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Impact of Heterotic Potential in Rice (*Oryza sativa* L.) for Certain Yield and its Contributing Traits in Salt-Affected Soil

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was undertaken with the objectives to estimate genetic variability for yield and yield contributing components. The experimental materials of rice for this investigation comprised of 22 genotypes as lines (female) and three testers (male) *viz.,* Narendra Usar 3, NDR 359 and CSR 36. Each of the three testers was crossed with 22 lines during *Kharif,* 2013. The experiment was based on the evaluation of a line × tester set of 66 hybrids (F1s) along with their 22 parents and check varieties *viz.,* Narendra Usar 3 and Arize 6444, for twelve quantitative trait in

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salt affected soil in randomized block design with three replications. The analysis of variance revealed that all the treatments, parents, parent *vs* crosses, crosses, lines and lines x testers were highly significant for majority of the yield and its contributing traits indicated sufficient variation among the treatment/materials under study.In the present investigation, a wide range of variation in estimates of heterobeltiosis and standard heterosis in positive and negative directions was observed for grain yield per plant and its contributing components. In case of grain yield per plant heterobeltiosis ranged from -1.76 per cent (IR 47427-2B-2-2B-1-1× Narendra Usar 3)to 100.14 per cent (Kashturi Chandauli× NDR 359), standard heterosis over SV_1varied from -30.85 per cent (AGAMI MI× CSR 36) to 50.84 per cent (Kashturi Chandauli× NDR 359) while over it ranged from -3677 per cent (AGAMI MI× CSR 36) to 37.92 per cent (Kashturi Chandauli× NDR 359). Kashturi Chandauli× NDR 359, IR 74095 AC 5 × NDR 359, Narendra 6096 × NDR 359, Sarjoo 52 × Narendra Usar 3 and Kashturi Chandauli× Narendra Usar 3 were found highly significant over BP, while Kashturi Chandauli× NDR 359, IR 74095 AC 5 × NDR 359, Narendra 6096 × NDR 359, Sarjoo 52 × Narendra Usar 3 and Jaya × Narendra Usar 3 had highly significant over standard variety SV_1. Further Kashturi Chandauli × NDR 359, IR 74095 AC 5 × NDR 359, Narendra 6096 × NDR 359, Sarjoo 52 × Narendra Usar 3 and Jaya × Narendra Usar 3 were found to be highly significant over SV_2 for grain yield per plant. The estimates of heterosis were attributed to genetic interaction arising from both additive as well as high degree of non additive gene action for major physiological traits. Two physiological traits *viz.,* biological yield per plant and harvest index followed by spikelets per panicle, 1000- grain weight, L: B ratio and flag leaf area remained as major contributors to heterobiltiosis and standard heterosis. It reflects that emphasis should be given to select these traits to enhance the production and productivity in salt affected soil.

Keywords: Heterosis; heterobeltiosis; standard heterosis; yield; rice (Oryza sativa L.*).*

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the most valuable crop in the terms of its contribution to the diet and in value of food production in the developing countries. Rice is the major source of calories for more than half of the global population. More than 90 per cent of the world's rice is grown and consumed in Asia, known as rice bowl of the world, where 60 per cent of the earth's people and two third of world's poor live. At the current growth of population rice necessity increases dramatically, hence, it is challenging task to certifying food and nutritional security to the country. Therefore, enhancing productivity of rice through novel genetic approaches like hybrid rice was felt necessary. Exploitation of heterosis is considered to be one of the outstanding achievements of plant breeding India has the largest area 43.39 million hectare constituting 28.01% of the land under rice in the world and rank second in total production 111.50 million tonnes next to China (187.490 million tonnes) with an average productivity of 2804 Kg/hectare (Anonymous 2017-18).Uttar Pradesh is an important rice growing state in the country. The area and production of rice in this state is about 6.45 million hectares and 18.251millon tons respectively with the productivity of 4.95 tonnes/hectares (Uttar Pradesh directorate of agricultural ministry, 2017-18). The heterosis breeding has been extensively utilized in improving the yield potential through development of hybrid cultivars in most of the allogamous crops and some autogamous crops as well. The exploitation of heterosis for developing high yielding hybrid cultivars in rice has been limited due to its autogamous nature. The presence of high heterosis for economically important characters is not only useful for developing hybrids, synthetics or composites through exploitations of heterosis but also helps in obtaining transgressive segregants for development of superior homozygous lines. Therefore, for breaking the yield barrier level and make rice cultivation more attractive, it is now necessary to explore alternative approaches. Among the all possible alternatives, heterosis is an important approach for increasing rice production. Ithas not only contributed to food security, but has also benefited the environment (Directorate of Economics and Statistics, 2017). The various crop species in which hybrid varieties are used commercially,rice ranks very high. Heterosis has been commercially exploited in rice with a yield advantageof 20-25% over the best pure lines (Rather et al., 2001). Hybrids offer opportunity tobreak through the yield ceilings of semi dwarf rice varieties. Significant heterosis,heterobiltiosis and standard heterosis have been reported in rice by a number of workers Devarathinam (U.P. Directorate of

