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Effects of Heterosis for Yield and Yield Contributing Characters in Rice (*Oryza sativa* L.) under Sodic Soil

Durgesh Kumar Shukla[1], S. N. Singh[1], S. C. Gaur[1*] and Anil Kumar[2]

[1]Department of Genetics and Plant Breeding, Baba Raghav Das P.G. College, Deoria, U.P., India.
[2]Department of Plant Breeding and Genetics, B.A.C., B.A.U., Sabour-813210, Bihar, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author DKS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SNS and SCG managed the analyses of the study. Author AK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The current experiment was conducted to know the genetic architecture of 12 physio-morphological traits under sodic soil through Line × Tester analysis.
Study Design: The experiment was laid out in randomized complete block design with three replications adopting a recommended spacing of 20 x 15 cm in the field. Recommended package of practices was followed to establish the crop.
Place and Duration of Study: Present investigation was conducted at Farmer Field of village Amwa Bhaluhi of Bhathat Block District: Gorakhpur, India.
Methodology: The hybrids along with parental lines and checks were evaluated through Line × Tester analysis. Lines were used as female while testers were used as male parents where the climate is semi-arid with hot summer and cold winter (sub-tropical) and the soil of experimental field was sodic [ECe = 2.21 (dSm-1); pH =9.2]. The water used for irrigating the experimental field was taken from the bore well with pH 9.00 and RSC is 10 meq/L.
Results: An outset on perusal of data for hybrids based on the cross combinations Jhona x Pusa 169 resulted from crossing between parents having high genetic distance showed high positive significant standard heterosis for seed yield. However, the crosses viz., Shriram 434 x PB 1,

**Corresponding author: E-mail: scgaur10@gmail.com;*

Halchal x IR 24, Magic x Pusa 169 and Super Moti x Pusa 169, gives sparingly high significant negative standard heterosis for seed yield although their parents having high genetic distance.
Conclusion: These cross combinations merit consideration for extensive testing across space and time in the target environment to verify their suitability for commercial exploitation. The reason for this could have been the linkage of alleles in repulsive phase for biomass and yield. As there was dominance gene action involved, inter se matings followed by recombination breeding might be advocated for the improvement of yield under sodicity. The cross combinations Jhona x Pusa 169 emerged as lines to be recommended for exploitation in hybridization programme to enhance the production and productivity of sodic soil.

Keywords: Heterosis; parents and Line × tester analysis.

1. INTRODUCTION

Rice (*Oryza sativa* L.) being the staple food for more than 70 per cent of our national population and source of livelihood for 120-150 million rural households is backbone to the Indian Agriculture. It is grown under a wide range of agro-climatic conditions. A total of 800 million hectares of land throughout the world are salt-affected either by salinity (397 million ha) or the associated condition of sodicity (434 million ha).Soil salinity negatively affects agricultural production worldwide [1]. In India, 6.73 million hectare under salt-affected area [2]. 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 [3]. The rapidly increasing demand due to ever increasing Indian population has forced us to search for another quantum jump in rice production. The projection of India's rice production target for 2020 AD is 120 million tonnes, which can be achieved only by increasing the rice production by over 2.0 million tones/year in the coming decade [4].

This has to be done through either improving health of problematic soil or develop stress free varieties under-exploited stress environments. Thus, the present investigation covered the adoption of high yielding rice varieties to various stress environments and unutilized lands such as sodic soil would be an important strategy to meet this challenge. Salinity affects rice growth in varying degrees at all stages starting from germination to maturation [5].

Considering the wide importance of rice cultivation under salt-affected environment, the present study was undertaken to access the effects of heterosis for genetic diversity of rice germplasm accessions and identification of better accessions for yield and yield attributing traits under sodic condition for sustainability.

2. MATERIALS AND METHODS

The present investigation was conducted at Farmer Field of village Amwa Bhaluhi of Bhathat Block District: Gorakhpur, where the climate is semi-arid with hot summer and cold winter (sub-tropical) and the soil of experimental field was sodic in nature [ECe = 2.21 (dSm-1); pH =9.2]. The water used for irrigating the experimental field was taken from the bore well with pH 9.00 and RSC is 10 meq/L. The hybrids along with parental lines and checks were evaluated during Kharif, 2015. Lines were used as female whereas testers as male parents. The experiment was laid out in randomized complete block design with three replications adopting a recommended spacing of 20 x 15 cm in the field. Recommended package of practices was followed to establish the crop. Ten plants were selected randomly from each entry in each replication to record data on 12 traits viz., Days to maturity, Plant height (cm), Panicle bearing tillers per plant, Panicle length (cm), Spikelets per panicle, Spikelet fertility (%), 1000-grain weight (g), Biological yield per plant (g), Harvest-index (%), L/B ratio and Grain yield per plant (g). The magnitude of heterosis in F1s was estimated in relation to better parent and the checks as percent increase or decrease of F1 over better parent (Heterobeltiosis) and the checks (standard/useful/commercial heterosis) by following the procedures out-lined [6].

