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EFFECT OF COMBINING ABILITY ON PARENTS AND HYBRIDS FOR YIELD AND ITS ATTRIBUTING TRAITS IN RICE (*ORYZA SATIVA* L.)

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ABSTRACT

Eighteen hybrids obtained by crossing three CMS lines and six testers for 15 yield attributing characters. Among the lines IR79156A was found to be the good general combiner and contribution of testers towards combining ability was significant in respect of majority of the traits. Male parental lines R1060-1674-1-1, JHITPITI and P-1460 appeared to be best general combiner for most of the characters. The present finding revealed that cross combinations IR58025A/PR-111 (9.63) showed highly significant positive SCA effects followed by IR79156A/R1060-1674-1-1(5.83), IR79156A/ JHITPITI (5.72), IR58 025A/ P-1460(4.39) and IR58025A/R-1213-3 (1.28) for grain yield per plant. Thus, the present study revealed that good general combiner was not necessarily best cross combinations, nor poor x poor hybrid always shows poor combinations.

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INTRODUCTION

Rice is one of the most important stable food crops of India (Singh *et al*., 2014).Extent of heterosis play an important role in the seed yield of rice and success of hybrids decides lead to success at commercial level. The success of any plant breeding method depends on the choice of appropriate genotypes as parents in the hybridization programme. Line x Tester analysis (Kempthorne, 1957) is the most popular method for self-fertilized crops especially in rice breeding programme (Peng and Virmani, 1990). The combining ability studies of the genotype provide information which helps in the selection of better parents for effective breeding and also effective genetic parameters in deciding the next phase of breeding programs. Combining ability is a complex trait that is controlled by polygenes. In general, GCA is less and SCA is more influenced by environment (Singh and Richharia, 1977). Generally good combing parents result in higher frequency of heterotic hybrids than poor combining parents. In a hybrid breeding programme plant breeders aim to identify parental lines with good general combining ability, and crosses showing high specific combining ability. AS proposed by Kempthorne (1957) the present investigation, therefore, was taken with 3 lines and 6 testers along with 18 F_1's for their combining ability using line x tester design (L x T).

MATERIALS AND METHODS

The present investigation was conducted at research farm, College of Agriculture, IGKV, Raipur and the experimental material of comprised three CMS lines, six testers including two checks (Indira Sona and Mahamaya) the experimental material were received from IRRI, Philippines, CRRI, Cuttack, DRR Hyderabad and IGKV, Raipur. The details of these lines are presented in Table 1.

The male sterile lines *i*.e. 3 CMS lines and six testers were sown in nursery bed. The 21 days old nursery of parents were transplanted in crossing block in five rows of one meter length keeping 20 x 15 cm spacing and three CMS lines were transplanted in separate blocks to avoid out crossing with other parents. The hybridization of selected six male parents were crossed to each of the three CMS lines to generate a set of hybrids in a line x tester manner as proposed by Kempthorne (1957). About 21 days old seedlings of total 18 hybrids and their 9 parents (3 lines along with the isogenic 'B' lines and 6 testers) along with maintainers were planted in Randomized complete block design (RCBD) with two replications during *kharif* 2011.The distance between row to row and plant to plant will be 20 and 15 cm, respectively. In the present investigation following observation are recorded *viz*., Days to 50% flowering, Plant height (cm), Flag leaf length (cm), Flag leaf area (cm^2), Leaf area index, Productive tillers/Plant, Pollen fertility (%), Panicle length/plant, Biological yield/plant, Filled spikelet/Panicle, sterile spikelet/Panicle, Spikelets fertility (%), Grain yield/plant, 1000 grain weight (g), Harvest index.

Anova for Line X Tester

The analysis of variance for combining ability of all the traits under study has been presented in the Table 2.

The variance due to treatments, parents, hybrids was highly significant for all the characters under study. The variance due to parent vs. hybrids was also found highly significant for almost all the characters except plant height, panicle length. The variance due to lines was found not significant for all the traits under study; it may be due to less number of entries. The variance due to testers was found significant for grain yield per plant, filled spikelets per panicle, sterile spikelets per panicle, pollen fertility percentage, spikelet fertility percentage and thousand grain weight. The variance due to line x testers was recorded highly significant for all the characters *viz*., days to 50 percent flowering, plant height, flag leaf length, flag leaf area, leaf area index, productive tiller per plant, pollen fertility, biological yield per plant, sterile spikelets per panicle, filled spikelets per panicle, spikelet fertility percent, panicle length, thousand grain weight, grain yield per plant and harvest index. The results suggested sufficient variability available for yield and yield components under study.

