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The Effects of Combining Ability for Yield Traits in Rice (*Oryza sativa* L.) under Sodic 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

Information on combining ability is derived from data on twelve yield and yield contributing characters in fifteen male and three female parents utilised in line x tester fashion to estimate combining ability of rice genotypes under coastal saline condition. Forty Five hybrids generated from crossing three lines with fifteen testers were studied along with their parents for combining ability and gene action involved in the expression of characters in rice. The gca and sca effects were significant for all the characters. The magnitude of sca variance was higher than the gca variance for all the characters revealed the presence of predominance of non-additive gene action for all the characters under study. Halchal (-12.29) was found to be good general combiners for days to 50% flowering and early maturity, Halchal (-13.39). However, IR-24 (1.88) was good general combiners with significant positive effect for tallness. Magic (-12.05) good general combiners for dwarfness and Shriram 434 (1.57) was good general combiners for test weight however, Moti was best general combiner with gca estimates of 7.07 for harvest index and Kuber (3.48) was the good general combiners for yield/hill. Cross combinations RHR 27 x IR 24 (4.04) was significant and positive effect for yield/hill, performance for ear bearing tillers per plant were

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RHR 27 x IR 24 (1.88). In general, the crosses showing significant and desirable combining ability effects were associated with better *per se* performance for the respective traits. These hybrids could be utilized in heterosis breeding to exploit hybrid vigour.

Keywords: Line x tester; characters; hybrid; sodic soil.

1. INTRODUCTION

Rice (*Oryza sativa* L.,) is the most important crop of India and it occupies 23.3 per cent of gross cropped area of the country. Rice contributes 43 per cent of total food grain production and 46 per cent of total cereal production. It continues to play vital role in the national food grain supply. It is the staple food of nearly half of the world population. It ranks third after wheat and maize in terms of worldwide production. Asia accounts for 90 per cent and 92 per cent of world's rice area and production respectively. Thus, rice production, consumption and trade are concentrated in Asia. One third of Asia's rice production is consumed in China and one fifth in India. Among the rice growing countries in the world, India has the largest area under rice crop (about 45 million ha.) and ranks second in production next to China (FAO, 2015). The various crop species in which hybrid varieties are used commercially, rice ranks very high. Line x tester analysis is one of the most powerful tools for estimating the general combining ability (GCA) of parents and selecting of desirable parents and crosses with high SCA for the exploitation of heterosis. Among abiotic stresses, salinity is foremost and second most widespread problem causing reduction in growth and productivity of crop plants Munns et al. [1]. Salinity is an environmental condition which adversely affects the physiological processes of crop plants and severely affects crop production. The adverse effects may be attributed to non availability of water and disturbance of water and disturbance nutrients uptake causing deficiency and ion toxicity to plants. The present study was undertaken to evaluate best combination (s) in respect of their combining ability effects among the parents and hybrids rice genotypes for sodic stress on the basis of different morphological characters, yield and yield components under field conditions during Kharif, 2015.

2. MATERIALS AND METHODS

The present experiment was conducted at Farmer Field of village Amwa Bhaluhi of Bhathat Block District: Gorakhpur during *Kharif*, 2015, 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 experiment was laid out in a randomized block design replicated three times. The parents and F1's were represented by a single row plot of 10 plants placed at 20 cm x 15 cm spacing. All the agronomical practices and plant protection measures were followed as and when required to raise a good crop of rice. Twelve plant characters viz., days to 50% flowering, days to maturity, plant height (cm), ear bearing tillers per plant, panicle length (cm), spikelet per panicle, spikelet fertility (%), test weight (g), biological yield per plant (g), length: breadth ratio, harvest index (%) and grain yield per plant were studied in the experiment. Lines were used as female whereas testers as male parents. The analysis of variance of RBD and their significance for all the characters were worked out in all the three environments (Panse and Sukhatme, 1964). The general and specific combining ability variances were estimated by Method 2 and Model 1 (Griffing??). The mean values of hybrids were used for the estimation of standard heterosis per cent i.e. the superiority of F1 over the standard variety MDU 5 Fonseca and Patterson, [2]. It is not always necessary that parents with high mean performance for yield and other traits would produce desirable F1s and/or segregants. The selection of a few parents having high genetic potential as per breeding objectives is essential because analyzing and handling of very large number of crosses resulting from numerous parents available in collections of a crop would be an impractical and perhaps impossible task. Among the various techniques of combining ability analysis, Line x Tester analysis has been widely utilized for screening of germplasm to identify valuable donor parents and promising crosses in many crops including rice Kempthorne [3].

3. RESULTS AND DISCUSSION

The analysis of variance (Table 1) revealed that highly significant differences among lines (females) for various characters under study i.e.,

days to 50% flowering, effective tillers per plant, panicle length (cm), number of spikelet per panicle, number of fertile spikelet, spikelet fertility percent, grain yield per plant, biological yield, harvest index except plant height and 1000 grain weight while, variance among males (testers) were highly significant for all traits. The variances among crosses due to males and females (lines x testers) interaction component, indicating their *sca* effects were highly significant for all the traits except for 1000 grain weight. These results are supporting by the findings of Sanghera and Waseem, [4], Gopikannan and Ganesh [5], Singh et al. [6], Moumeni and Vahed [7] Singh et al. [8] and Vanave et al. [9].