$$\text{i). Heterobeltiosis} = \frac{(F_1 - BP)}{BP} \times 100$$

Where,

F1 = Mean performance of single cross.
BP = Mean performance of better parent.

$$\text{ii). Standard heterosis} = \frac{(F_1 - SC)}{SC} \times 100$$

Where,

SC = Mean performance of the standard check
Further, the significance was tested using t-test suggested by Snedecor and Cochran (1967) as follows;

$$\text{Heterobeltiosis 't cal'} = \frac{(F1 - BP)}{\sqrt{2EMS/r}}$$

$$\text{Standard heterosis 't}_{cal}\text{'} = \frac{(F_1 - MP)}{\sqrt{3EMS/2r}}$$

$$\text{Standard heterosis 't cal'} = \frac{(F1 - SC)}{\sqrt{2EMS/r}}$$

Where,

EMS = Error mean squares in the ANOVA table.
r = Number of replications.

Calculated 't' values were compared with table value of 't' at the respective error degrees of freedom.

3. RESULTS AND DISCUSSION

Out of 45 crosses 23 crosses over better parent and 17 crosses over standard variety exhibited significant positive heterosis during 2015. The cross RHR27 x PB-1 exhibited maximum heterosis over better parent (18.61%) and over standard variety (12.97%), respectively during 2015. The estimates of heterosis ranged from -14.17 per cent (SHRIRAM453 x PUSA 169) to 14.26% (RHR27 x IR24) and from -17.18% (MAGIC x PUSA 169) to 11% (SUPER MOTI x IR24) over better parent and standard variety respectively during 2015. Out of 45 crosses 15 crosses over better parent and 21 crosses over standard parents showed significant negative heterosis during 2015 for days to maturity. Negative heterosis for early maturing was also reported in rice [7].

In plant height ranged from -12.32 (MAGIC x PB-1) to 22.26 (SARJU 52 x IR24) per cent over better parent and -6.91 (SARJU 52 x PB-1) to 23.72 (SHRIRAM 432 x PUSA 169) standard variety during 2015. Among 45 crosses studied significant negative heterosis was observed in 10 crosses over better parent and 2 crosses over standard variety in for plant height during 2015. Negative heterosis for plant height is desirable for breeding short-statured hybrids and varieties. None of the hybrids manifested significantly negative mid-parent and high-parent heterosis for plant height [8-11].

Out of 45 hybrids only two hybrids i.e., JHONA 349 x IR24 and KUBER x IR24 over better parent and only cross KUBER x IR24 over standard variety showed significant positive heterosis in 2015 on ear bearing tillers per plant. The extent of heterosis ranged from 22.81 (SHRIRAM 453 x PB-1) to 7.46 (JHONA 349 x IR24) per cent over better parent and from 36.38 (SHRIRAM 453 x PB-1) to 5.50 (KUBER x PB-1) per cent over standard variety in year 2015 [12-14].

Three crosses over better parent and 26 crosses over standard variety exhibited significant positive heterosis and none of the cross exhibited significant negative over standard variety for panicle length and the cross SHRIRAM 434 x IR24 exhibited maximum heterosis (76.55%) and 112.46%) over better parent and standard variety, respectively in year 2015 [10,12,13]. However, negative heterosis found for panicle length [15].

The estimates of heterosis ranged from -27.92 (SUPER MOTI x PUSA 169) to 8.98 (SHRIRAM RESHMA x PB-1) per cent over better parent and from -13.19 (SUMO x PUSA 169) to 23.67 (KUBER x IR24) per cent over standard variety for spikelets per panicle. Among 45 crosses studied, two crosses over better parent and 22 crosses over standard variety exhibited significant positive heterosis in year 2015 [10,12,13].

On the extents of heterosis for spikelet fertility per cent over better parent ranged from -24.19 (SUPER MOTI x PUSA 169) to 21.87 (MAGIC x PUSA 169) and from -22.64 (SUPER MOTI x PUSA 169) to 11.87 (SHRIRAM 432 x IR24) per cent during 2015. However, the extent of heterosis over standard variety was ranged from -4.86 (SUPER MOTI x IR24) to 66.99 (SHRIRAM 434 x PUSA 169) per cent. Out of 45 crosses, only 5 crosses over better parent and 39 crosses over standard variety showed significant positive heterosis during 2015. Thirty crosses over better parent showed significant negative heterosis while, none of the cross showed significant negative heterosis over standard variety during year 2015 [16].

The heterosis values for test weight over better parent ranged from -17.83 (SUPER MOTI x PUSA 169) to 13.70 (SHRIRAM 432 x IR24) and from -19.05 (SHRIRAM 453 x IR24) to 17.35 (KUBER x IR24) per cent while over standard variety in ranged from -16.94 (SUMO x PUSA 169) to 15.77 (VIDYA 295 x PB-1) and from -17.97 (SUMO x IR24) to 18.07 (VIDYA 295 x PB-1) per cent during 2015. Among 45 crosses studied, only 8 crosses over better parent and 7 crosses over standard variety exhibited significant positive heterosis for this character during the year 2015 [12,13].