Similar finding have been reported by Saleem *et al*. (2010) for treatments, patents, parents vs. crosses and hybrids and Saidaiah *et al* (2010) for treatments, parents, parents vs. crosses, testers except panicle length and lines vs. testers.

RESULTS AND DISCUSSION

The estimates of general combining ability (GCA) effects of lines and testers and specific combining ability (SCA) effects of hybrids for different characters are presented in Table 3, 4 and 5.

In the present study among the lines, IR79156A showed positive (2.79) and significant GCA effect for grain yield per plant. Among three CMS line IR58025A good general combiner (GCA) for almost all the character under study except for productive tiller per plant and grain yield per plant. Line IR 79156A have good GCA for plant height (cm), flag leaf length (cm), flag leaf area (cm^2), leaf area index, panicle length per plant biological yield per plant, sterile spikelet per panicle, grain yield per plant and harvest index. Line CRMS 31A negative significant for most of character under study viz., plant height (cm), flag leaf length (cm), flag leaf area (cm^2), pollen fertility, sterile spikelet per panicle, spikelet fertility, grain yield per plant and harvest index indicating poor performance

Table 1: Details of the seed material along with source

S. No.	Designation	Seed source
CMS LINES		
1.	IR 58025A	DRR, Hyderabad
2.	CRMS 31A	CRRI, Cuttack
3.	IR 79156A	IRRI, Philippines
S. No.	Designation	Seed source
TESTERS		
1.	OR2310-12	DRR, Hyderabad
2.	R-1213-3	IGKV, Raipur, C.G.
3.	R1060-1674-1-1	IGKV, , C.G.
4.	JHITPITI	Germplasm, IGKV, Raipur, C.G.
5.	PR-111	PAU, Punjab
6.	P-1460	IARI, New Delhi
CHECKS		
1.	INDIRA SONA	IGKV, Raipur, C.G.
2.	MAHAMAYA	IGKV, Raipur, C.G.

Table 2: Analysis of Variance for Line x Tester

Source	df	Characters 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Replication	1	0.11	0.26	0.24	0.54	0.0062	0.047	0.23	0.42	22.72	2.43	42.58	0.87	3.37	0.036	1.96
Treatments	26	43.58**	176.96**	31.41**	241.25**	1.06**	5.21**	1507.52**	7.11**	354.80**	10850.42**	11601.16**	1294.57**	123.19**	20.40**	340.70**
Parents	8	63.72**	365.55**	23.28**	266.66**	0.74**	10.01**	861.98**	6.31**	316.66**	9264.92**	8239.24**	763.81**	50.27**	18.43**	210.65**
Hybrids	17	35.72**	67.10**	33.59**	249.34**	1.24**	3.24**	1892.05**	5.03**	326.38**	11874.22**	12834.63**	1603.46**	155.20**	21.68**	415.43**
Parent vs. hybrids	1	16.33**	551.98**	59.52**	220.33**	0.66**	0.42	134.80**	49.03**	1143.35**	6129.87**	17527.44**	289.56**	162.26*	14.52**	110.78**
Lines	2	25.53	160.30	76.90	1140.96**	3.18	0.10	329.73	1.94	149.27	455.78	3639.90	335.96	96.95	11.44	186.74
Testers	5	42.84	73.55	16.25	153.62	1.19	5.65	5179.55**	10.83*	211.31	28995.57*	26735.90*	4451.90**	336.85**	51.35**	1025.71
Line x Tester	10	34.19**	45.23**	33.59**	118.89**	0.88**	2.65**	560.76**	2.74**	419.33**	5597.24**	7722.94**	432.73**	76.02**	8.88**	1546.03**
Error	26	0.29	0.25	0.15	0.30	0.01	0.55	0.56	0.30	0.28	0.68	11.02	1.20	0.07	0.073	0.36
Variance of GCA		5.82	9.57	3.27	42.37	0.17	0.40	368.85	0.81	18.82	2026.24	1957.77	318.49	26.09	3.89	76.42
Variance of SCA		42.74	56.53	41.99	148.62	1.10	3.32	700.96	3.44	524.16	6996.55	9653.69	540.92	95.04	11.11	195.04
Variance of GCA/Variance of SCA		0.136	0.169	0.077	0.285	0.154	0.120	0.526	0.235	0.035	0.289	0.202	0.588	0.274	0.350	0.391

