (11.44) %. Twenty crosses showed positive and highly significant or significant heterosis over standard variety.

Based on magnitude of heterosis over SV, the best five cross combinations were IR 79156A X NDR 1126 (32.26) %, IR 68888A X NDR 2706 (27.73) %, IR 58025A X NDR2701 (23.94) %, IR 68888A X NDR 2705 (23.10) % and 68897A X NDR 3112-1 (17.05) % for spikelets per panicle. Nineteen crosses recorded positive and highly significant or significant heterosis for spikelet fertility over better-parent, the best five cross combinations were IR 58025A X NDR 2702 (5.96) %, IR 68897A X NDR 2704 (5.24) %, IR 58025A X NDR 2705 (5.11) %, IR 79156A X IR 27723 (5.09) % and IR 58025A X NDR 1127 (4.66) %. Out of 60 cross combinations, none of the crosses expressed significant and positive heterosis over standard variety.

Out of sixty crosses, only sixteen crosses showed positive and significant heterobeltiosis and the best five cross combinations were IR 79156A X Sugandha 5 (37.13) per cent, IR 58025A X NDR 1127 (32.30) per cent, IR 68897A X NDR 2704 (31.78) per cent, IR 68888A X NDR 370133 (31.09) per cent and IR 68888A X CR 2499-50 (18.34) per cent for biological yield per plant. Out of 60 crosses, only one hybrid, IR 58025A X NDR 2705 (8.32) per cent exhibited positive and highly significant heterosis over SV. The heterosis over better parent for biological yield per plant ranged from -20.24 per cent (IR 68897A X CR 2499-50) to 101.77 per cent (IR 68897A X NDR 2702) with the mean heterosis of 39.32 per cent.

Out of 60 cross combinations, desirable positive and highly significant or significant heterosis were exhibited by thirty-one crosses over better-parent and the best five cross combinations among them were IR 68897A X NDR 2702 (101.77) per cent, IR 68888A X NDR 370132 (65.11) per cent, IR 79156A X NDR 370132 (54.02) per cent, IR 68897A X NDR 370132 (28.52) per cent, IR 58025A X CR 2499-50 (28.18) per cent. Seventeen cross combinations exhibit positive and significant heterosis over SV and the best five cross combinations among them were IR 68888A X NDR 1127 (22.70) per cent, IR 68888A X NDR 1126 (21.66) per cent, IR 58025A X Sugandha 5 (19.52) per cent, IR 58025A X NDR 1127 (19.10) per cent and IR 79156A X NDR 2702 (18.57) per cent. The heterobeltiosis for harvest-index varied from -0.23 % (IR 68888A x NDR 1126) to 13.99 % (IR 68888A X IR 87651) with the mean heterosis of 35.60 %.

Table 1(a). Extent of per cent heterosis over better parent (BP) and standard variety (SV-NDR 359) among 5 characters in rice