The estimates of heterosis values for biological yield over better parent ranged from -19.33 (SUPER MOTI x PUSA 169) to 15.19 (VIDYA 295 x PB-1) and from -21.46 (SUPER MOTI x PUSA 169) to 14.76 (VIDYA 295 x PB-1) per cent during study year. The extent of heterosis over standard variety ranged from -16.49 (SUPER MOTI x PUSA 169) to 16.62 (SHRIRAM 434 x PB-1) and from -16.48 (SUPER MOTI x PB-1) to 18.71 (SHRIRAM 432 x IR24) per cent during the study year 2015. Out of 45 crosses studied, 13 crosses over better parent and 14 crosses over standard variety showed significant positive heterosis during the year 2015 [12-14].

Seventeen crosses over better parent and standard variety showed significant positive heterosis during the year 2015 for harvest index. The extent of heterosis values over better parent ranged from -17.94 (SHRIRAM RESHMA x PUSA 169) to 15.19 (VIDYA295 x PB-1) and over standard variety it ranged from -16.49 (SUPER MOTI x PUSA 169) to 16.62 (SHRIRAM 434 x PB-1) per cent [12-13].

Only three crosses i.e., KUBER x IR24, SHRIRAM 434 x PUSA 169 and SHRIRAM 434 x PB-1 over better parent and 19 crosses over standard variety exhibited significant positive heterosis however, maximum of heterosis over better parent and standard variety was obtained from same crosses KUBER x IR24 with their values 72.89% and 11.32%, respectively for L:B ratio during the year 2015 [12,13,17].

Only 6 crosses over better parent and 4 crosses over standard variety showed significant positive heterosis for yield in 2015. However, the maximum heterosis values over better parent and standard variety ranged from -18.66 (SHRIRAM 453 x PUSA 169) to 10.16 (KUBER x PB-1) per cent and from -22.49 (HALCHAL x IR24) to 10.16 (KUBER x PB-1), respectively [10,12,13,17,18].

Results are in agreement on all the tested traits with the findings [19,20,21]. However, maximum desirable heterobeltiosis and standard heterosis for harvest index was noticed [22]. Significant and desirable heterosis was observed in nine crosses for tiller number, 10 for plant height, 11 for days to 50% flowering, six for panicle length, 10 for spikelets per panicle and three for spikelet fertility (%). In an ideal situation, hybrids with high tiller number, semi dwarf plant type, short days to 50% flowering, high panicle length, high spikelets per panicle, high panicle fertility and grain yield are preferable. As this situation hardly exists, compromises will have to be made among morphological traits while selecting superior genotypes [8,21,23]. Many of the crosses in present study showed low expression of heterosis for yield and its component characters which are attributed to disharmony between the gene combinations of the parents involved [24]. In general, it was also observed that hybrid showing high heterosis for grain yield per plant, also manifested heterotic effects for productive tillers per plant, panicle length, number grains per panicle and 1000-grain weight [14,19,21, 24-30].

4. CONCLUSION

Frequency of heterotic crosses and magnitude of heterosis for yield and its components were found to be higher in crosses between the parents with intermediate genetic distance than the extreme ones. It is concluded from the results of the present experiment, that there is the possibility to breed more sodic tolerance with agronomically adapted high yielding rice varieties than the existing tolerant varieties either through heterosis breeding or through recombinant breeding with selection in later generation can help to develop high yielding sodic tolerant rice varieties. As a whole, on perusal of data for hybrids based on standard heterosis were presented in Table 1 and the hybrids viz., Shriram 434 x PB 1, Halchal x IR 24, Magic x Pusa 169 and Super Moti x Pusa 169, were found to be suitable for heterosis breeding under sodic environment. These hybrids emphasizes heterosis breeding for commercial exploitation in rice improvement under salt effected soil.