Agricultural Statistics Reports, 2017), Peng and Virmani, 1991,(Ali & Khan, 1995), Watanesk 1993, Zhang et al., 1994, Ali and Khan (Sriwastava et al., 2014), Rao et al., (Bisne et al., 2008), Mishra and Pandey, 1998, Dwivedi et al*.,* (Fonseca & Patterson, 1968), Li et al., (Jennings, 1967), Faizet al., 2006, Saleem et al., (Salem et al., 2008), Rashid et al., (Duvick, 1999), Rahimi et al*.,* (Devi et al., 2017). In the present study, the estimates of heterosis over better parents and standard varieties were calculated for 22 single way crosses and three way crosses to assess their genetic potential as breeding material.

2. MATERIALS AND METHODS

The material for present study comprised A line × tester set of 66 hybrids (F_1s) was derived by crossing 22 lines (female) with three higher yielding testers (male) *viz.,*Narendra Usae-3, NDR 359 and CSR 36. The twenty two lines are NDRK 50032, Narendra Usar 2009, NDRK 50005, Narendra Usar 2008, Narendra Usar 2, IR 45427-2B-2-2B-1-1, IR 66946-3R-178-1-1 (FL 478), AGAMI MI, AT 401, NDRK 50006, IR 74095 AC 5, KashturiChandauli, Deepak, CSR 10, Moti Gold, Improved Pusa Basmati 1, PusaSugandha 4, Pusa 1121, Jaya, Sugandha 3, Sarjoo 52 and Narendra 6093. The experiments were conducted at Research Farm of Genetics and Plant Breeding, Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya (U.P.) during Kharif, 2014. The material was sown in Randomized Block Design with three replications. Observations were recorded on 12 characters *viz.,* days to 50% flowering, flag leaf area (cm), plant height (cm), panicle bearing tillers per plant, panicle length (cm), spikelets per panicle, spikelet fertility (%),biological yield per plant (g), harvest index (%),L:B ratio, 1000-grain weight (g), and grain yield per plant. The data on different characters were utilized for the analysis of estimation of heterosis over better parent (heterobeltiosis) and standard heterosis (standard varieties, SV_1 = Narendra UsarDhan 3; SV_2 = Arize 6444), following Fonseca and Patterson, (Devi et al., 2017).

3. RESULTS AND DISCUSSION

Analysis of variance revealed highly significant differences for yield and its contributing components (Table 2). A wide range of variation in the estimates of heterobeltiosis and standard heterosis in positive and negative directions was observed for grain yield per plant (Table 1).The nature and magnitude of heterosis as well as direction of heterosis over batter parent and standerd variety seemed defer for different traits in various produced cross combinations. Days to 50% flowering has great significance in crop productivity and cropping system. For days to 50% flowering negative heterosis is desirable, because this will cause the hybrids to mature earlier as compare to its parents, thereby increasing their productivity per days and per unit area. Majority of the hybrids (30), (21) and (0) exhibited significant negative heterosis over BP, SV_1 (Narendra UsarDhan 3) and SV_2 (Arize 6444) with mean heterosis of -0.76, -0.03 and 0.34 per cent respectively. Five crosses for 50% flowering showed significantly desirable superiority over BP, SV_1 and SV_2 for earliness. These results are in agreement with those of other workers (Vemaet al., 2002) (Dwivedi et al., 1999). The early maturing hybrids in rice might be much useful for commercial point of view as the produce more grain yield per days and fit well in multiple cropping systems for irrigated rice (Verma et al,. 2002). More no of productive tillers per plant is generally associated with higher productivity. In this investigation the most desirable cross combinations were 39.39% BP; 74.24% over SV1 and 0% over SV2. Out of 66 hybrids tested, 57, 62 and 8 crosses expressed significantly positive heterosis over BP, SV_1 and SV_2 respectively, for spikelets per panicle. In general, the hybrids with greater yield also expressed high magnitude of heterosis for these traits except in a few Sugandh 3 x Narendra Usar 3, Sugandha 3 x NDR 359 and Narendra 9093 x NDR 359 similar results have been reported by (Verma et al,. 2002), (Dwivedi et al,. 1999), (Devarathinam at al,. 1984), (Li W et al,. 2002), (Kumari et al,. 2017), (Lokaprakash et al,. 1992), (Mitra et al,. 1962), (Rahimi et al,. 2010), (Rao et al,. 1996), (Rashid et al,. 2007), (Virmani et al,. 1993) and (Verma et al,. 2004).