S. N.	Crosses	Days to 50% Flowering		Days to Maturity		Plant Height (Cm)		Panicle Bearing Tillers per Plant		Panicle Length (Cm)	
		BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
1.	IR 58025A X NDR 1126	-30.60**	-38.61**	-24.52**	-30.28**	-6.66**	13.71**	-1.05	-0.79	-0.01	-9.99**
2.	IR 68888A X NDR 1126	-30.60**	-38.61**	-24.52**	-30.28**	-9.69**	22.14**	7.00	37.20**	-8.77**	-24.08**
3.	IR 68897A X NDR 1126	-11.57**	-21.78**	-9.92**	-16.79**	-4.71**	10.94**	10.18*	14.25**	2.78	-8.46**
4.	IR 79156A X NDR 1126	-18.28**	-27.72**	-14.88**	-21.37**	-3.11	11.87**	1.79	20.32**	-0.49	-8.90**
5.	IR 58025A X NDR 1127	-9.15**	-14.85**	-6.95**	-11.45**	-3.25	3.84	13.38**	40.90**	5.04	-12.59**
6.	IR 68888A X NDR 1127	-7.14**	-9.90**	-5.47**	-7.63**	-6.39**	7.23**	-6.84	-6.60	-4.87	-20.83**
7.	IR 68897A X NDR 1127	-29.85**	-37.95**	-23.42**	-29.26**	-8.85**	-7.24**	-2.37	-2.11	10.69**	-7.89**
8.	IR 79156A X NDR 1127	-31.72**	-39.60**	-24.79**	-30.53**	-9.25**	1.42	5.26	5.54	2.94	-3.33
9.	IR 58025A X IR 27723	-30.60**	-38.61**	-23.97**	-29.77**	-6.80**	9.74***	6.68	22.16**	5.51*	-0.21
10.	IR 68888A X IR 27723	-32.09**	-39.93**	-25.07**	-30.79**	-4.58**	9.09**	19.10**	33.25*	3.61	0.27
11.	IR 68897A X IR 27723	-29.10**	-37.29**	-22.87**	-28.75**	-4.76**	3.60	20.26**	20.58**	6.91**	14.07**
12.	IR 79156A X IR 27723	-30.97**	-38.94**	-24.79**	-30.53**	-6.02**	7.62**	33.16**	33.51**	-0.11	-3.20
13.	IR 58025A X CR 2499-50	-20.52**	-29.70**	-16.99**	-22.90**	-5.41**	0.97	-6.84	-6.60	3.23	-13.36**
14.	IR 68888A X CR 2499-50	-18.28**	-27.72**	-14.88**	-21.37**	-5.58**	7.67**	4.74	5.01	20.28**	0.09
15.	IR 68897A X CR 2499-50	-31.72**	-39.60**	-24.79**	-30.53**	-22.85**	-20.79**	-1.58	-1.32	-9.48**	-24.67**
16.	IR 79156A X CR 2499-50	-26.69**	-39.27**	-19.94**	-30.53**	-5.48**	15.15**	-46.78**	6.86	-1.84	-11.63**
17.	IR 58025A X Sugndha 5	-24.70**	-37.62**	-18.77**	-29.52**	-9.01**	23.05**	-34.69**	31.13**	0.86	-28.18**
18.	IR 68888A X Sugndha 5	-9.02**	-23.43**	-6.09**	-17.56**	-11.09**	3.51	-47.31**	5.80	-1.20	-12.01**
19.	IR 68897A X Sugndha 5	-15.14**	-29.70**	-11.14**	-22.90**	-4.10*	10.73***	-44.02**	12.40**	0.50	-7.99**
20.	IR 79156A X Sugndha 5	-11.27**	-16.83**	-16.58**	-20.61**	-3.76*	3.28	-37.98**	24.54**	3.33	-14.39**
21.	IR 58025A X NDR 3112-1	-9.18**	-11.88**	-7.03**	-9.16**	-8.20**	5.14*	-58.74**	-17.15**	8.72**	-16.46**
22.	IR 68888A X NDR 3112-1	-24.30**	-37.29**	-19.06**	-29.77**	-1.90	-0.17	-51.51**	-2.64	5.79	-12.77**
23.	IR 68897A X NDR 3112-1	-27.49**	-39.93**	-19.65**	-30.28**	-3.87*	7.44**	-41.52**	17.41**	-1.64	-7.63**
24.	IR 79156A X NDR 3112-1	-27.09**	-39.60**	-19.94**	-30.53**	-3.80*	13.28**	-32.72**	35.09**	0.74	-4.72
25.	IR 58025A X NDR 2701	-30.68**	-42.57**	-21.70**	-32.06**	-4.95**	8.67**	-34.95**	30.61**	1.41	-1.87