The merits of parent are judged on the basis of gca effects. General combiners with negative values are desirable. Out of 15 restorers, Magic (12.29), Halchal (10.86) and Shriram 453 (-7.03) were found to be good general combiners. Among female lines Pusa 169 (-3.35) exhibited desirable significant gca effects, rest of the females showed significant positive gca effects. The significant negative sca effects were observed in 13 cross combinations. The superior 5 most promising crosses in order of performance are negative value of sca were SHRIRAM 434 x PB-1 (-11.61), JHONA 349 x PB-1 (-9.99), SUPER MOTI x PUSA 169 (-8.80), VIDYA 295 x PUSA 169 (-8.38) and KUBER x PUSA 169 (-8.22) during 2015. Out of 15 restorer, 3 restorer namely Halchal (-13.39), Magic (-13.17) and Shriram 453 (-9.48) were found to be good general combiners. Among female lines, Pusa 169 (-3.86) exhibited desirable significant negative gca effects for days to maturity. The significant negative sca effects were observed in 8 cross combinations and 5 most promising crosses in order of performance for negative value of sca were JHONA 349 xPB-1 (-11.44), SUPER MOTI x PUSA 169 (-10.88), VIDYA 295 x PUSA 169 (-9.08), KUBER x PUSA 169 (-8.60) and SHRIRAM 432 x IR 24 (-7.81) during study period. The female line PB-1 (-2.62) exhibited significant and negative general combining ability for plant height, in general than potential of general combiners for dwarfness. On the other hand, IR-24 (1.88) was good general combiner with significant positive effect for tallness. Among the male parental lines Magic (-12.05) was top general combiner followed by Halchal (-9.22), Shriram 453 (-8.60) and Sarju 52 (-7.00) for dwarfness while Shriram 432 (6.43), Sumo (5.32), Veda (4.68) and Super Moti (4.06) for tallness during study year 2015.

The significant and negative sca effects of plant height were observed in 13 cross combinations during study period. The best five promising crosses in order of performance over SHRIRAM 434 x PB-1 (-12.54), VEDA x IR 24 (-10.62), JHONA 349 x PB-1 (-10.53), SUPER MOTI x PUSA 169 (-9.49) and KUBER x PUSA 169 (-9.32) during study period. The significant and positive sca effects were observed for 15 cross combinations with maximum value of 12.89 for cross combination RHR 27 x IR 24. Out of three female line PB-1 (1.38) and IR 24 (0.46) and PB-1 (0.91) exhibited significant positive gca effects while Pusa 169 (-165) exhibited significant negative gca effects for the character ear bearing tillers per plant during 2015. The significant and positive gca effects for restorers were observed in Jhona 349 (1.53), Kuber (1.51), Shriram 432 (1.08), Veda (0.96), Nagina (0.88), Shriram Reshma (0.61), Sumo (0.60) and Shriram 434 (0.45) during 2015 were found to be good restorer for ear bearing tillers per plant. Among 45 crosses, 13 combinations had positive and significant sca effect, the best five crosses order of performance for ear bearing tillers per plant were RHR 27 x IR 24 (1.88), SUPER MOTI x PB-1 (1.49), VIDYA 295 x PB-1 (1.34), SHRIRAM 434 x IR 24 (1.23) and KUBER x PB-1 (1.11). Out of the three female lines IR-24 showed positive significant gca effect with the value of 2.06 and negative general combining ability for panicle length with values of -2.62 during the year 2015. The estimate of gca effects were restores were observed significant and positive in order of Shriram 434 (7.55), Shriram 432 (0.98) Veda (0.72) and Sumo (0.67) during 2015 were good general combiners. Among 45 crosses, 12 cross combinations expressed positive and significant sca effect. The best five cross combinations in order of performance were SHRIRAM 434 xIR 24 (14.37), SUPER MOTI x PB-1 (2.91), VIDYA 295 x PB-1 (2.76), KUBER x PB-1 (2.18) and RHR 27 x IR 24 (2.11). Contribution of interactions of line x tester was higher than lines for tiller number, number of spikelets per panicle, spikelet fertility and grain yield, indicating higher estimates of GCA variances for interaction Bagheri, [10]. These findings are in close conformity with the findings of Sanghera and Waseem,[4], Gopikannan and Ganesh [5], Singh et al. [6], Moumeni and Vahed [7] Singh et al. [8] and Vanave et al. [9].