Table 1. Heterosis over better parent and standard variety 2015

Crosses	Days to 50% flowering		Days to maturity		Plant height		EBT	
	BP	**SV**	**BP**	**SV**	**BP**	**SV**	**BP**	**SV**
SARJU 52 X PUSA 169	-3.41	-5.31*	-3.23	-6.69**	10.21*	1.33	-4.67	-26.81**
SARJU 52 X PB-1	-3.04	-4.94*	-4.25	-7.68**	1.25	-6.91**	-15.66**	-15.66**
SARJU 52 X IR 24	14.81**	12.56**	-3.8	-7.25**	22.26**	12.41**	1.69	-5.64*
NAGINA X PUSA 169	5.44*	3.77	1.28	-1.23	9.97**	19.68**	-1.01	-14.17**
NAGINA X PB-1	6.85**	5.16*	1.88	-0.65	3.62	12.76**	-1.04	-1.04
NAGINA X IR 24	-2.81	-4.35	-1.86	-4.3	-2.21	6.42*	-8.11**	-14.74**
JHONA X PUSA 169	5.64*	4.83*	-0.05	-0.7	9.98**	19.68**	-4.49	-10.49**
JHONA X PB-1	-6.79**	-6.79**	-8.70**	-9.29**	-1.86	-1.86	-9.92**	-9.92**
JHONA X IR 24	9.35**	9.84**	5.39*	4.71	8.88**	18.48**	7.46**	0.72
MAGIC X PUSA 169	-10.80**	-15.75**	-14.77**	-17.18**	-8.29**	-1.06	-21.57**	-25.01**
MAGIC X PB-1	-7.36**	-12.5	-11.73**	-14.23**	-12.32**	-5.42*	-11.98**	-11.98**
MAGIC X IR 24	-8.04**	-13.14**	-12.03**	-14.52**	-9.88**	-2.78	-13.29**	-17.10**
KUBER X PUSA 169	-8.40**	-9.10**	-10.91**	-10.90**	-10.77**	4.38	-18.08**	-23.34**
KUBER X PB-1	10.51**	10.51**	6.41*	6.41*	17.89**	17.89**	5.50*	5.50*
KUBER X IR 24	5.10**	8.01**	1.58	2.36	6.88**	18.20**	4.56	-2.15
SUMO X PUSA 169	-3.45**	-7.22**	-8.30**	-11.62**	-3.35	13.07**	0.95	-22.49**
SUMO X PB-1	2.03**	-1.95	-2.19	-5.74*	10.38**	10.38**	-6.80**	-6.80**
SUMO X IR 24	9.78**	5.50*	6.01*	2.17	10.86**	22.61**	2.35	-5.03*
SHRIRAM RESHMA X PUSA 169	3.78**	2.98	-1.55	-2.42	10.48**	14.92**	-3.29	-15.41**
SHRIRAM RESHMA X PB-1	2.37**	2.37	-1.56	-2.43	1.01	5.07*	-4.39	-4.39
SHRIRAM RESHMA X IR 24	-3.95**	-3.25	-2.68	-3.54	-0.96	3.01	-7.73**	-14.38**
SHRIRAM 432 X PUSA 169	6.15**	5.04*	3.70*	2.33	8.27**	23.72**	0.05	-13.47**
SHRIRAM 432 X PB-1	7.57**	6.44**	5.7	4.31	15.71**	15.71**	-0.23	-0.23
SHRIRAM 432 X IR 24	-1.04*	-2.08	-3.49	-4.76	-3.58	10.19**	-6.30*	-13.05**
SHRIRAM 434 X PUSA 169	6.88**	6.06**	2.28	2.3	11.69**	20.13**	3.99	-17.01**
SHRIRAM 434 X PB-1	-6.59**	-6.59**	-1.45	-1.45	-2.45	-2.45	-16.39**	-16.39**
SHRIRAM 434 X IR 24	13.15**	14.15**	-2.76	1.09	14.59**	23.26**	4.16	-3.35
SHRIRAM 453 X PUSA 169	-10.24**	-10.92**	-14.17**	-14.16**	-8.95**	1.82	-17.14**	-36.38**
SHRIRAM 453 X PB-1	-6.52**	-6.52**	-11.14**	-11.14**	-1.5	-1.5	-22.81**	-22.81**
SHRIRAM 453 X IR 24	-9.89**	-7.22**	-13.16**	-11.45**	-8.49**	1.2	-22.11**	-27.73**
VIDYA 295 X PUSA 169	-8.65**	-9.35**	-11.56**	-12.42**	-4.15	3.46	-15.03**	-34.76

Crosses	Days to 50% flowering		Days to maturity		Plant height		EBT	
	BP	SV	BP	SV	BP	SV	BP	SV
VIDYA 295 X PB-1	13.00**	13.00**	9.54**	8.47**	18.52**	18.52**	-5.87*	-5.87*
VIDYA 295 X IR 24	5.54**	5.54*	-0.58	-1.56	6.29**	14.73**	-10.68**	-17.11**
RHR 27 X PUSA 169	-6.07**	-10.54**	-9.09**	-12.81**	-5.69*	7.30**	-10.30**	-31.13**
RHR 27 X PB-1	-1.60**	-6.28**	-2.97	-6.94**	3.68	3.68	-16.99**	-16.99**
RHR 27 X IR 24	18.61**	12.97**	14.62**	9.93**	16.65**	29.01**	1.81	-5.53*
VEDA X PUSA 169	11.45**	2.1	5.62*	0.53	13.19**	20.80**	3.74	-15.18**
VEDA X PB-1	18.17**	8.26**	10.73**	5.40*	17.83**	17.83**	2.69	2.69
VEDA X IR 24	1.94**	-6.61**	-2.71	-7.40**	-1.24	5.40*	-9.71**	-16.22**
HALCHAL X PUSA 169	-9.70**	-12.93**	-12.20**	-15.71**	-8.40**	3.47	-11.62**	-31.18**
HALCHAL X PB-1	-6.30**	-9.64**	-10.17**	-13.76**	-0.97	-0.97	-18.18**	-18.18**
HALCHAL X IR 24	-11.09**	-14.27**	-13.56**	-17.02**	-12.07**	-2.75	-20.92**	-26.62**
SUPER MOTI X PUSA 169	-7.85**	-8.55**	-12.23**	-12.21**	-5.39*	4.74	-12.98**	-33.19**
SUPER MOTI X PB-1	15.00**	15.00**	10.99**	10.99**	21.15**	21.15**	-3.06	-3.06
SUPER MOTI X IR 24	13.42*	13.7**	9.80**	11.00**	15.30**	18.65**	-3.6	3.7
No. of crosses with (+) value	5	39	8	7	13	14	17	17
No. of crosses with (-) value	30	0	20	17	21	15	19	21
Range of heterosis	-24.19 to 21.87	-4.86 to 66.99	-17.83 to 13.70	-16.94 to 15.77	-19.23 to 15.19	-16.49 to 16.62	-17.94 to 15.19	-16.49 to 16.62