26.	IR 68888A X NDR 2701	-24.30**	-37.29**	-18.48**	-29.26**	-6.03**	2.22	-47.17**	6.07	4.58*	11.58**
27.	IR 68897A X NDR 2701	-23.90**	-36.96**	-18.18**	-29.01**	-5.08**	8.70**	-32.59**	35.36**	0.36	-2.75
28.	IR 79156A X NDR 2701	-13.15**	-28.05**	-16.16**	-22.14**	-5.16**	1.25	-47.17**	6.07	14.81**	-3.64
29.	IR 58025A X NDR 2702	-14.74**	-29.37**	-10.85**	-22.65**	-4.39*	9.03**	-46.65**	7.12	25.86**	-3.98
30.	IR 68888A X NDR 2702	-27.09**	-39.60**	-19.94**	-30.53**	-21.62**	-19.52**	-39.95**	20.58**	7.88*	-14.86**
31.	IR 68897A X NDR 2702	-23.65**	-39.27**	-15.41**	-28.75**	-7.55**	12.63**	-48.70**	19.53**	-7.64**	-4.26
32.	IR 79156A X NDR 2702	-21.99**	-37.95**	-16.62**	-29.77**	-8.98**	23.10**	-48.81**	19.26**	-23.57**	-20.77**
33.	IR 58025A X NDR 2704	-8.24**	-22.77**	-6.09**	-17.56**	-10.02**	4.75*	-53.91**	7.39	-14.21**	-11.07**
34.	IR 68888A X NDR 2704	-8.71**	-27.39**	-6.95**	-21.63**	-8.82**	5.28**	-41.79**	35.62**	-10.67**	-7.39**
35.	IR 68897A X NDR 2704	-9.51**	-15.18**	-15.24**	-19.34**	-8.19**	-1.47	-43.49**	31.66**	-17.55**	-14.53**
36.	IR 97156A X NDR 2704	-6.46**	-9.24**	-6.25**	-8.40**	-3.12	10.97**	-60.48**	-7.92	-22.80**	-19.98**
37.	IR 58025A X NDR 2706	15.77**	-7.92**	-15.71**	-29.01**	-3.94*	-2.24	-60.25**	-7.39	-13.64**	-10.48**
38.	IR 68888A X NDR 2706	-24.90**	-40.26**	-16.92**	-30.03**	-2.94	8.48**	-42.24**	34.56**	-8.72**	-5.38*
39.	IR 68897A X NDR 2706	-23.24**	-38.94**	-16.92**	-30.03**	-3.33*	13.83**	-46.21**	25.33**	-7.59**	-4.20
40.	IR 79156A X NDR 2706	-26.56**	-41.58**	-19.34**	-32.06**	-4.75*	8.90**	-38.17**	44.06**	-9.11**	-5.79*
41.	IR 58025A X NDR 370131	-20.33**	-36.63**	-14.80**	-28.24**	-7.62**	0.49	-44.85**	28.50**	3.29	10.21**
42.	IR 68888A X NDR 370131	-24.07**	-39.60**	-17.82**	-30.79**	-3.27	10.77**	-43.49**	31.66**	-3.35	0.19
43.	IR 68897A X NDR 370131	-13.88**	-30.36**	-17.53**	-23.41**	-4.11*	2.37	-60.59**	-8.18	-10.25**	-6.96**
44.	IR 79156A X NDR 370131	-9.54**	-28.05**	-6.93**	-21.37**	-9.79**	2.87	-58.21**	-2.64	-17.24**	-14.21**
45.	IR 58025A X NDR 370132	-22.82**	-38.61**	-16.62**	-29.77**	-6.13**	-3.62	-58.03**	-2.22	-19.67**	-16.73**
46.	IR 68888A X NDR 370132	-34.03**	-37.29**	-26.19**	-29.01**	-4.89**	15.88**	-14.08**	-6.60	10.87**	-0.19
47.	IR 68897A X NDR 370132	-34.38**	-37.62**	-26.98**	-29.77**	-9.85**	21.91**	-5.97	20.58**	21.96**	-15.46**
48.	IR 79156A X NDR 370132	-15.63**	-19.80**	-11.90**	-15.27**	-9.75**	5.07*	13.35**	23.22**	12.70**	0.38
49.	IR 58025A X NDR 370133	-21.53**	-25.41**	-17.20**	-20.36**	-7.61**	6.68**	-9.15*	7.39	-1.04	-9.40**
50.	IR 68888A X NDR 370133	-11.81**	-16.17**	-16.67**	-19.85**	-6.67**	0.17	-1.27	22.69**	1.19	-16.16**
51	IR 68897A X NDR 370133	-6.46**	-9.24**	-5.47**	-7.63**	-7.69**	5.74**	-14.32**	-6.86	8.03*	-16.98**
52.	IR 79156A X NDR 370133	-32.64**	-35.97**	-24.60**	-27.48**	-5.40**	-3.73	-17.96**	-10.82*	4.50	-13.84**