* = Significance p>0.05, ** = Significance p>0.01; 1. Days to 50% flowering, 2. Plant height (cm), 3.Flag leaf length (cm), 4.Flag leaf area (cm^2), 5.Leaf area index, 6. Productive tillers/Plant, 7.Pollen fertility (%), 8. Panicle length/plant, 9. Biological yield/plant, 10. Filled spikelet/Panicle, 11. Sterile spikelet/Panicle, 12.Spikelets fertility (%), 13. Grain yield/plant, 14.1000 grain weight (g), 15. Harvest index

Table 3: General Combining Ability (GCA) effects

Parents	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Lines															
IR58025A	-1.47*	-2.24*	-1.70*	-6.53**	-0.50**	-0.01	5.83**	-0.33*	-3.36**	4.04**	4.02**	5.56**	0.11	-0.95**	1.87**
IR 79156A	0.03	4.22**	2.91**	11.21*	0.52**	-0.09	-1.52**	0.45**	3.67**	-7.09**	15.05**	-0.59	2.79**	-0.06	2.67**
CRMS 31A	1.44**	-1.98	-1.21**	-4.68**	-0.02	0.10	-4.31**	-0.11	0.31	3.05**	-19.07**	-4.97**	-2.90*	1.00**	-4.53**
Testers															
OR2310-12	0.78**	0.87**	2.98**	2.67**	0.24**	-0.40	-38.37**	0.27	-6.33**	-110.63**	99.52**	-33.61**	-8.05*	2.48**	-12.79**
R1060-1674-1-1	-2.72**	-0.67*	-0.61*	-0.27	0.04	-0.57*	27.98**	1.85**	-2.29**	35.12**	-79.88**	28.55**	8.31**	1.98**	15.68**
R-1213-3	0.94**	-4.28**	0.87**	5.99**	0.51**	-1.24**	-32.62**	-0.34	2.97**	-46.53**	36.89**	-28.96**	-9.04**	2.63**	-15.83**
JHITPITI	-2.89**	6.27**	-1.19**	3.41**	0.20**	1.25**	20.79**	0.79*	-0.76	41.58**	-15.07**	19.00**	6.34**	-0.66*	12.48**
PR-111	4.28**	-0.89**	-1.14**	-7.27**	-0.76**	-0.10	-1.51*	-2.15**	-3.89**	-1.95*	21.29**	-7.54**	-2.09**	-4.76**	-4.18*
P-1460	-0.39	-1.30**	-0.90**	-4.53**	-0.22**	1.06**	23.72**	-0.42	10.31**	82.42**	-62.85**	22.56**	4.54**	-1.67*	4.64**

* = Significance p > 0.05, ** = Significance p > 0.01; 1. Days to 50% flowering, 2. Plant height (cm), 3.Flag leaf length (cm), 4.Flag leaf area (cm^2), 5.Leaf area index, ; 6. Productive tillers/Plant, 7.Pollen fertility (%), 8. Panicle length/plant 9. Biological yield/plant; 10. Filled spikelet/Panicle, 11. Sterile spikelet/Panicle, 12.Spikelets fertility (%), 13. Grain yield/plant, 14.1000 grain weight (g), 15. Harvest index

Table 4: Classification of parents with respect to general combining ability (GCA) effects for various characters in rice

Parents	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Lines															
IR58025A	G	G	P	P	P	A	P	P	P	G	P	G	A	P	G
IR 79156A	A	P	G	G	G	A	G	G	G	P	P	A	G	A	G
CRMS 31A	P	A	P	P	A	A	G	A	A	G	G	P	P	G	P
Testers															
OR2310-12	P	P	G	G	G	A	P	A	P	P	P	P	P	G	P
R1060-1674-1-1	G	G	P	A	A	P	G	G	P	G	G	G	G	G	G
R-1213-3	P	G	G	G	G	P	P	A	G	P	P	P	P	G	P
JHITPITI	G	P	P	G	G	G	G	G	A	G	G	G	G	P	G
PR-111	P	G	P	P	P	A	P	P	P	P	P	P	P	P	P
P-1460	A	G	P	P	P	G	G	A	G	G	G	G	G	P	G