In majority of the cases, 1000 seed weight has positive and significant association with grain yield per plant. Variable manifestation for heterosis concerning 1000 grain weight expressed very low to high in positive (32.03 to -18.50 and 26.86 to -12.39) as well as in negative (24.65 to -18.93%) directions over BP, SV_1 and SV_2 respectively, which is inconformity with those of (Verma et al,. 2002), (Dwivedi et al,. 1999), (Devarathinam at al,. 1984), (Dwivedi et al., 1999; Devarathinam, 1984). The maximum heterosis over BP, SV_1 and SV_2 was recorded in the cross combination KashturiChandauli x Narendra Usar 3, KashturiChandauli x NDR 359

Table 1. Estimate of per cent heterosis over better parent (BP) and standard varieties (SV_1 and SV_2) for 12 characters in rice

S. No.	Crosses	Days to 50% flowering			Panicle bearing tillers per plant			Spikelets per panicle		
		BP	SV_1	SV_2	BP	SV_1	SV_2	BP	SV_1	SV_2
1	NDRK 50032 x Narendra Usar 3	-3.32**	-4.90**	0.00	11.05	25.61**	-24.90**	17.68**	22.42**	-16.24**
2	NDRK 50032 x NDR 359	-3.63**	-4.58**	0.34	9.23	32.80**	-20.59**	26.34**	33.42**	-8.72**
3	NDRK 50032 x CSR 36	-6.62**	1.31	6.53**	-11.41	0.21	-40.08**	4.82	22.00**	-16.53**
4	Narendra Usar 2009 x Narendra Usar 3	-1.33	-2.94**	2.06*	13.04	0.45	-39.94**	25.27**	24.98**	-14.49**
5	Narendra Usar 2009 x NDR 359	-1.32	-2.29**	2.75**	-9.80	9.66	-34.43**	5.82*	11.75**	-23.54**
6	Narendra Usar 2009 x CSR 36	-3.69**	2.29**	7.56**	2.58	1.32	-39.42**	8.94**	26.79**	-13.25**
7	NDRK 50005 x Narendra Usar 3	-0.33	-1.96*	3.09**	0.20	0.66	-39.81**	13.36**	17.52**	-19.59**
8	NDRK 50005 x NDR 359	-4.95**	-5.88**	-1.03	5.98	28.85**	-22.95**	7.67**	13.70**	-22.21**
9	NDRK 50005 x CSR 36	-4.31**	1.63*	6.87**	24.18**	24.74**	-25.41**	8.98**	26.84**	-13.22**
10	Narendra Usar 2008 x Narendra Usar 3	-1.64*	-1.96*	3.09**	-7.75	-6.99	-44.38**	11.63**	11.79**	-23.52**
11	Narendra Usar 2008 x NDR 359	-0.33	-0.65	4.47**	-1.42	19.85**	-28.34**	2.87	8.63**	-25.68**
12	Narendra Usar 2008 x CSR 36	-3.69**	2.29	7.56**	25.52**	26.55**	-24.33**	10.98**	29.16**	-11.63**
13	Narendra Usar 2 x Narendra Usar 3	-4.32**	-5.88**	-1.03	-4.78	-1.69	-41.21**	-7.98**	-8.20**	-37.19**
14	Narendra Usar 2 x NDR 359	-0.99	-1.96*	3.09**	4.53	27.09**	-24.01**	-6.23*	-0.98	-32.25**
15	Narendra Usar 2 x CSR 36	-2.46**	3.59**	8.93**	-0.92	2.30	-38.83**	-6.30*	9.05**	-25.39**
16	IR 45427-2B-2-2B-1-1 x Narendra Usar 3	-1.66*	-3.27**	1.72*	9.85	-2.38	-41.63**	1.20	0.97	-30.92**
17	IR 45427-2B-2-2B-1-1 x NDR 359	-0.99	-1.96*	3.09**	-6.32	13.89*	-31.90**	13.26**	19.61**	-18.17**
18	IR 45427-2B-2-2B-1-1 x CSR 36	-5.54**	0.33	5.50**	4.00	2.71	-38.58**	-8.93**	5.99*	-27.48**
19	IR 66946-3R-178-1-1 (FL 478) x Narendra Usar 3	-0.33	-1.96*	3.09**	-1.95	3.16	-38.31**	25.24**	24.94**	-14.52**
20	IR 66946-3R-178-1-1 (FL 478) x NDR 359	0.00	-0.98	4.12**	8.52	31.94**	-21.11**	11.53**	17.78**	-19.42**
21	IR 66946-3R-178-1-1 (FL 478) x CSR 36	-6.15	-0.33	4.81**	6.64	12.21	-32.91**	14.53**	33.30**	-8.80**
22	AGAMI MI x Narendra Usar 3	-2.99**	5.88**	11.34**	13.55	0.90	-39.67**	5.67	5.42	-27.87**
23	AGAMI MI x NDR 359	-2.10**	6.86**	12.37**	-0.10	21.45**	-27.38**	16.80**	23.34**	-15.61**
24	AGAMI MI x CSR 36	-4.79**	3.92**	9.28**	10.49	9.12	-34.75**	10.69**	28.83**	-11.89**
25	AT 401 x Narendra Usar 3	-2.33**	-3.92**	1.03	18.59*	5.38	-36.99**	14.14**	13.88**	-22.09**
26	AT 401 x NDR 359	0.66	-0.33	4.81**	-1.59	19.65**	-28.46**	17.56**	24.15**	-15.06**