53.	IR 58025A X IR 87651	-37.50**	-40.59**	-28.31**	-31.04**	-3.27	8.11**	5.34	14.51**	3.42	-2.88
54.	IR 68888A X IR 87651	-35.07**	-38.28**	-26.72**	-29.52**	-6.71**	9.85**	3.69	18.73**	1.40	-4.10
55.	IR 68897A X IR 87651	-38.89**	-41.91**	-28.84**	-31.55**	-2.00	12.04**	19.58**	33.77**	-0.65	-3.86
56.	IR 79156A X IR 87651	-36.46**	-39.60**	-27.78**	-30.53**	-4.07*	4.35*	2.18	11.08*	-2.02	4.54
57.	IR 58025A X NDR 2705	-35.42**	-38.61**	-26.98**	-29.77**	-10.45**	2.55	23.79**	34.56**	2.83	-0.35
58.	IR 6888A X NDR 2705	-23.96**	-27.72**	-19.05**	-22.14**	-4.41*	2.05	-16.50**	-9.23	3.52	-13.11**
59.	IR 68897A X NDR 2705	-25.35**	-29.04**	-19.84**	-22.90**	-6.29**	6.87**	-8.25	-0.26	16.74**	-10.94**
60.	IR 79156A X NDR 2705	-35.07**	-38.28**	-26.72**	-29.52**	-4.75*	-2.19	-8.98*	-1.06	12.78**	-11.00**
	Mean heterosis (%)	-9.64	-31.66	-8.67	-25.25	3.28	6.10	1.36	13.92	6.93	-8.32
	SE	1.04		1.08		1.82		0.59		0.70	
	No. of crosses with positive heterosis	1	0	0	0	0	51	16	42	34	8
	No. of crosses with negative heterosis	59	60	60	60	60	9	44	18	26	52
	Range of heterosis	-38.89-15.77	-42.57-(-7.92)	-28.84-(-5.47)	-32.06-(-7.63)	-22.85-(-1.90)	-20.79-23.10	-60.59-33.16	-17.15-44.06	-23.57-25.86	-28.18-14.07