G = Good; A = Average & P = Poor.* A = Avg. parent having either + ve or –negative but non-significant gca effect; 1. Days to 50% flowering, 2. Plant height (cm), 3.Flag leaf length (cm), 4.Flag leaf area (cm^2), 5.Leaf area index, 6. Productive tillers/Plant, 7.Pollen fertility (%), 8.Panicle length/plant ; 9. Biological yield/plant 10. Filledspikelet/Panicle, 11. Sterile spikelet/Panicle, 12.Spikelets fertility (%),13. Grain yield/plant, 14.1000 grain weight (g), 15. Harvest index

Table 5: Specific combining ability (SCA) effects

Hybrids	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
IR58025A															
IR58025A*OR2310-12	1.47**	0.10	-3.49**	-10.24**	-0.47**	-1.09*	-13.27**	-0.08	5.66**	-2.33**	13.18**	-12.49**	-3.16**	-0.07	-8.62**
IR58025A*R1060-1674-1-1	3.47**	0.36	2.86**	10.30**	0.93**	-0.22	-7.92**	0.45	-2.67*	-29.88**	12.28**	-9.19**	-6.14**	1.58**	-8.80**
IR58025A*R-1213-3	-0.69*	1.30*	-0.10	1.84*	-0.25*	-1.26*	-1.98**	1.30**	-8.44**	-35.76**	74.24**	-3.48**	1.28**	1.23**	2.06*
IR58025A*JHITPITI	-2.36**	-19.00**	2.87**	-5.65**	-0.41**	0.41	-5.03**	-1.01*	-16.81**	-21.24**	-50.43**	-1.55*	-6.00**	-2.79**	0.33
IR58025A*PR-111	1.47**	5.09**	-3.17**	-2.16**	0.20*	1.51**	28.68**	-0.61	24.23**	49.29**	-88.99**	28.85**	9.63**	1.01**	7.65**
IR58025A*P-1460	-3.36**	-4.13**	1.03*	5.91**	0.01	0.64	-0.48	-0.05	1.97*	39.92**	39.75**	-2.15*	4.39**	-0.97**	7.38**
IR 79156A															
IR79156A*OR2310-12	-4.53**	-0.75*	2.75**	1.73**	0.54**	0.69	8.40**	-0.41	-7.07**	3.16**	11.55**	6.94**	3.47**	1.04**	11.04**
IR79156A*R1060-1674-1-1	1.47**	-2.02**	-4.44	-3.37**	-0.30**	-1.05*	8.71**	0.57	4.49**	32.86**	-37.05**	4.93**	5.83**	-3.51**	6.89**
IR79156A*R-1213-3	-4.19**	-1.05**	4.35**	1.15*	0.23*	1.02*	2.74**	0.21	-2.47*	-43.00**	13.88**	2.32*	-2.10**	-0.11	-2.17**
IR79156A*JHITPITI	4.14**	8.75**	-4.15**	-2.17**	-0.79**	0.64	14.62**	0.24	4.26**	-63.47**	-16.66**	12.57**	5.72**	0.72**	5.84**
IR79156A*PR-111	-1.03*	-5.49**	-1.23	-0.43	0.13	-1.11*	-34.56**	1.24**	-14.81**	62.39**	34.98**	-25.19**	-9.15**	-0.28	-10.77**
IR79156A*P-1460	4.14**	1.02*	2.72**	3.10**	0.19*	-0.18	0.09	0.63	15.59**	8.06**	-6.69*	-1.57*	-3.77**	2.14**	-10.84**
CRMS 31A															
CRMS31A*OR2310-12	3.06**	0.75*	0.73*	8.51**	-0.07	0.40	4.86**	0.48	1.41	-0.83	-24.72**	5.55**	-031	-0.97**	-2.42**
CRMS31A*R1060-1674-1-1	-4.94**	2.38**	1.59**	-6.94**	-0.62**	1.27*	-0.79	-1.01*	-1.82*	-2.98**	24.77**	4.26**	0.31	1.93**	1.91**
CRMS31A*R-1213-3	4.89**	0.20	-4.24**	-2.98**	0.02	0.24	-0.76	-1.51**	10.91**	78.76**	-88.09**	1.16	0.82*	-1.12**	0.11
CRMS31A*JHITPITI	-1.78**	-6.85**	1.27**	7.82**	1.19**	-1.05*	-9.58**	0.77	12.54**	-41.15**	67.09**	-11.03**	0.29	2.06**	-6.17**
CRMS31A*PR-111	-0.44	0.41	4.39**	2.59**	-0.32**	-0.40	5.88**	1.86**	-9.42**	14.18**	54.01**	-3.66**	-0.48	-0.74**	3.12**
CRMS31A*P-1460	-0.78*	3.12**	-3.74**	-9.00**	-0.20*	-0.46	0.38	-0.58	-13.62**	-47.98**	-33.06**	3.72**	-0.62*	-1.17**	3.46**