The line IR-24 show positive and significant gca effect with estimate of 9.23 and 11.39 of spikelets per panicle. On the other hand, Pusa 169 exhibited significant negative gca effect with

estimates of -8.10 during study period while, PB-1 exhibited significant negative gca effect with value of -2.78. Among restores Magic (25.85), Kuber (24.21), Shriram 434 (23.58), Veda (21.68), Sarju 52 (12.19), Nagina (7.19) and Vidya 295 (4.92) were the good general combiner with significant positive gca effects for spikelets per panicle. The study of estimates of sca effects that the cross SHRIRAM 432 xIR 24 (25.82) was good specific cross combination followed by VIDYA 295 x PB-1 (22.99), SHRIRAM RESHMA x PB-1 (20.27), SARJU 52 x PB-1 (16.65) and RHR 27 x IR 24 (14.26) during year 2015. Out of 45 crosses, 15 cross combinations showed significant positive sca effects in desired directions. These resuls are closely related to findings of Sanghera and Waseem, [4], Gopikannan and Ganesh [5], Singh et al. [6], Moumeni and Vahed [7] Singh et al. [8] and Vanave et al. [9].

The female line Pusa-169 expressed positive and significant gca effects with estimates of 6.15 during 2015. On the other hand, PB-1 and IR-24 seed parent possessed significant negative gca effects for spikelet fertility per cent. Among restores during 2015 Shriram 434 (9.72), Vidya 295 (9.51), Shriram Reshma (7.83), Kuber (6.81), Veda (4.50), Nagina (2.78), Sarju 52 (2.65), Halchal (2.55) and Jhona 349 (2.24) were the good general combiners with significant positive gca estimates for spikelet fertility per cent (Tables 3 & 4). A perusal of Tables 2 & 3 revealed that 15 crosses exhibited positive and significant sca effect during the course of study. Among them SHRIRAM 432 xIR 24 (8.00), VIDYA 295 x PB-1 (7.21), SHRIRAM RESHMA x PB-1 (6.58), RHR 27 x PB-1 (6.02), KUBER x IR 24 (4.93) were found to be good specific combinations for spikelet fertility per cent.

The estimate of gca effects of all the female lines were significant either in positive or in negative on the test weight of grain. Estimates of gca effects were observed with positive values of 1.57, 1.27, 1.14, 1.11 and 0.48 in order of merit for restores line Shriram 434, Vidya 295, RHR 27, Halchal and Shriram 432 during study period (Table 1). Shriram 434 (1.57) was good general combiners for test weight.

Out of 45 crosses, 15 cross combinations had positive and significant sca effect on test weight. Some of the promising crosses in order of sca estimates were SHRIRAM 432xIR 24 (2.47), RHR 27 x IR 24 (1.99), VIDYA 295 x PB-1 (1.98), SHRIRAM RESHMA x PB-1 (1.75), KUBER x IR 24 (1.40) during 2015 (Tables 2 & 3). The cross SHRIRAM 432 xIR 24 (2.47) was observed as good specific combiner. The estimate of gca effects of all the female lines were significant either in positive or in negative direction except Sarju 52, Halchal among pollen per cent Pusa 169, IR 24 among seed parent Pusa 169, PB-1, IR-24 among seed parent were non significant. Out of 15 restores order, 8 lines during the study years exhibited significant positive gca effect in which Super Moti was best general combiner with value of 15.93 for the test weight of grain per panicle. These observations are similar to the findings of Singh et al. [8] and Vanave et al. [9].

Among 45 crosses, 14 cross combinations possessed sca effect in positive direction with significant values for the test weight of grain per panicle. The outstanding crosses in order of merit were SHRIRAM 432 xIR 24 (11.60), VIDYA 295 x PB-1 (8.79), RHR 27 x IR 24 (7.97), SHRIRAM RESHMA x PB-1 (7.21), KUBER x PB-1 (6.79) (Tables 2&3). The cross SHRIRAM 432 xIR 24 (2.47) was observed as good specific combinations when considered *per se* performance and sca effects. The estimate of gca effects of all the lines were significant either in positive or in negative direction except Kuber among pollen per cent during 2015 were non significant for the harvest index. Out of 15 restores order, 6 lines exhibited significant positive gca effect in which Super Moti was best general combiner with gca estimates of 7.07 for harvest index (Table 3). Out of 45 crosses under study, 13 cross combinations possessed sca effect in positive direction with significant values for harvest index. The outstanding crosses during 2015 in order of merit were KUBER xPB-1 (7.38), SHRIRAM 434 x IR 24 (6.28), SHRIRAM RESHMA x IR 24 (5.35), SHRIRAM 432 x PUSA 169 (4.46), HALCHAL x PB-1 (4.34), JHONA 349 x IR 24 (3.97) and SARJU 52 x PUSA 169 (3.75). The estimate of gca effects of all the lines were significant either in positive or in negative direction except RHR 27, Veda among pollen and seed parent were non-significant for L:B ration. Out of 15 restores order, 5 lines exhibited significant positive gca effect in which Kuber (1.12) and Magic (0.47) were the best general combiners. These findings are closely related to the observations of Singh et al. [8] and Vanave et al. [9].