Table 1(b). Extent of percent heterosis over better parent (BP) and standard variety (SV-NDR 359) among 4 characters in rice

S. N.	Crosses	Spikelets per Panicle		Spikelet Fertility (%)		1000-Grain Weight (g)		Biological Yield per Plant (g)	
		BP	SV	BP	SV	BP	SV	BP	SV
1.	IR 58025A X NDR 1126	-7.30**	9.18**	3.58**	0.63	0.00	-7.29*	14.55	-37.67**
2.	IR 68888A X NDR 1126	-11.10**	4.70**	2.47*	-1.85	-4.50	-21.36**	18.12**	21.66**
3.	IR 68897A X NDR 1126	-31.36**	-19.16**	-1.84	-9.38**	3.73	-14.71**	18.61**	-16.09**
4.	IR 79156A X NDR 1126	12.27**	32.23**	2.41	-3.39**	15.67**	1.02	15.07**	-7.12
5.	IR 58025A X NDR 1127	-35.58**	-24.13**	4.66**	-3.46**	32.30**	-2.05	16.16**	19.10**
6.	IR 68888A X NDR 1127	-4.83**	12.08**	1.36	-3.58**	0.00	1.92	15.85**	22.70**
7.	IR 68897A X NDR 1127	-9.57**	6.51**	1.08	-6.62**	-13.25**	-7.93**	25.02**	3.22
8.	IR 79156A X NDR 1127	-40.80**	-30.27**	3.79**	-3.20**	-20.39**	-22.63**	15.01**	8.24*
9.	IR 58025A X IR 27723	-33.39**	-21.55**	0.32	-6.27**	-6.32**	-5.24*	8.67*	9.12*
10.	IR 68888A X IR 27723	-20.02**	-5.80**	0.52	-6.52**	-1.53	-1.02	7.65	9.52*
11.	IR 68897A X IR 27723	-20.49**	-6.35**	0.84	-6.88**	7.22**	-8.82**	7.23	3.66
12.	IR 79156A X IR 27723	-33.58**	-21.78**	5.09**	-3.03**	-2.36	-10.10**	14.95**	10.06*
13.	IR 58025A X CR 2499-50	-16.67**	-1.86	-2.27	-6.42**	-12.46**	-25.45**	28.18**	-16.98**
14.	IR 68888A X CR 2499-50	-22.31**	-8.50**	2.74*	-5.22**	18.34**	3.96	8.48	-11.32**
15.	IR 68897A X CR 2499-50	-10.31**	5.63**	-2.39	-7.76**	-14.04**	-9.21**	-20.24**	-26.37**
16.	IR 79156A X CR 2499-50	-29.92**	-22.06**	-0.42	-3.26**	5.66*	-2.05	15.47*	-37.17**
17.	IR 58025A X Sugndha 5	-19.26**	-5.16**	-3.51**	-7.58**	-9.32**	-25.32**	16.05**	19.52**
18.	IR 68888A X Sugndha 5	-24.56**	-16.10**	-0.28	-7.94**	5.75*	-13.04**	8.62	-23.16**
19.	IR 68897A X Sugndha 5	-28.21**	-16.01**	-1.69	-7.26**	-1.61	-14.07**	14.68**	-7.43
20.	IR 79156A X Sugndha 5	-42.38**	-35.93**	1.18	-6.66**	37.13**	1.53	3.62	6.25
21.	IR 58025A X NDR 3112-1	4.47**	16.19**	-2.05	-6.82**	-0.25	1.66	8.26*	14.65**
22.	IR 68888A X NDR 3112-1	-30.89**	-23.14**	3.60**	-4.30**	-7.95**	-2.30	10.13*	-9.08*
23.	IR 68897A X NDR 3112-1	5.25**	17.05**	0.35	-6.41**	-8.82**	-11.38**	2.29	-3.73
24.	IR 79156A X NDR 3112-1	-29.17**	-21.23**	1.63	-5.05**	0.13	1.28	-1.57	-1.16
25.	IR 58025A X NDR 2701	11.44**	23.94**	3.45**	-3.81**	-7.38**	-6.91**	3.45	5.25
26.	IR 68888A X NDR 2701	-0.41	10.75**	-0.47	-8.09**	0.75	-14.32**	-0.29	-3.61
27.	IR 68897A X NDR 2701	-30.07**	-22.23**	3.37**	-4.62**	-5.56*	-13.04**	16.09**	11.15**
28.	IR 79156A X NDR 2701	-6.05**	4.48**	-2.27	-6.42**	6.16*	-9.59**	23.62**	-19.93**
29.	IR 58025A X NDR 2702	-4.69**	5.99**	5.96**	-2.26	-1.16	-13.17**	1.84	-16.74**
30.	IR 68888A X NDR 2702	-29.40**	-21.49**	-2.19	-7.58**	-18.04**	-13.43**	-18.10**	-24.40**
31.	IR 68897A X NDR 2702	-16.60**	-3.57*	2.42*	-0.50	-2.62	-9.72**	101.77**	9.78*
32.	IR 79156A X NDR 2702	-2.62**	14.40**	-1.46	-5.61**	-8.85**	-24.94**	15.42**	18.87**
33.	IR 58025A X NDR 2704	-26.44**	-14.95**	2.61*	-5.27**	5.60*	-13.17**	19.45**	-15.50**
34.	IR 68888A X NDR 2704	-6.92**	8.90**	0.23	-5.44**	-9.66**	-21.10**	19.16**	-3.82
35.	IR 68897A X NDR 2704	-49.43**	-41.52**	5.24**	-2.92*	31.78**	-2.43	1.13	3.70
36.	IR 97156A X NDR 2704	-5.22**	9.59**	-4.15**	-8.82**	2.38	4.35	6.39	12.68**