S. No.	Crosses	Days to 50% flowering			Panicle bearing tillers per plant			Spikelets per panicle		
		BP	SV_1	SV_2	BP	SV_1	SV_2	BP	SV_1	SV_2
27	AT 401 x CSR 36	-3.08**	2.94**	8.25**	6.70	5.38	-36.99**	15.90**	34.90**	-7.71**
28	NDRK 50006 x Narendra Usar 3	-0.33	-1.96*	3.09**	3.89	4.23	-36.68**	13.74**	20.63**	-17.47**
29	NDRK 50006 x NDR 359	-0.99	-1.96*	3.09**	12.95*	37.32**	-17.89**	18.92**	26.12**	-13.71**
30	NDRK 50006 x CSR 36	-4.00	1.96*	7.22**	40.97**	41.43**	-15.43**	18.01**	37.35**	-6.03**
31	IR 74095 AC 5 x Narendra Usar 3	-4.30	-5.56	-0.69	27.93**	31.03**	-21.65**	16.14**	15.89**	-20.73**
32	IR 74095 AC 5 x NDR 359	0.00	-0.98	4.12**	7.61	30.83**	-21.77**	19.21**	25.89**	-13.87**
33	IR 74095 AC 5 x CSR 36	-9.85**	-4.25**	0.69	27.77**	30.87**	-21.75**	10.94**	29.13**	-11.66**
34	KashturiChandauli x Narendra Usar 3	-4.78**	-2.29**	2.75**	23.17**	13.60*	-32.07**	12.12**	19.35**	-18.35**
35	KashturiChandauli x NDR 359	-4.46**	-1.96*	3.09**	4.23	26.72**	-24.23**	18.40**	26.04**	-13.77**
36	KashturiChandauli x CSR 36	-7.69**	-1.96*	3.09**	44.15**	42.38**	-14.87**	13.64**	32.26**	-9.51**
37	Deepak x Narendra Usar 3	-2.50**	1.96*	7.22**	13.01*	14.22*	-31.70**	13.86**	13.60**	-22.28**
38	Deepak x NDR 359	-1.88*	2.61**	7.90**	-6.05	14.22*	-31.70**	13.45**	19.81**	-18.03**
39	Deepak x CSR 36	-1.54*	4.58**	9.97**	15.45*	16.69*	-30.23**	8.89**	26.74**	-13.29**
40	CSR 10 x Narendra Usar 3	1.99	0.33	5.50**	16.12*	18.41**	-29.20**	16.92**	16.65**	-20.19**
41	CSR 10 x NDR 359	1.98	0.98	6.19**	0.78	22.52**	-26.74**	12.72**	19.03**	-18.56**
42	CSR 10 x CSR 36	0.31	6.54**	12.03**	10.88	13.07*	-32.39**	2.27	19.03**	-18.56**
43	Moti Gold x Narendra Usar 3	3.58**	3.92**	9.28**	8.40	27.39**	-23.89**	29.96**	53.36**	4.93*
44	Moti Gold x NDR 359	5.21**	5.56**	11.00**	13.15*	37.57**	-17.74**	32.38**	56.23**	6.89**
45	Moti Gold x CSR 36	-1.23	4.90**	10.31**	8.75	27.70**	-23.64**	27.32**	50.26**	2.80
46	Improved PB 1 x Narendra Usar 3	-0.30	8.50**	14.09**	24.91**	17.88**	-29.52**	30.13**	44.44**	-1.18
47	Improved PB 1 x NDR 359	-1.50*	7.19**	12.71**	-2.10	19.03**	-28.83**	38.73**	53.99**	5.36**
48	Improved PB 1 x CSR 36	1.50	10.46**	16.15**	18.85**	17.39**	-29.81**	28.21**	49.22**	2.09
49	PusaSugandha 4 x Narendra Usar 3	1.31	1.31	6.53**	22.19**	13.15*	-32.34**	40.51**	40.84**	-3.64
50	PusaSugandha 4 x NDR 359	5.23**	5.23**	10.65**	-0.17	21.37**	-27.43**	31.11**	38.46**	-5.27**
51	PusaSugandha 4 x CSR 36	-3.08**	2.94**	8.25**	22.89**	21.37**	-27.43**	31.27**	52.79**	4.53*
52	Pusa 1121 x Narendra Usar 3	1.66*	0.00	5.15**	8.97	19.85**	-28.34**	57.51**	57.14**	7.51**
53	Pusa 1121 x NDR 359	1.98*	0.98	6.19**	-1.05	20.30**	-28.07*	28.45**	35.65**	-7.19**
54	Pusa 1121 x CSR 36	-5.85**	0.00	5.15**	18.68**	30.54**	-21.95**	18.60**	38.04**	-5.56**
55	Jaya x Narendra Usar 3	1.33	-0.33	4.81..	14.38*	30.74**	-21.82**	16.40**	52.54**	4.36
56	Jaya x NDR 359	2.97**	1.96*	7.22**	21.06**	47.18**	-11.99**	18.96**	55.88**	6.65**
57	Jaya x CSR 36	-5.54**	0.33	5.55**	15.46**	31.98**	-21.09**	9.11**	42.98**	-2.17