Table 1. Analysis of variance parent, hybrids and combining ability (mean sum of square)

Different traits	Replication	Treat	Parent	PvsC	Crosses	L	T.	LxT	Error
DF	2	62	17	1	44	14	2	28	124
Days to 50%	34.00**	156.29**	27.01**	2.32	209.74**	277.04**	393.45**	162.97**	6.92
Days to Maturity	32.70	199.02**	25.89*	629.88**	256.12**	404.05**	468.74**	166.97**	13.56
Plant Height	18.16	196.70**	102.18**	8.46	237.50**	337.14**	246.33**	187.04**	9.00
Ear Bearing Tillers per plant	0.73	11.64**	10.95**	8.50**	11.98**	14.03**	98.01**	4.82**	0.32
Panicle length (cm)	1.68	39.16**	5.24**	26.20**	52.56**	53.36**	148.46**	45.32**	0.80
Spikelets per panicle	139.60	2390.84**	3365.92**	7477.44**	1898.49**	3793.47**	3421.90**	842.19**	46.18
Spikelets fertility	16.34	320.97**	358.12**	381.46**	305.25**	545.54**	1503.06**	99.54**	6.63
Test grain weight (g.)	0.87	7.93**	4.42**	0.42	9.46**	10.52**	29.85**	7.48**	0.52
Biological Yield	21.95	232.36**	205.07**	170.76**	244.31**	425.41**	81.85**	165.36**	8.16
Harvest Index	3.19	63.54**	49.94**	1.38	70.20**	110.14**	42.57**	52.21**	1.29
L B ratio	0.02	1.20**	0.95**	2.50**	1.27**	1.65**	2.99**	0.95*	0.03
Yield/hill	3.99	35.21**	36.68**	30.82**	34.74**	56.81**	75.14**	20.83**	1.50

Table 2. Estimation of general combining ability of lines and testers for twelve characters of paddy

Line/Tester	Days to 50% flowering	Days to Maturity	Plant height	Ear bearing tillers per plant	Panicle length	Spikelets per panicle	Spikelet fertility	Test weight	Biological yield	Harvest index	L :B ratio	Yield per hill
Line												
Sarju52	1.47	1.60	-7.00**	-0.27	-0.87**	12.19**	2.65**	-0.19	1.20	2.80**	-0.18**	3.24**
Nagina	2.18*	3.36**	3.06**	0.88**	0.54	7.19**	2.78**	-0.61*	-5.12**	4.50**	-0.69**	2.20**
Jhona 349	3.22**	3.71**	2.25*	1.53**	-0.10	-25.14**	2.24**	-0.62**	3.83**	-2.45**	-0.28**	-0.75
Magic	-12.29**	-13.17**	-12.05**	-0.64**	-2.71**	25.85**	-3.10**	0.10	6.75**	-4.25**	0.49**	-1.46**
Kuber	3.71**	3.32**	3.56**	1.51**	-0.23	24.21**	6.81**	0.16	8.40**	0.24	1.12**	3.48**
Sumo	-0.41	-0.82	5.32**	0.60**	0.67*	-32.94**	-7.23**	-2.23**	-5.12**	2.53**	-0.47**	0.50
Shriram Reshma	1.40	1.91	-1.92*	0.61**	-0.45	-6.31**	7.83**	0.31	-5.50**	-0.03**	0.12*	-2.12**
Shriram432	3.70**	6.04**	6.43**	1.08**	0.98**	-14.05**	-4.91**	0.48*	4.84**	0.63**	-0.24**	2.47**
Shriram434	5.03**	2.73*	3.71**	0.45*	7.55**	23.58**	9.72**	1.57**	8.92**	-1.78**	0.23**	1.59**
Shriram453	-7.03**	-9.48**	-8.67**	-2.72**	-2.46**	-33.62**	-13.86**	-1.13**	-6.11**	-3.08**	-0.04	-4.86**
Vidya295	3.64**	3.07*	2.38*	-0.88**	-0.27	4.92*	9.51**	1.27**	4.48**	-2.05**	0.22**	0.07
RHR27	-0.47	1.33	3.41**	-0.62**	-0.06	-15.81**	-5.18**	1.14**	0.87**	-1.35**	0.10	-0.61
Veda	1.92*	4.69**	4.68**	0.96**	0.72*	21.68**	4.50**	0.26	-4.68**	3.06**	-0.12*	1.15**
HALCHAL	-10.86**	-13.39**	-9.22**	-2.03**	-3.02**	0.41	2.55**	1.11**	3.17	-5.86**	-0.02	-4.39**
Super Moti	4.80**	5.12**	4.06**	-0.48	-0.29	3.28	-14.31**	-1.52**	15.93**	7.07**	-0.24**	-0.50
SE(gca line)	0.877	1.287	0.976	0.19	0.30	2.27	0.86	0.24	0.95	0.38	0.06	0.406
SE(gi-gj)line	1.240	1.820	1.380	0.27	0.42	3.20	1.21	0.34	1.35	0.53	0.08	0.574
Tester												
Pusa 169	-3.35**	-3.68**	0.74	-1.65**	-0.68**	-8.10**	6.15**	-0.94**	-0.78	-1.12**	-0.21**	-1.35**
PB1	1.09**	2.36**	-2.62**	1.19**	-1.38**	-1.14	-5.31**	0.51**	1.56**	0.66**	-0.07**	1.23**
IR24	2.26**	1.32*	1.88**	0.46**	2.06**	9.23**	-0.84*	0.43**	-0.77	0.45**	0.29**	0.12
SE(gca tester)	0.392	0.549	0.447	0.085	0.134	1.013	0.384	0.108	0.426	0.169	0.026	0.182
SE(gi-gj) tester	0.555	0.776	0.633	0.120	0.189	1.433	0.543	0.153	0.602	0.239	0.036	0.258