37.	IR 58025A X NDR 2706	-25.36**	-13.69**	0.81	-6.87**	-18.67**	-13.68**	-0.40	-17.77**
38.	IR 68888A X NDR 2706	10.47**	27.73**	2.04	-4.83**	-10.26**	-12.79**	15.95**	9.12*
39.	IR 68897A X NDR 2706	-23.16**	-11.15**	-1.10	-7.60**	0.13	1.28	6.55	7.00
40.	IR 79156A X NDR 2706	-20.52**	-8.10**	-0.46	-7.44**	-4.83*	-4.35	-1.33	0.39
41.	IR 58025A X NDR 370131	-3.35**	11.76**	1.81	-5.98**	15.34**	-1.92	11.52**	7.81
42.	IR 68888A X NDR 370131	-26.61**	-15.14**	2.11	-5.78**	2.64	-5.50*	6.68	2.14
43.	IR 68897A X NDR 370131	-28.43**	-17.24**	-2.73*	-6.86**	-3.90	-18.16**	28.52**	-16.76**
44.	IR 79156A X NDR 370131	-9.12**	5.08**	3.63**	-4.40**	0.87	-11.38**	3.19	-15.64**
45.	IR 58025A X NDR 370132	-26.44**	-14.95**	1.27	-4.30**	-28.93**	-24.94**	-10.77*	-17.63**
46.	IR 68888A X NDR 370132	2.13	-7.40**	1.71	-1.18	-6.34*	-13.17**	65.11**	-10.16*
47.	IR 68897A X NDR 370132	-10.19**	5.50**	2.93*	-1.41	0.93	-16.88**	12.86**	16.24**
48.	IR 79156A X NDR 370132	-1.55	1.01	2.99*	-4.92**	5.91*	-12.92**	54.02**	8.96*
49.	IR 58025A X NDR 370133	-26.77**	-14.32**	1.56	-4.18**	6.73*	-6.78**	15.95**	-6.41
50.	IR 68888A X NDR 370133	-15.69**	-27.35**	1.22	-6.63**	31.09**	-2.94	2.45	5.04
51.	IR 68897A X NDR 370133	14.82**	11.82**	-3.96**	-8.63**	-2.63	-0.77	11.12**	17.69**
52.	IR 79156A X NDR 370133	-40.88**	-50.53**	1.77	-5.99**	-2.77	3.20	3.35	-14.67**
53.	IR 58025A X IR 87651	14.62**	0.80	1.24	-5.58**	-18.03**	-20.33**	8.63	2.23
54.	IR 68888A X IR 87651	-25.83**	-19.94**	4.53**	-2.34*	-3.67	-2.56	1.39	1.81
55.	IR 68897A X IR 87651	-12.55**	-21.72**	-0.43	-7.41**	-3.44	-2.94	-18.57**	-17.15**
56.	IR 79156A X IR 87651	-6.88**	-12.69**	1.28	-6.48**	1.05	-14.07**	6.48	2.94
57.	IR 58025A X NDR 2705	-51.35**	-50.61**	5.11**	-3.02*	18.19**	8.82**	8.59*	3.97
58.	IR 68888A X NDR 2705	52.85**	23.10**	-3.28**	-7.39**	8.56**	-7.54**	17.96**	-23.60**
59.	IR 68897A X NDR 2705	-15.34**	-23.37**	3.74**	-4.31**	-1.60	-13.55**	1.09	-17.36**
60.	IR 79156A X NDR 2705	-21.06**	-35.64**	-3.44**	-8.76**	-23.24**	-18.93**	-9.06*	-16.05**
	Mean heterosis (%)	-4.81	-7.64	27.87	-5.36	25.10	-9.05	39.32	-2.67
	SE	0.70		2.46		1.05		2.36	
	No. of crosses with positive heterosis	9	23	40	1	27	10	51	31
	No. of crosses with negetive heterosis	51	37	20	59	33	50	9	29
	Range of heterosis	-51.35-52.85	-50.61-32.23	-4.15-5.96	-9.38-0.63	-28.93-37.13	-25.45-8.82	-20.24-101.77	-37.67-22.7

Table 1(c). Extent of per cent heterosis over better parent (BP) and standard variety (SV-NDR 359) among 3 characters in rice

S. N.	Crosses	Harvest Index (%)		L/B Ratio		Grain Yield per Plant (g)	
		BP	SV	BP	SV	BP	SV
1.	IR 58025A X NDR 1126	8.59**	-1.73	-0.25	-25.14**	24.07**	-38.97**
2.	IR 68888A X NDR 1126	-0.23	-15.98**	3.52	-11.96**	17.74**	2.05
3.	IR 68897A X NDR 1126	9.80**	1.42	-11.16**	-19.63**	30.43**	-14.86**
4.	IR 79156A X NDR 1126	9.10**	0.43	33.95**	-12.62**	25.75**	-6.68
5.	IR 58025A X NDR 1127	5.46*	1.46	22.17**	-6.26**	22.48**	20.78**
6.	IR 68888A X NDR 1127	2.07	-8.56**	6.48**	-6.26**	18.44**	12.18**
7.	IR 68897A X NDR 1127	2.92	-0.45	8.70**	-6.54**	28.74**	2.68
8.	IR 79156A X NDR 1127	6.18**	2.61	-6.05**	-14.39**	22.17**	11.03**
9.	IR 58025A X IR 27723	6.92**	-1.91	-0.50	-7.10**	16.20**	6.97*
10.	IR 68888A X IR 27723	6.99**	4.85*	-15.91**	-21.96**	15.17**	14.81**
11.	IR 68897A X IR 27723	9.17**	2.86	-5.66**	-11.21**	16.85**	6.43
12.	IR 79156A X IR 27723	8.85**	4.44*	2.67	-6.73**	25.20**	14.87**
13.	IR 58025A X CR 2499-50	9.79**	7.15**	-6.18**	-9.25**	40.71**	-11.07**
14.	IR 68888A X CR 2499-50	3.07	-2.25	2.80	-7.20**	11.73**	-13.43**
15.	IR 68897A X CR 2499-50	4.63	-5.87**	1.84	-6.73**	-16.54**	-30.68**
16.	IR 79156A X CR 2499-50	1.91	-7.77**	-0.50	-25.33**	17.80*	-42.06**
17.	IR 58025A X Sugndha 5	12.12**	-5.59*	8.68**	-7.57**	30.19**	12.84**
18.	IR 68888A X Sugndha 5	5.76*	-2.30	6.10**	-4.02*	14.89**	-25.00**
19.	IR 68897A X Sugndha 5	4.46	-3.84	49.57**	-2.43	19.91**	-11.01**
20.	IR 79156A X Sugndha 5	9.09**	4.95*	-1.83	-24.67**	13.05**	11.48**
21.	IR 58025A X NDR 3112-1	3.73	-7.07**	7.22**	-5.61**	12.43**	6.48