Continued……

Crosses	Panicle length		Spikelets/ panicle		Spikelet fertility		Test weight	
	BP	SV	BP	SV	BP	SV	BP	SV
SARJU 52 X PUSA 169	-9.65**	5.8	-19.18**	-4.56	-12.45**	34.86**	-10.87**	-15.99**
SARJU 52 X PB-1	-8.50**	-3.35	-2.12	15.59**	-8.08**	33.89**	4.88	4.88
SARJU 52 X IR 24	-1.42	18.63**	-2.46	15.19**	-5.24*	38.02**	1.21	0.83
NAGINA X PUSA 169	-0.45	16.57**	-14.84**	-0.89	-2.94	43.30**	-6.96*	-12.30**
NAGINA X PB-1	-5.05	10.18**	-10.76**	3.87	-16.13**	23.82**	-4.81	-4.81
NAGINA X IR 24	-6.70**	12.28**	0.2	16.62**	-4.91	40.39**	1.08	0.7
JHONA X PUSA 169	-1.46	15.39**	-10.94**	-7.51**	0.21	54.36**	1.23	-4.58
JHONA X PB-1	-13.65**	-3.82	-9.40**	-9.40**	-14.00**	25.31**	-2.58	-2.58
JHONA X IR 24	-0.83	19.34**	-16.58**	-6.34*	-14.28**	24.90**	-9.10**	-9.44**
MAGIC X PUSA 169	-17.06**	-0.36	-4.98*	16.78**	21.87**	44.47**	4.03	-1.94

Crosses	Panicle length		Spikelets/ panicle		Spikelet fertility		Test weight	
	BP	SV	BP	SV	BP	SV	BP	SV
MAGIC X PB-1	-20.29**	-4.24	-4.78*	17.02**	-1.37	16.92**	2.06	2.06
MAGIC X IR 24	-15.07**	2.2	-10.06**	10.53*	-3.53	14.36**	-7.32*	-7.66**
KUBER X PUSA 169	-15.35**	-0.87	-6.81**	16.99**	5.10*	61.89**	4.55	-1.45
KUBER X PB-1	-0.28	13.12**	-19.15**	1.49	-22.79**	16.91**	-10.87**	-10.87**
KUBER X IR 24	-2.87	16.89**	-1.49	23.67**	-0.64	50.45**	7.54*	7.14*
SUMO X PUSA 169	-12.50**	8.50**	-13.53**	-13.19**	-16.46**	28.69**	-11.89**	-16.94**
SUMO X PB-1	-13.29**	7.52*	-12.17**	-11.83**	-20.77**	9.68*	-10.53**	-10.53**
SUMO X IR 24	0.49	24.61**	-8.90**	-8.55**	-16.89**	15.05**	-12.31**	-12.64**
SHRIRAM RESHMA X PUSA 169	-4.15	12.24**	-10.32**	-10.28**	-10.84**	43.13**	-9.19**	-14.04**
SHRIRAM RESHMA X PB-1	-7.24**	3.86	8.98**	9.02**	-8.30**	47.20**	9.99**	9.99**
SHRIRAM RESHMA X IR 24	-8.31**	10.35**	-8.29**	2.98	-10.02**	44.44**	1.41	1.03
SHRIRAM 432 X PUSA 169	2.55	20.08**	-15.86**	-12.62**	-18.35**	25.78**	-10.71**	-10.56**
SHRIRAM 432 X PB-1	-2.27	13.44**	-8.56**	-8.56**	-11.79**	5.31	-4.08	-3.92
SHRIRAM 432 X IR 24	-7.67**	11.11**	0.31	12.64**	12.98**	34.88**	13.70**	13.88**
SHRIRAM 434 X PUSA 169	1.4	18.74**	-3.73	15.02**	5.63*	66.99**	3.1	4.82
SHRIRAM 434 X PB-1	-16.12**	-2.92	-0.81	18.52**	-7.76**	45.82**	12.07**	13.94**
SHRIRAM 434 X IR 24	76.55**	112.46**	-9.80**	7.77**	-16.40**	32.16**	-4.96	-3.38
SHRIRAM 453 X PUSA 169	-13.99**	0.71	-15.03**	-11.75**	-22.47**	19.43**	-16.95**	-9.64**
SHRIRAM 453 X PB-1	-19.29**	-3.26	-12.60**	-11.39**	-13.77**	-1.4	-11.72**	-3.95
SHRIRAM 453 X IR 24	-14.17**	3.29	-21.03**	-11.33**	-15.06**	-0.42	-10.04**	-10.38**
VIDYA 295 X PUSA 169	-14	0.7	-15.21**	-7.22**	-12.16**	45.41**	-12.90**	-10.19**
VIDYA 295 X PB-1	3.26*	15.41**	5.26**	15.18**	-8.57**	51.36**	12.28**	15.77**
VIDYA 295 X IR 24	-6.45**	12.57**	-3.25	8.64**	-11.17**	47.05**	2.24	5.42
RHR 27 X PUSA 169	-12.69**	2.24	-10.86**	-7.42**	-15.73**	29.81**	-9.02**	-4.22
RHR 27 X PB-1	-10.33*	1.01	-10.21**	-10.21**	3.87	3.87	-6.41*	-1.46
RHR 27 X IR 24	6.48**	28.14**	-4.93*	6.75**	11.60**	30.84**	8.99**	14.75**
VEDA X PUSA 169	0.97	18.24**	-7.75**	13.39**	3.11	58.84**	4.23	-0.28
VEDA X PB-1	2	14.74**	-7.51**	13.69**	-11.31**	31.71**	8.40**	3.71
VEDA X IR 24	-10.03**	8.27**	-9.11**	11.72**	-15.00**	26.23**	-3.04	-7.23*
HALCHAL X PUSA 169	-14.31**	0.35	0.46	5.46*	0.52	54.84**	0.18	3.98
HALCHAL X PB-1	-18.16**	-4.84	-6.73**	-6.73**	-20.50**	12.02**	-8.70**	-5.24
HALCHAL X IR 24	-18.40**	-1.81	-0.35	11.89	-1.07	39.39**	5.83*	9.85**
SUPER MOTI X PUSA 169	-15.33**	-0.85	-27.92**	4.52	-24.19**	16.77**	-17.83**	-12.87**