Table 3. Estimation of specific combining ability of lines and testers for twelve characters of paddy for year 2015

Crosses	Days to 50% flowering	Days to maturity	Plant height	EBT	Panicle length	Spikelet per panicle	Spikelet fertility	Test weight	Biological yield	Harvest index	L :B ratio	Yield per hill
SARJU 52 x PUSA 169	-2.40	4.30*	-1.63	-0.39	0.39	-22.02**	-6.56**	-1.64**	-8.42**	3.75**	-0.24*	-0.10
SARJU 52 x PB-1	-6.48**	-2.93	-6.03**	-1.12**	-1.07*	16.65**	4.37**	1.19**	6.14**	-4.96**	0.30**	-2.20**
SARJU 52 x IR 24	8.88**	-1.37	7.66**	1.51	0.68	5.37	2.19	0.45	2.28	1.21	-0.06	2.30**
NAGINA x PUSA 169	5.46**	4.68*	5.59**	0.86**	1.52**	-8.71*	-2.01	-0.47	-2.28	3.01**	-0.02	1.69*
NAGINA x PB-1	2.35	-0.66	2.44	0.50	0.71	-4.90	-1.36	-0.38	-1.83	1.27	-0.01	0.43
NAGINA x IR 24	-7.81**	-4.02	-8.03**	-1.36	-2.23**	13.61**	3.37*	0.84*	4.11*	-4.28**	0.03	-2.12**
JHONA 349 x PUSA 169	5.43**	4.96*	6.39**	0.91**	1.88**	8.64*	4.68**	1.14**	5.91**	-0.22	0.20*	2.04**
JHONA 349 x PB-1	-9.99**	-11.44**	-10.53**	-1.83**	-1.95**	-2.60	0.01	0.09	0.92	-3.75**	0.03	-3.24**
JHONA 349 x IR 24	4.56**	6.48**	4.13*	0.92**	0.07	-6.04	-4.69**	-1.23**	-6.84**	3.97**	-0.23*	1.20
MAGIC x PUSA 169	1.50	1.42	1.17	0.33	0.78	12.63**	4.52**	1.06*	5.62**	-1.36*	0.27**	0.57
MAGIC x PB-1	0.14	-1.06	0.43	-0.04	0.57	6.21	0.69	0.43	2.51	-0.99	0.17	-0.01
MAGIC x IR 24	-1.64	-0.37	-1.59	-0.28	-1.35**	-18.84**	-5.21**	-1.49**	-8.14**	2.36**	-0.44**	-0.56
KUBER x PUSA 169	-8.22**	-8.60**	-9.32**	-1.51**	-1.82**	14.76**	4.29**	1.00*	4.43**	-5.27**	-0.73**	-3.59**
KUBER x PB-1	5.88**	6.22**	6.77**	1.11**	2.18**	-27.30**	-9.22**	-2.39**	-11.23**	7.38**	-1.36**	2.76**
KUBER x IR 24	2.34	2.38	2.56	0.40	-0.37	12.54**	4.93**	1.40**	6.79**	-2.12**	2.09**	0.84
SUMO x PUSA 169	-2.32	-4.23	-2.89	-0.45	-0.51	3.56	-0.11	0.20	0.27	-1.21	0.12	-0.92
SUMO x PB-1	-1.78	-3.17	-2.06	-0.31	-0.04	-0.31	0.80	0.07	0.35	-1.02	0.06	-0.74
SUMO x IR 24	4.09**	7.40	4.95**	0.76*	0.55	-3.25	-0.69	-0.28	-0.62	2.24**	-0.19	1.65*
SHRIRAM RESHMA x PUSA 169	5.50**	4.13**	6.09**	0.89**	1.49	-16.48**	-7.15**	-1.74**	-7.56**	5.35**	-0.22*	1.64*
SHRIRAM RESHMA x PB-1	0.49	-1.92	0.17	0.14	0.21**	20.27**	6.58**	1.75**	7.21**	-3.56**	0.42**	-0.38
SHRIRAM RESHMA x IR 24	-5.99**	-2.21	-6.26**	-1.02**	-1.70	-3.79	0.57	-0.01	0.35	-1.79**	-0.20*	-1.27
SHRIRAM 432 x PUSA 169	5.15**	5.73**	6.03**	0.79*	1.90**	-14.03**	-4.05**	-1.19**	-6.28**	4.46**	-0.16	1.94**
SHRIRAM 432 x PB-1	2.03	2.08	1.84	0.45	1.04*	-11.80**	-3.95**	-1.28**	-5.32**	2.57**	-0.12	0.69
SHRIRAM 432 x IR 24	-7.18**	-7.81**	-7.86**	-1.24**	-2.95**	25.82**	8.00**	2.47**	11.60**	-7.04**	0.28**	-2.63**
SHRIRAM 434 x PUSA 169	4.78**	5.67**	5.37**	0.75*	-4.98**	10.93**	4.21**	0.88*	4.03*	0.06	0.24*	1.84**
SHRIRAM 434 x PB-1	-11.61**	-4.88*	-12.54**	-1.98**	-9.39**	11.89**	3.92**	1.30**	5.69**	-6.34**	0.25*	-4.36**
SHRIRAM 434 x IR 24	6.82**	-0.78	7.17**	1.23**	14.37**	-22.82**	-8.14**	-2.18**	-9.72**	6.28**	-0.48**	2.52**
SHRIRAM 453 x PUSA 169	0.80	1.38	0.50	0.25	0.79	7.51	1.38	0.60	2.19	-0.30	0.19	0.62
SHRIRAM 453 x PB-1	0.52	-1.02	0.73	-0.02	0.55	1.36	1.27	0.32	1.29	-0.56	0.10	-0.07
SHRIRAM 453 x IR 24	-1.31	-0.36	-1.22	-0.22	-1.34**	-8.87*	-2.65	-0.92*	-3.48*	0.86	-0.29**	-0.55