22.	IR 68888A X NDR 3112-1	2.50	-0.86	-0.98	-14.86**	12.75**	-10.07**
23.	IR 68897A X NDR 3112-1	7.84**	4.22	-9.54**	-17.57**	10.39**	0.32
24.	IR 79156A X NDR 3112-1	13.48**	4.11	-1.00	-7.57**	11.76**	2.89
25.	IR 58025A X NDR 2701	0.42	-1.59	-22.56**	-28.13	3.79	3.47
26.	IR 68888A X NDR 2701	10.92**	4.51*	-14.80**	-19.81**	10.40**	0.55
27.	IR 68897A X NDR 2701	5.65*	1.38	-18.31**	-25.79**	22.57**	12.46**
28.	IR 79156A X NDR 2701	9.90**	7.26**	-9.66**	-12.62*	35.80**	-14.17**
29.	IR 58025A X NDR 2702	4.26	-1.12	-17.49**	-25.51**	6.14	-17.76**
30.	IR 68888A X NDR 2702	8.04**	-2.80	-0.51	-8.88**	-11.50**	-26.50**
31.	IR 68897A X NDR 2702	12.61**	1.91	-0.87	-25.61**	27.47**	11.88**
32.	IR 79156A X NDR 2702	0.16	-15.65**	-13.85**	-26.73**	15.43**	0.04
33.	IR 58025A X NDR 2704	7.77**	-0.45	-11.05**	-19.53**	28.88**	-15.87**
34.	IR 68888A X NDR 2704	3.07	-5.12*	34.24**	-12.43**	22.85**	-8.82*
35.	IR 68897A X NDR 2704	6.55**	2.50	1.58	-22.06**	7.78*	6.29
36.	IR 97156A X NDR 2704	5.04*	-5.91**	-0.21	-12.15**	11.84**	5.92
37.	IR 58025A X NDR 2706	7.55**	4.03	0.87	-13.27**	7.23	-14.48**
38.	IR 68888A X NDR 2706	6.69**	3.10	0.31	-8.60**	23.71**	12.43**
39.	IR 68897A X NDR 2706	12.46**	3.17	-9.31**	-15.33**	19.84**	10.33**
40.	IR 79156A X NDR 2706	8.75**	6.57**	-20.95**	-26.64**	7.22*	6.89*
41.	IR 58025A X NDR 370131	6.22**	0.08	-1.29	-7.10**	18.31**	7.76*
42.	IR 68888A X NDR 370131	9.11**	4.69*	6.48**	-3.27	16.44**	6.83*
43.	IR 68897A X NDR 370131	11.49**	8.81**	-28.79**	-31.12**	43.33**	-9.41**
44.	IR 79156A X NDR 370131	7.86**	2.30	-5.80**	-14.95**	11.26*	-13.79**
45.	IR 58025A X NDR 370132	9.11**	-1.84	4.80*	-4.02*	-2.79	-19.26**
46.	IR 68888A X NDR 370132	0.84	-8.74**	14.57**	-14.02*	66.69**	-18.01**
47.	IR 68897A X NDR 370132	9.26**	-7.99**	-13.74**	-26.64**	23.41**	6.96*
48.	IR 79156A X NDR 370132	11.70**	3.18	-3.00	-12.24*	72.19**	12.40**
49.	IR 58025A X NDR 370133	7.99**	-0.59	38.68**	-9.53**	25.46**	-6.89*
50.	IR 68888A X NDR 370133	9.77**	5.61*	26.19**	-3.18	12.41**	10.84**
51.	IR 68897A X NDR 370133	5.96*	-5.08*	7.01**	-5.79**	17.76**	11.53**
52.	IR 79156A X NDR 370133	9.91**	6.31**	-22.50**	-33.36**	13.70**	-9.32**
53.	IR 58025A X IR 87651	8.05**	4.42*	4.51*	-4.77*	17.41**	6.71*
54.	IR 68888A X IR 87651	13.99**	4.58*	-8.31**	-14.39**	15.59**	6.41
55.	IR 68897A X IR 87651	9.19**	7.00**	0.10	-7.10**	-11.15**	-11.42**
56.	IR 79156A X IR 87651	6.96**	0.78	1.79	-4.21*	13.92**	3.76
57.	IR 58025A X NDR 2705	3.29	-0.89	2.06	-7.29**	12.32**	3.06
58.	IR 6888A X NDR 2705	7.81**	5.23*	-19.61**	-22.24**	27.13**	-19.65**
59.	IR 68897A X NDR 2705	3.57	-1.78	0.52	-9.25**	4.65	-18.91**
60.	IR 79156A X NDR 2705	6.07*	-4.58*	0.00	-8.41**	-3.50	-19.85**
	Mean heterosis (%)	35.60	-0.04	25.26	-13.81	49.03	-2.93
	SE	0.91		0.07		0.80	
	No. of crosses with positive heterosis	59	32	28	0	55	34
	No. of crosses with negetive heterosis	1	28	32	60	5	26
	Range of heterosis	-0.23-13.99	-15.98-8.81	-28.79-49.57	-33.36-(-2.43)	-16.54-127.47	-42.06-20.78