S. No.	Crosses	Days to 50% flowering			Panicle bearing tillers per plant			Spikelets per panicle		
		BP	SV_1	SV_2	BP	SV_1	SV_2	BP	SV_1	SV_2
58	Sugandha 3 x Narendra Usar 3	1.31	0.98	6.19**	21.33**	16.89*	-30.11**	37.58**	37.26**	-6.09**
59	Sugandha 3 x NDR 359	2.62**	2.29**	7.56**	6.29	29.22**	-22.73**	45.81**	53.98**	5.35**
60	Sugandha 3 x CSR 36	-4.00**	1.96*	7.22**	15.44*	14.02*	-31.83**	17.93**	37.26**	-6.09**
61	Sarjoo 52 x Narendra Usar 3	4.97**	3.59**	8.93**	22.40**	34.77**	-19.42**	22.75**	57.24**	7.58**
62	Sarjoo 52 x NDR 359	1.98*	0.98	6.19**	6.46	29.43**	-22.61**	17.90**	51.03**	3.33
63	Sarjoo 52 x CSR 36	-4.31**	1.63*	6.87**	15.08*	26.72**	-24.23**	7.46**	37.65**	-5.82**
64	Narendra 6093 x Narendra Usar 3	0.33	-1.31	3.78**	11.07	29.70**	-22.45**	22.74**	25.08**	-14.43**
65	Narendra 6093 x NDR 359	-0.99	-1.96*	3.09**	-2.60	18.41**	-29.20**	32.69**	40.12**	-4.13*
66	Narendra 6093 x CSR 36	-7.38	-1.63*	3.44	17.60**	37.32**	-17.89**	12.18**	30.57**	-10.67**