Crosses	Days to 50% flowering	Days to maturity	Plant height	EBT	Panicle length	Spikelet per panicle	Spikelet fertility	Test weight	Biological yield	Harvest index	L :B ratio	Yield per hill
VIDYA 295 x PUSA 169	-8.38**	-9.08**	-9.01**	-1.29**	-1.41**	-20.78**	-7.56**	-1.91**	-8.95**	0.47	-0.28**	-2.91**
VIDYA 295 x PB-1	8.30**	10.06**	8.54**	1.34**	2.76**	22.99**	7.21**	1.98**	8.79**	-0.26	0.45**	3.05**
VIDYA 295 x IR 24	0.08	-0.98	0.47	-0.05	-1.35**	-2.20	0.35	-0.06	0.16	-0.20	-0.17	-0.14
RHR 27 x PUSA 169	-5.40**	-7.81**	-6.42**	-0.86**	-1.26*	-0.49	-1.54	-0.55	-2.04	-1.56*	0.05	-2.23**
RHR 27 x PB-1	-5.81**	-6.78**	-6.47**	-1.02**	-0.85	-13.77**	-4.48**	-1.44**	-5.92**	0.59	-0.17	-1.80*
RHR 27 x IR 24	11.21**	14.59**	12.89**	1.88**	2.11**	14.26**	6.02**	1.99**	7.97**	0.97	0.12	4.04**
VEDA x PUSA 169	4.15**	4.91*	5.03**	0.59	1.74**	9.13*	4.90**	1.14**	6.16**	-1.15	0.21*	1.52*
VEDA x PB-1	5.53**	4.74**	5.59**	1.13**	1.61**	2.85	1.30	0.51	1.24	1.64*	0.10	2.10**
VEDA x IR 24	-9.69**	-9.64	-10.62**	-1.72**	-3.35**	-11.98**	-6.21**	-1.65**	-7.40**	-0.49	-0.30**	-3.62**
HALCHAL x PUSA 169	2.73	3.42	2.61	0.54	1.26*	12.45**	4.63**	1.17**	5.30**	-0.75	0.26**	1.22
HALCHAL x PB-1	1.40	-0.27	1.78	0.16	0.73	-22.13**	-7.68**	-2.18**	-11.10**	4.34**	-0.28**	0.18
HALCHAL x IR 24	-4.13**	-3.15	-4.39*	-0.70*	-1.99**	9.68*	3.05*	1.01*	5.80**	-3.59**	0.02	-1.40*
SUPER MOTI x PUSA 169	-8.80**	-10.88**	-9.49**	-1.38**	-1.75**	2.90	0.35	0.33	1.61	-5.28**	0.12	-3.31**
SUPER MOTI x PB-1	9.02**	11.04**	9.34**	1.49**	2.91**	0.60	0.55	0.02	1.27	3.66**	0.07	3.58**
SUPER MOTI x IR 24	-0.23	-0.17	0.15	-0.10	-1.16*	-3.50	-0.90	-0.35	-2.87	1.63*	-0.19	-0.27
SE(sca)	1.52	2.13	1.73	0.33	0.52	3.92	1.49	0.42	1.65	0.66	0.10	0.71
SE(sij-skj)	2.15	3.01	2.45	0.46	0.73	5.55	2.10	0.59	2.33	0.93	0.14	1.00