Crosses	Panicle length		Spikelets/ panicle		Spikelet fertility		Test weight	
	BP	SV	BP	SV	BP	SV	BP	SV
SUPER MOTI X PB-1	4.62	15.96**	-26.50**	6.57**	-15.66**	-3.52	-12.56**	-7.28*
SUPER MOTI X IR 24	5.1	11.42**	-20.35**	5.80*	-14.56**	-4.86	-9.87**	-11.56*
No. of crosses with (+) value	3	19	6	4	23	17	10	6
No. of crosses with (-) value	26	4	22	28	19	19	15	21
Range of heterosis	-27.22 to 72.89	-18.03 to 111.32	-18.66 to 10.16	-22.49 to 10.16	-11.09 to 18.61	-15.75 to 14.15	-14.17 to 14.62	-17.18 to 11.00

Continued……

Crosses	Biological yield		Harvest index		L :B ratio		Yield/hill	
	BP	SV	BP	SV	BP	SV	BP	SV
SARJU 52 X PUSA 169	-11.96**	-8.97**	-11.96	-8.97*	-16.66**	-9.35*	-4.4	-3.94
SARJU 52 X PB-1	8.92**	8.92**	8.92**	8.92**	1.73	10.65*	-3.23	-2.77
SARJU 52 X IR 24	8.33**	2.37	8.33	2.37	-1.69	10.67**	5.18*	5.69*
NAGINA X PUSA 169	-12.14**	-9.16**	-12.14	-9.16**	-19.67**	-18.03**	2.45	-2.09
NAGINA X PB-1	-6.21*	-6.21*	-6.21	-6.21**	-13.54**	-13.54**	1.18	1.18
NAGINA X IR 24	0.79	-2.39	0.79**	-2.39*	-12.70**	-1.73	-3.3	-7.90**
JHONA X PUSA 169	4.59	8.99**	4.59**	8.99**	-2.56	0.58	-4.32	-8.56**
JHONA X PB-1	1.9	6.19*	1.90**	6.19**	-3.53	-0.42	-15.27**	-15.27**
JHONA X IR 24	-8.35**	-4.5	-8.35	-4.5	-8.95*	2.5	-2.32	-6.98**
MAGIC X PUSA 169	7.90**	11.77**	7.90**	11.77**	-11.21**	25.14**	-15.85**	-13.95**
MAGIC X PB-1	7.11**	10.96**	7.11**	10.96**	-10.25**	26.49**	-8.99**	-8.99**
MAGIC X IR 24	-6.16**	-2.79	-6.16**	-2.79**	-15.46**	19.15**	-15.02**	-13.10**
KUBER X PUSA 169	7.43**	12.26**	7.43**	12.26**	-6.42	14.38**	-13.87**	-12.02**
KUBER X PB-1	-6.07**	-1.84	-6.07**	-1.84**	-18.18**	0	10.16**	10.16**
KUBER X IR 24	9.83**	14.77**	9.83**	14.77**	72.89**	111.32**	0.49	2.63
SUMO X PUSA 169	-9.54**	-6.47**	-9.54	-6.47**	-20.23**	-7.17	-8.73**	-12.78**
SUMO X PB-1	-8.01**	-3.91	-8.01	-3.91	-18.19**	-4.8	-5.94*	-5.94*
SUMO X IR 24	-11.35**	-7.40**	-11.35**	-7.40*	-15.40**	-1.55	2.12	-2.74
SHRIRAM RESHMA X PUSA 169	-17.94**	-15.15**	-17.94**	-15.15	-20.21**	0.09	-8.88**	-12.93**
SHRIRAM RESHMA X PB-1	2.96	2.96	2.96**	2.96**	-2.05	22.86**	-11.54**	-11.54**
SHRIRAM RESHMA X IR 24	-3.73	-6.76**	-3.73**	-6.76**	-7.97*	15.44**	-12.32**	-16.50**
SHRIRAM 432 X PUSA 169	-5.96*	-2.85	-5.96**	-2.85	-11.38**	-8.79*	3.81	-0.8