**, ** Significant at 5 and 1 per cent probability levels, respectively*

S. No.	Crosses	Spikelet fertility			1000- grain weight (g.)			Grain yield per plant (g.)		
		BP	SV_1	SV_2	BP	SV_1	SV_2	BP	SV_1	SV_2
1	NDRK 50032 x Narendra Usar 3	7.67**	0.79	-3.98**	6.73**	11.08**	2.799	18.03**	-3.29	-11.57**
2	NDRK 50032 x NDR 359	3.02	0.55	-4.20**	9.10**	13.55**	5.07*	27.24**	4.26	-4.67
3	NDRK 50032 x CSR 36	7.02**	0.18	-4.56**	-4.57	10.05**	1.83	7.23*	-12.14**	-19.66**
4	Narendra Usar 2009 x Narendra Usar 3	7.15**	0.27	-4.47**	5.78*	2.28	-5.36*	19.61**	-5.40*	-13.51**
5	Narendra Usar 2009 x NDR 359	3.11	0.64	-4.11**	28.06**	24.67**	15.37**	26.34**	-0.61	-9.12**
6	Narendra Usar 2009 x CSR 36	3.97*	-2.71	-7.31**	-5.89*	8.52**	0.42	9.41**	-13.93**	-21.30**
7	NDRK 50005 x Narendra Usar 3	9.26**	1.88	-2.93	-0.42	5.67*	-2.21	30.94**	12.45**	2.81
8	NDRK 50005 x NDR 359	4.76**	2.25	-2.58	1.27	7.46**	-0.56	15.27**	-1.01	-9.49**
9	NDRK 50005 x CSR 36	11.03**	1.14	-3.64*	8.29**	24.88**	15.56**	22.41**	5.12	-3.88
10	Narendra Usar 2008 x Narendra Usar 3	8.34**	1.02	-3.75*	8.75**	15.53**	6.90**	17.75**	-1.79	-10.20**
11	Narendra Usar 2008 x NDR 359	1.60	-0.84	-5.52**	-5.15*	0.77	-6.75**	28.54**	7.21**	-1.98
12	Narendra Usar 2008 x CSR 36	11.34**	1.40	-3.40*	-2.45	12.50**	4.10	15.92**	-3.32	-11.60**
13	Narendra Usar 2 x Narendra Usar 3	-0.49	-7.21**	-11.60**	-5.59	-12.39**	-18.93**	15.59**	-8.58**	-16.42**
14	Narendra Usar 2 x NDR 359	1.51	-0.92	-5.60**	-1.94	-4.54	-11.66**	18.89**	-10.27**	-17.96**
15	Narendra Usar 2 x CSR 36	8.15**	-1.26	-5.93**	-18.50**	-6.601*	-13.03**	3.92	-21.57**	-28.29**
16	IR 45427-2B-2-2B-1-1 x Narendra Usar 3	6.43**	-0.76	-5.45**	9.82**	1.91	-5.70*	-1.76	-22.31**	-28.96**
17	IR 45427-2B-2-2B-1-1 x NDR 359	3.37*	0.89	-3.87*	4.72	1.95	-5.66*	23.40**	-7.10**	-15.06**
18	IR 45427-2B-2-2B-1-1 x CSR 36	9.38**	-0.22	-4.94**	1.18	16.68**	7.97**	30.62**	-17.91**	-24.94**
19	IR 66946-3R-178-1-1 (FL 478) x Narendra Usar 3	8.14**	0.83	-3.93*	10.78**	2.79	-4.88	11.64**	-6.28*	-14.31**
20	IR 66946-3R-178-1-1 (FL 478) x NDR 359	-0.03	-2.43	-7.04**	1.35	-1.33	-8.69**	24.68**	4.68	-4.29
21	IR 66946-3R-178-1-1 (FL 478) x CSR 36	9.92**	0.10	-4.63**	-4.46	10.18**	1.95	14.10**	-4.20	-12.41**
22	AGAMI MI x Narendra Usar 3	2.59	-4.33**	-8.86**	-0.43	-7.61**	-14.50**	4.29	-17.53**	-24.59**
23	AGAMI MI x NDR 359	4.11*	1.60	-3.18*	10.29**	7.37**	-0.64	15.18**	-13.29**	-20.72**
24	AGAMI MI x CSR 36	6.68**	-2.85	-7.44**	5.92	22.15**	13.03**	12.07**	-30.85**	-36.77**
25	AT 401 x Narendra Usar 3	5.34**	-1.77	-6.42**	2.63	9.50**	1.33	5.06*	-7.79**	-15.69**