Table 4. Per *se* performance on gca and sca effect

Characters	Per se performance	GCA effect of parents	SCA effect
	2015	2015	2015
Days to 50% flowering	Magic	-12.29	Shriram 434 x PB-1 (-11.61)
	Halchal	-10.86	Veda x IR24 (-9.69)
	Shriram 453	-7.03	Super Moti x Pusa 169 (-8.80)
	RHR 27	-0.47	Vidya 295 x Pusa 169 (-8.38)
	Sumo	0.41	Kuber x Pusa 169 (-8.22)
Days to maturity	Halchal	-13.39	Jhona 349 x PB-1 (-11.44)
	Magic	-13.71	Super Moti x Pusa 169 (-10.88)
	Shriram 453	-9.48	Veda x IR24 (-9.64)
	Sumo	-0.82	Vidya 295 x Pusa 169 (-9.08)
	RHR 27	1.33	Kuber x Pusa 169 (-8.60)
Spikelet fertility (%)	Shriram 434	9.72	Shriram 432 x IR24 (8.00)
	Vidya 295	9.51	Vidya 295 x PB-1 (7.21)
	Shriram Reshma	7.83	Shriram Reshma x PB-1 (6.58)
	Kuber	6.81	RHR 27 x IR24 (6.02)
	Veda	4.5	Kuber x IR24 (4.93)
Spikelet per panicle	Magic	25.85	Shriram 432 x IR24 (25.82)
	Kuber	24.21	Vidya 295 x PB-1 (22.99)
	Shriram 434	23.58	Shriram Reshma x PB-1 (20.27)
	Veda	21.68	Sarju 52 x PB-1 (16.65)
	Sarju 52	12.19	RHR 27 x IR24 (14.26)
Panicle length (cm)	Shriram 434	7.55	Shriram 434 x IR24 (14.37)
	Shriram 432	0.98	Super Moti x PB-1 (2.91)
	Veda	0.72	Vidya 295 x PB-1 (2.76)
	Sumo	0.67	Kuber x PB-1 (2.18)
	Nagina	0.54	RHR 27 x IR24 (2.11)
Ear Bearing tillers per plant	Jhona 349	1.53	RHR 27 x IR24 (1.88)
	Kuber	1.51	Super Moti x PB-1 (1.49)
	Shriram 432	1.08	Vidya 295 x PB-1 (1.34)
	Veda	0.96	Shriram 434 x IR24 (1.23)
	Nagina	0.88	Kuber x PB-1 (1.11)
Plant height (cm)	Magic	-12.05	Shriram 434 x PB-1 (-12.54)
	Halchal	-9.22	Veda x IR24 (-10.62)
	Shriram 453	-8.67	Jhona 349 x PB-1 (-10.53)
	Sarju 52	-7.00	Super Moti x Pusa 169 (-9.49)
	Shriram Reshma	-1.92	Kuber x Pusa 169 (-9.32)
Test Weight	Shriram 434	1.57	Shriram 432 x IR24 (2.47)
	Vidya 295	1.27	RHR 27 x IR24 (1.99)
	RHR 27	1.14	Vidya 295 x PB-1 (1.98)
	Halchal	1.11	Shriram Reshma x PB-1 (1.75)
	Shriram 432	0.48	Kuber x IR24 (1.40)
Biological yield per plant (g)	Super Moti	15.93	Shriram 432 x IR24 (11.60)
	Shriram 434	8.92	Vidya 295 x PB-1 (8.79)
	Kuber	8.4	RHR 27 x IR24 (7.97)
	Vidya 295	4.48	Shriram Reshma x PB-1 (7.21)
	Jhona 349	3.83	Kuber x IR24 (6.79)
Grain yield per plant (g)	Kuber	3.48	RHR 27 x IR24 (4.04)
	Sarju 52	3.24	Super Moti x PB-1 (3.58)
	Shriram 432	2.47	Vidya 295 x PB-1 (3.05)
	Nagina	2.20	Kuber x PB-1 (2.76)
	Shriram 434	1.59	Shriram 434 x IR24 (2.52)

Characters	Per se performance	GCA effect of parents	SCA effect
	2015	2015	2015
Harvest index (%)	Super Moti	7.07	Kuber x PB-1 (7.38)
	Nagina	4.5	Shriram 434x IR24 (6.28)
	Veda	3.06	Shriram Reshma x Pusa 169 (5.35)
	Sumo	2.53	Shriram 432 x Pusa 169 (4.46)
	Shriram 432	0.63	Halchal x PB-1 (4.34)
Grain L/B ratio	Kuber	1.12	Kuber x IR24 (2.09)
	Magic	0.49	Super Moti x PB-1 (0.45)
	Shriram 434	0.23	Shriram 453 x IR24 (0.42)
	Vidya 295	0.22	Sarju 52 x PB-1 (0.30)
	Shriram Reshma	0.12	Shriram 432 x IR24 (0.28)

Among 45 crosses during course of study, 11 crosses possessed sca effect in positive direction with significant values for L:B ratio. Some of the promising crosses in order of sca effect during 2015 were KUBER xIR 24 (2.09), VIDYA 295 x PB-1 (0.45), SHRIRAM RESHMA x PB-1 (0.42), SARJU 52 x PB-1 (0.30) and SHRIRAM 432 x IR 24 (0.28). The estimate of gca effects on the seed parent were significant either in positive or in negative direction during the study years except IR-24 during 2015 was non-significant for the character yield/hill. Among restorer lines Kuber (3.48), Sarju 52 (3.24), Shriram 432(2.47), Nagina (2.20), Shriram 434 (1.59), Veda (1.15). These results are in line with findings by Muhammad et al. [11] that maternal effects were significant in 1000 grain weight and fertility percentage in rice.