SHRIRAM 432 X PB-1	-2.58	0.63	-2.58	0.63	-6.35	-3.61	2.5	2.5
SHRIRAM 432 X IR 24	12.38**	16.09**	12.38**	16.09**	5.29	18.52**	-3.94	-8.51**
SHRIRAM 434 X PUSA 169	9.31**	12.38**	9.31**	12.38**	14.07**	16.40**	1.27	-3.23
SHRIRAM 434 X PB-1	13.43**	16.62**	13.43**	16.62**	20.95**	20.95**	-12.22**	-12.22**
SHRIRAM 434 X IR 24	-4.84	-2.17	-4.84**	-2.17*	-2.29	10.00*	7.23**	2.12
SHRIRAM 453 X PUSA 169	-9.42**	-5.48**	-9.42**	-5.48**	-27.22**	7.25	-18.66**	-22.27**
SHRIRAM 453 X PB-1	-7.96**	-3.95	-7.96**	-3.95**	-26.14**	8.84*	-17.60**	-17.60**
SHRIRAM 453 X IR 24	-15.16**	-11.47**	-15.16**	-11.47**	-26.80**	7.88	-17.61**	-21.53**
VIDYA 295 X PUSA 169	-9.15**	-6.07**	-9.15**	-6.07**	-22.38**	0.99	-15.03**	-18.80**
VIDYA 295 X PB-1	15.19**	15.19**	15.19**	15.19**	-2.73	26.56**	2.42	2.42
VIDYA 295 X IR 24	5.05*	3.59	5.05**	3.59**	-8.61**	18.92**	-3.67	-8.26**
RHR 27 X PUSA 169	-5.77**	-2.57	-5.77**	-2.57**	-13.31**	7.22	-15.03**	-18.80**
RHR 27 X PB-1	-4.2	-4.2	-4.20**	-4.20**	-15.00**	5.13	-11.33**	-11.33**
RHR 27 X IR 24	8.49**	8.04**	8.49*	8.04**	0.28	24.04**	5.45*	0.43
VEDA X PUSA 169	-3.05	0.24	-3.05*	0.24*	-3.09	5.41	-0.72	-5.12*
VEDA X PB-1	-2.49	-2.49	-2.49*	-2.49*	6.47	6.47	2.73	2.73
VEDA X IR 24	-11.31**	-14.11**	-11.31	-14.11	-6.6	5.14	-9.94**	-14.23**
HALCHAL X PUSA 169	4.11	7.65**	4.11**	7.65**	-4.99	10.01*	-15.91**	-19.64**
HALCHAL X PB-1	-8.75**	-7.24**	-8.75**	-7.24**	-15.20**	-1.82	-15.81**	-15.81**
HALCHAL X IR 24	6.43**	8.18**	6.43**	8.18**	1.57	17.61**	-18.61**	-22.49**
SUPER MOTI X PUSA 169	-19.23**	-16.49**	-19.23	-16.49*	-26.13**	-0.65	-17.56**	-21.22**
SUPER MOTI X PB-1	-14.38**	-14.38**	-14.38**	-14.38**	-24.16**	2.01	2.32**	2.32**
SUPER MOTI X IR 24	-12.35**	-10.35**	-10.85**	-10.80**	-15.60**	3.3	4.45**	3.90**
No. of crosses with (+) value	21	27	2	1	3	26	2	22
No. of crosses with (-) value	10	2	24	34	25	0	33	16
Range of heterosis	-12.32 to 22.26	-6.91 to 23.72	-22.81 to 7.46	-36.38 to 5.50	-20.29 to 76.55	-4.84 to 112.46	-27.92 to 8.98	-13.19 to 23.67