S. No.	Crosses	Spikelet fertility			1000- grain weight (g.)			Grain yield per plant (g.)		
		BP	SV_1	SV_2	BP	SV_1	SV_2	BP	SV_1	SV_2
26	AT 401 x NDR 359	4.79**	2.28	-2.55	2.63	9.50**	1.33	24.11**	8.94**	-0.39
27	AT 401 x CSR 36	2.03	-6.28**	-10.71**	-14.01**	-0.84	-8.24**	20.24**	5.54*	-3.51
28	NDRK 50006 x Narendra Usar 3	9.24**	1.86	-2.95	3.54	4.98	-2.86	40.40**	20.57**	10.24**
29	NDRK 50006 x NDR 359	6.27**	3.72*	-1.18	-4.65	-3.32	-10.54**	27.58**	9.56**	0.18
30	NDRK 50006 x CSR 36	10.17**	0.74	-4.02**	-3.39	11.40**	3.09	11.44**	-4.29	-12.49**
31	IR 74095 AC 5 x Narendra Usar 3	7.48**	1.59	-3.21	3.28	2.20	-5.53	23.89**	8.56**	-0.74
32	IR 74095 AC 5 x NDR 359	1.80	-0.64	-5.33**	19.71**	18.45**	9.61**	64.19**	43.87**	31.55**
33	IR 74095 AC 5 x CSR 36	7.47**	1.58	-3.22*	3.01	18.79**	9.92**	37.08**	20.12**	9.83**
34	KashturiChandauli x Narendra Usar 3	3.87*	-0.22	-4.93**	32.03**	22.51**	13.37**	60.73**	27.12**	16.23**
35	KashturiChandauli x NDR 359	0.71	-1.71	-6.35**	30.30**	26.86**	17.39**	100.14**	50.84**	37.92**
36	KashturiChandauli x CSR 36	5.58**	1.43	-3.36**	-11.70**	1.83	-5.77*	51.06**	13.85**	4.10
37	Deepak x Narendra Usar 3	5.22**	-1.89	-6.53**	26.43**	27.21**	17.72**	41.98**	15.14**	5.28*
38	Deepak x NDR 359	1.28	-1.15	-5.82**	24.96**	25.73**	16.35**	29.20**	4.78	-4.20
39	Deepak x CSR 36	4.00*	-3.38*	-7.94**	9.03**	25.73**	16.35**	29.20**	4.78	-4.20
40	CSR 10 x Narendra Usar 3	4.36*	-2.13	-6.75**	17.15**	19.07**	10.18**	20.10**	6.11*	-2.98
41	CSR 10 x NDR 359	1.04	-1.38	-6.04**	14.53**	16.41**	7.72**	23.45**	9.07**	-0.27
42	CSR 10 x CSR 36	4.36	-2.13	-6.75**	4.79*	20.85**	11.83**	23.45**	9.07**	-0.27
43	Moti Gold x Narendra Usar 3	3.51*	-1.13	-5.81**	19.18**	10.59**	2.34	40.35**	11.00**	1.49
44	Moti Gold x NDR 359	1.29	-1.13	-5.81**	4.49	1.73	-5.86*	30.19**	2.12	-6.63**
45	Moti Gold x CSR 36	3.51*	-1.13	-5.81**	8.71**	25.37**	16.01**	49.07**	16.92**	6.90**
46	Improved PB 1 x Narendra Usar 3	3.65*	-3.35*	-7.92**	-5.08	-11.92**	-18.50**	28.21**	1.39	-7.29**
47	Improved PB 1 x NDR 359	1.31	-1.12	-5.79**	-16.36**	-18.57**	-24.65**	58.28**	19.15**	8.95**
48	Improved PB 1 x CSR 36	7.35**	-2.23	-6.85**	22.98**	-11.18**	-17.81**	37.11**	-1.57	-10.00**
49	PusaSugandha 4 x Narendra Usar 3	4.29*	-0.26	-5.16**	7.95**	0.25	-7.23**	51.43**	19.76**	9.50**
50	PusaSugandha 4 x NDR 359	-1.06	-3.43*	-8.00**	-0.52	-3.15	-10.38**	58.93**	19.76**	9.50**
51	PusaSugandha 4 x CSR 36	3.51*	-1.20	-5.87**	-13.07**	0.25	-7.23**	58.93**	19.76**	9.50**
52	Pusa 1121 x Narendra Usar 3	5.97	-1.19	-5.86**	6.47*	-0.34	-7.78**	54.42**	26.01**	15.21**
53	Pusa 1121 x NDR 359	0.09	-2.31	-6.92**	7.53**	4.68	-3.13	59.86**	30.45**	19.27**
54	Pusa 1121 x CSR 36	4.79**	-2.31	-6.92**	-10.38**	3.35	-4.36	54.42**	26.01**	15.21**
55	Jaya x Narendra Usar 3	7.32**	3.69*	-1.21	0.48	-6.77*	-13.73**	55.26**	33.50**	22.06**