The significant and positive effect for yield/hill were observed in 14 cross combinations. The best five cross combinations RHR 27 x IR 24 (4.04), SUPER MOTI x PB-1 (3.58), VIDYA 295 x PB-1 (3.05), KUBER x PB-1 (2.76) and SHRIRAM 434 x IR 24 (2.52) observed significant and negative sca effects however, cross SHRIRAM 434 x PB-1 exhibited maximum negative sca effects (-4.36) during the study period, (Table 3). Above cross combinations were found to be good specific combinations with high heterotic effects for grain yield along with most of the yield contributing characters found good specific cross combinations in rice. None of the cross combinations were found to be good specific cross combinations for all the characters studied. Generally, in most of the good specific cross combinations at least one low general combiner parents were involved for all the characters along with grain yield. It also indicated both additive and non-additive types of gene action Bagheri, [10]. Such a differential response of parents to combining ability was also reported by Kumar et al. [12], Shanthi et al. [13], Peyman et al. [14], Sharifi [15], Gopikannan and Ganesh [5], Singh et al. [6], Moumeni and Vahed [7], Singh et al. [8] and Vanave et al. [9].

Further it can be revealed that with high sca effects at least one good general combiner was necessary for the hybrids. In view of the per se performance of parents and their gca effect for grain yield per plant, its components and salt tolerance studied Vanave et al. [9].

The estimation of general combining ability (gca) variances for females (σ 2 f) were significant for all the characters except productive tillers hill-1 and panicle length. General combining ability (gca) variances for males (σ 2 m) also recorded significant reaction for all the characters under study except productive tillers hill-1, days to maturity and harvest index Vanave et al. [9].

4. CONCLUSION

The gca and sca effects were significant for all the characters in this study. The magnitate of sca variance was higher than gca variance for all the characters and were shown presence of predominance of non-additive gen action for all the observation under study. The Halchal variety was found to be good general combiner for days to 50 % flowering and early maturity while for tallness IR-24 was good general combiner with significant desirable effects. Magic variety was good general combiner for dwarfness and Shriram for the test weight. The variety Moti was best general combiner for the harvest index, Kuber for yield per hills also was found under study. The best cross combination RHR-27 × IR-24 for yield per hill and ear bearing tillers per plant were found in the present study. The best cross combination in Shriram × PB-1 for plant height, RHR-27 × IR-24 for ear bearing tillers, panicle length, spike length per panicle followed

by Vidya 295 × PB-1 were showed significant positive. This suggested that selection would be quite efficient in improving yield and yield components in context of sodic soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Munns R, James RA, Lauchli A. Approaches to increasing the salt tolerance of wheat and other cereals. J. Exp. Bot. 2006;57(5):1025-1043.
2. Fonseca S, Patterson FL. Hybrid vigour in a seven parent diallel crosses in common wheat (*T. aestivum* L.). Crop Sci. 1968;8: 85-95.
3. Kempthorne O. An introduction to genetic studies. John Wiley and Sons, New York; 1957.
4. Sanghera GS, Waseem Hussain. Heterosis and combining ability estimates using Line x tester analysis to develop rice hybrids for temperate conditions. Notulae Scientia Biologicae. 2012;4(3):131-142.
5. Gopikannan M, Ganesh SK. Investigation on combining ability and heterosis for sodicity tolerance in rice (*Oryza sativa* L.). African Journal Agriculture Research. 2013a;8(32):4326–4333.
6. Singh Y, Patel PB, Singh PK, Singh V. Combining ability analysis for salt tolerance in rice (*Oryza sativa* L.) under costal salt affected soil. Trends in Biosciences. 2013;6(6):776-780.
7. Moumeni A, Vahed HS. Genetic analysis of salt tolerance in Iranian selected rice genotypes. Iranian Journal of Crop Science. 2013;15(2):90-106.
8. Singh SK, Diwvedi AK, Said M, Singh VP, Srivastav S. Analysis of variance for yield and its contributing characters rice (*Oryza sativa*) under sodic soil. Bull. Env. Pharmacol. Life Sci. 2017;6:226-235.
9. Vanave PB, Vaidya GB, Jadhav BD. Combining ability of rice genotypes under coastal saline conditions. Electronic Journal of Plant Breeding. 2018;9(1):116-123.
10. 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.
11. Muhammad Y, Saleem Y, Mirza J, Muhamad AH. Combining ability for yield and yield related traits in Basmati rice (*Oryza sativa* L.) Pakistan Journal of Botany. 2010;42:627-637.
12. Kumar M, Kumar K, Verma GP, Verma OP. Combining ability analysis for yield and component traits under salinealkali soil in rice. Oryza. 2010;47(3):193-200.
13. Shanthi P, Jebaraj S, Geetha S. Study on gene action for sodic tolerance traits in rice (*Oryza sativa* L.). Electronic Journal of Plant Breeding. 2011;2(1):24-30.
14. Peyman S, Motlagh MRS, Aminpanah H. Diallel analysis for salinity tolerance in rice traits at germination stage. African Journal of Biotechnology. 2012;11(14):3276-3283.
15. Sharifi P. Graphic analysis of salinity tolerance traits of rice (*Oryza sativa* L.) using biplot method. Cer. Res. Comm. 2012;40(3):342-350.

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