*, ** Significant at 5% and 1% probability levels, respectively

Out of sixty, 44 crosses exhibited positive and significant heterobeltiosis and the most promising ones among them were IR 68888A X IR 87651 (13.99) %, IR 79156A X NDR 3112-1 (13.48) %, IR 68897A X NDR 2702 (12.61) % IR 68897A X NDR 2706 (12.46) % and IR 58025A X Sugandha 5 (12.12) %. The heterosis for harvest-index over standard variety ranged from -15.98 % (IR 68888A X NDR 1126) to 8.81 % (IR 68897A X NDR 370131) with the mean heterosis of -0.04%. Out of sixty hybrids, 15 hybrids showed positive and significant heterosis over standard variety SV and the most promising ones among them were IR 68897A X NDR 370131(8.81) %, IR 79156A X NDR 2701 (7.26) %, IR 58025A X CR 2499-50 (7.15) %, IR 68897A X IR 87651(7.00) % and IR

79156A X NDR 2706 (6.57) %. Similar findings were also observed by (Joshi *et al.*, 2004, Liu *et al.*, 2004, Jayasudha and Sharma, 2010, Kumar and Saravanan, 2011, Latha *et al.*, 2013). For L/B ratio, the positive and significant estimates of heterobeltiosis were exhibited by fifteen crosses and the best five crosses among them were IR 68897A X Sugandha 5 (49.57) %, IR 58025A X NDR 370133 (38.68) %, IR 68888A X NDR 2704 (34.24) %, IR 79156A X NDR 1126 (33.95) % and IR 68888A X NDR 370133 (26.19) %.Out of 60 cross combinations, none of the crosses expressed significant and positive heterosis over standard variety. Out of sixty crosses, 51 showed positive and highly significant or significant heterosis over BP and the best five crosses among them were IR 79156A X NDR 370132 (72.19) per cent, IR 68888A X NDR 370132 (66.69) per cent, IR 68897A X NDR 370131 (43.33) per cent IR 58025A X CR 2499-50 (40.71) per cent and NDR 79156A X NDR 2701 (35.80) per cent.

Out of sixty cross combinations, twenty crosses showed positive and significant heterosis over SV and the best five crosses among them were IR 58025A X NDR 1127 (20.78) per cent, IR 79156A X IR 27723 (14.87) per cent, IR 68888A X IR 27723 (14.81) per cent, IR 58025A X Sugandha 5 (12.84) per cent and IR 68897A X NDR 2701 (12.46) per cent. These results are similar to (Yuan and Vimani, 1988, Rao and Kulkarni, 2004, Serial *et al.*, 2006, Mirarab *et al.*, 2011, Reddy *et al.*, 2013).

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