S. No.	Crosses	Spikelet fertility			1000- grain weight (g.)			Grain yield per plant (g.)		
		BP	SV_1	SV_2	BP	SV_1	SV_2	BP	SV_1	SV_2
56	Jaya x NDR 359	4.71**	2.20	-2.63	5.33	2.54	-5.11*	51.64**	30.39**	19.22**
57	Jaya x CSR 36	3.54*	0.04	-4.69**	-8.78**	5.20	-2.65	48.20**	27.**	16.51**
58	Sugandha 3 x Narendra Usar 3	5.15**	-1.20	-5.87**	4.49	-3.04	-10.28**	51.45**	19.78**	9.51**
59	Sugandha 3 x NDR 359	3.89*	1.40	-3.39*	-7.69**	-10.13**	-16.84**	58.52**	19.48**	9.24**
60	Sugandha 3 x CSR 36	8.71**	2.15	-2.68	-10.16**	3.60	-4.13	53.02**	15.33**	5.24**
61	Sarjoo 52 x Narendra Usar 3	5.70**	3.41*	-1.47	13.41**	5.23	-2.62	61.61**	35.89**	24.25**
62	Sarjoo 52 x NDR 359	2.28	0.06	-4.67**	8.09**	5.23	-2.60	56.33**	31.45**	20.19**
63	Sarjoo 52 x CSR 36	2.66	0.44	-4.31**	12.59**	0.80	-6.73**	51.05**	27.01**	16.13**
64	Narendra 6093 x Narendra Usar 3	2.45	-4.46**	-8.98**	17.83**	9.34**	1.18	38.35**	17.48**	7.42**
65	Narendra 6093 x NDR 359	2.07	-0.37	-5.08**	8.66**	5.79*	-2.11	62.75**	38.20**	26.36**
66	Narendra 6093 x CSR 36	5.27**	-3.35*	-7.92**	-13.52**	-0.27	-7.71**	52.29**	29.32**	18.27**

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

Table 2. Analysis of variance for randomized block design for 12 characters in rice

Characters	Source of variation		
d. f.	Replications 2	Treatments 90	Error 180
Days to 50% flowering	0.27	50.98**	1.03
Flag leaf area(cm^2)	4.62*	156.53**	1.06
Plant height (cm)	0.84	131.01**	1.31
Panicle bearing tillers per plant	0.04	4.16**	0.42
Panicle length(cm)	1.91	25.15**	0.89
Spikelets per panicle	36.28	2279.06**	23.96
Spikelet fertility(%)	0.98	34.45**	3.06
Biological yield per plant (g)	17.42*	352.67**	4.01
Harvest-index (%)	3.29	19.77**	1.95
L/B Ratio	0.01	2.74**	0.00
1000- grain weight (g)	0.04	22.17**	0.54
Grain yield per plant (g)	0.71	64.52**	0.53

, Significant at 5% and 1% probability levels, respectively* and Improved Pusa Basmati 1 x NDR 359while minimum heterosis was found in case of Narendra Usar 3 x CSR 36 over BP, SV_1 Narendra Usar 2 x Narendra Usar 3 and Narendra Usar 2 x Narendra Usar 3 SV_2.Grain yield, being a complex trait, is the end product with multiplicative product of several basic components of grain yield. The extent of heterosis over BP, SV_1 and SV_2 for this trait varied from -1.76 to 100.14, -30.85 to 50.84 and -36.77 to 37.92 per cent exhibiting desirable and highly significant heterosis in 63, 37 and 26 hybrids respectively. Among these top 5 promising hybrids *viz*., Kashturi Chandauli x NDR 359, IR 74094 AC 5 x NDR 359, Narendra 6093 x NDR 359, Sarjoo 52 x Narendra Usar 3 and Kashturi Chandauli x Narendra Usar 3 were recorded to exhibit more than 20 % heterosis over BP, Kashturi Chandauli x NDR 359, IR 74094 AC 5 x NDR 359, Narendra 6093 x NDR 359, Sarjoo 52 x Narendra Usar 3 and Jaya x Narendra Usar 3 SV_1 and Kashturi Chandauli x NDR 359, IR 74094 AC 5 x NDR 359, Narendra 6093 x NDR 359, Sarjoo 52 x Narendra Usar 3 and Jaya x Narendra Usar 3 SV_2respectively. It reflects the presence of exploitable heterosis for this trait among the several hybrids. Similar findings have been recorded by various rice breeders (Verma et al,. 2002), (Devarathinam at al,. 1984), (Li W et al,. 2002), (Kumari et al,. 2017), (Lokaprakash et al,. 1992), (Mitra et al,. 1962), (Rahimi et al,. 2010), (Rao et al,. 1996), (Rashid et al,. 2007), (Virmani et al,. 1993) and (Verma et al,. 2004), (Venkatesan et al,. 2019) and (Rasheed et al,. 2021).

4. CONCLUSION

It can be concluded that the observed stronger heterosis can be exploited in the crosses for grain yield Kashturi Chandauli x NDR 359, Kashturi Chandauli x NDR 359 and Kashturi Chandauli x NDR 359. The substantial heterosis obtained in these cross combinations is attributed to non-additive gene action i.e. additive x dominance and dominance x dominance types for high grain yield. It reflects that the concentration of desirable genes attributed by divergent parents as involved in certain cross combinations, may be rewarding for heterosis breeding to sustain the production and productivity of salt affected soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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