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO, Extent of salt affected soils; 2014. www.fao.org/soils-portal/soil-management of-some problem-soil/salt-affected soils/ more-information-on-saltaffected-soils/en
2. Mandal AK, Sharma RC, Singh GB. Assessment of salt affected soils in India using GIS. Geocarto Int. 2004;24(6):437-456.
3. Khush GS, Virk PS. Rice breeding achievements and future strategies. Crop Improvemt. 2000;27(2):115-144.
4. Viraktamath BC, Shobha Rani N. Rice: Pivotal position achieved by combination of factors. The Hindu Survey of Indian Agriculture. 2008;22-24.
5. Manneh B. Genetic, physiological and modelling approaches towards tolerance to salinity and low nitrogen supply in rice (*Oryza sativa* L.). Wageningen Universiteit; 2004.
6. Fonseca S, Patterson FL. Hybrid vigour in a seven parent diallel crosses in common wheat (*Triticum aestivum* L.). Crop Sci. 1968;8:85-95.
7. Alam ASMS, Sarker U, Mian MAK, Line x tester analysis in hybrid rice (*Oryza sativa* L.). Annals of Bangladesh Agri. 2007;11 (1):37-44.
8. Bagheri N. Heterosis and combining ability analysis for yield and related-yield traits in hybrid rice. International Journal of Biology. 2010;2(2):222-231.
9. Michael Gomez S, Rangasamy P, Nadarajan N. Assesing the best combiners in rice (*Oryza sativa* L.) suitable for drought prone areas of Tamil Nadu. Res. on Crops. 2003;4(1):79-84.
10. Rosamma CA, Vijayakumar NK. Heterosis and combining ability in rice (*Oryza sativa* L.). Indian J. Genet. 2005;65(2):119-120.
11. Gnansekaran M, Vivekanandan P, Muthuramu S. Combining ability and heterosis for yield and grain quality in two line rice (*Oryza sativa* L.) hybrids. Indian. J. Genet. 2006;66(1):6-9.
12. Panwar LL. Genetic variability, heritability and genetic advance for panicle characters in transplanted rice. Res. on Crops. 2005; 6(3):505-508.
13. Rita Binse and Motiramani, N. K. Study on gene action and combining ability in rice. Oryza. 2005;42(2):153-155.
14. Singh CM, Babu GS. Magnitude of heterosis and combining ability in relation to yield and some morphological traits for improvement of upland rice (*Oryza sativa* L.). Madras Agric. J. 2012;99(7-9):447-453.
15. Rahimi M, Rabiei B, Samizadeh H, Kafi GA. Combining ability and heterosis in rice (*Oryza sativa* L.) cultivars. J. Agr. Sci. Tech. 2010;12:223-231.
16. Rao AM, Ramesh S, Kulkarni RS, Savithramma DL, Madhusudhan K. Heterosis and combining ability in rice. Crop Imp. 1996;23:53-56.
17. Sarker U, Biswas PS, Prasad B, Khaleque Mian MA. Heterosis and genetic analysis in rice hybrid. Pakistan Journal of Biological Sciences. 2002;5(1):1-5.
18. Hossain K, Akhter A, Begum H, Ansari A, Rahman MM. Line x Tester analysis for yield and its related traits in rice (*Oryza sativa* L.). Bangladesh J. Pl. Breed. Genet. 2009;22(2).
19. Pandya R, Tripathi RS. Heterosis breeding in hybrid rice. Oryza. 2006;43(2):87-93.
20. Parihar A, Pathak AR. Heterosis for quantitative traits in rice. Oryza. 2008;45 (3):181-187.
21. Roy SK, Senapati BK, Sinhamahapatra SP, Sarkar KK. Heterosis for yield and quality traits in rice. Oryza. 2009;46(2):87-93.
22. Kumar S, Singh HB, Sharma JK, Sood S. Heterosis for morpho physiological and qualitative traits in rice. Oryza. 2010;47(1): 17-21.
23. Veni BK, Rani NS, Prasad ASR. Heterosis for yield components and key quality traits in basmati rice. Oryza. 2005;42(2):97-102.
24. Paramasivan KS, Rangaswamy SSR. Heterosis in hybrids of rice varieties. Oryza. 1988;25:396-401.
25. Patil SR, Vashi RD, Patil PP, Shinde DA. Combining ability in rice (*Oryza sativa* L.). Plant Archives. 2011;11(1):439-442.
26. Belhekar PB. Genetic analysis in aromatic rice (*Oryza sativa* L.) with cytoplasmic genetic male sterile lines. Ph.D. thesis (unpublished) submitted to Navsari Agricultural University, Navsari; 2012.
27. Chandara, N. Genetic analysis using line x tester analysis in rice (*Oryza sativa* L.). M.Sc. (Agri.) thesis (unpublished)

submitted to Navsari Agricultural University, Navsari; 2012.
28. Prasad C. Heterosis and combining ability in rice (*Oryza sativa* L.). M.Sc. (Agri.) thesis (unpublished) submitted to Navsari Agricultural University, Navsari; 2012.
29. Reddy MR, Raju CS, Sravani D, Reddy TD, Reddy GN. Heterosis for yield and kernel size in aromatic rice (*Oryza sativa*. L). Ann. of Bio. Res. 2012;3(6):2662-2666.
30. Pratap N, Shekhar R, Singh PK, Soni SK. Combining ability, gene action and heterosis using cms lines in hybrid rice (*Oryza sativa* L.). The Bioscan. 2013;8(4): 1521-1528.

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