* = Significance $p > 0.05$, ** = Significance $p > 0.01$; 1. Days to 50% flowering, 2. Plant height (cm), 3.Flag leaf length (cm), 4.Flag leaf area (cm^2), 5.Leaf area index, ; 6. Productive tillers/Plant, 7.Pollen fertility (%), 8. Panicle length/plant 9. Biological yield/plant 10. Filledspikelet/Panicle, 11.Sterile spikelet/Panicle,12.Spikelets fertility (%), 13.Grain yield/plant, 14.1000 grain weight (g), 15. Harvest index

of line hence not useful for exploiting heterosis. Line IR 79156A performed best among all the three CMS line used in hybrid breeding programme.

The tester JHITPITI recorded negatively significant GCA effect (-2.89) followed by R1060-1674-1-1(-2.72) therefore recorded best general combiners for earliness. The testers R-12132-3, P-1460, PR-111 and R1060-1674-1-1 exhibited negatively significant GCA effects for plant height Minimum plant height is needed to protect the crop from lodging. Tester OR2310-12(2.98) followed by R-1213-3 positively significant GCA effect recorded for flag leaf length. Testers R-1213-3, JHITPITI and OR2310-12 recorded positively significant GCA effects for character flag leaf area and leaf area index. The flag leaf length influenced to the photosynthetic area followed by photosynthesis. Similar finding was also supported by Saidaiah *et al.* (2010) for flag leaf length. The tester JHITPITI and P-1460 registered the best general combiner among the parents for productive tillers per plant. More productive tillers per plant are a desirable trait of rice hybrids with increased yield per plant. Among the testers, pollen fertility highly significant positive GCA effect was shown by R1060-1674-1-1 (27.98) followed by P -1460 (23.72) and JHITPITI (20.79) while, OR2310-12 (-38.37) and R-1213-3 (-32.62) showed negatively significant GCA effects. In case of testers, R1060-1674-1-1 (1.85) and JHITPITI (0.79) showed significant GCA effects for panicle length. Among the testers P-1460 shows highly significant positive GCA effect (10.31) followed by R-1213-3 (2.97) for biological yield per plant. Among the testers R1060-1674-1-1, JHITPITI and P-1460 showed positively significant GCA effects with the characters viz., filled spikelet per panicle, sterile spikelet per panicle, spikelet fertility percentage and grain yield per plant. Tester R1060-1674-1-1 and JHITPITI were found as good general combiners for bring improvement in harvest index.

When estimates of GCA effects compared with per se performance, it was observed that the parents, which possessed higher GCA effects for grain yield and its components were good in their *per se* performance. Thus, choice of the parents on the basis of *per se* performance may be effective for grain yield in the population under study.

The SCA effect of the hybrids *viz.*, IR58025A/JHITPITI, CRMS31A/JHITPITI, IR79156A/PR-111, IR58025A/P-1460, IR79156A/R1060-1674-1-1 and IR79156A/OR2310-12 were highly significant for plant height. The SCA variance was greater than the GCA variance for plant height, indicating predominance of non-additive gene action. Therefore, the improvement of such trait hybridization should be recommended for improvement towards dwarfness. Similar findings were obtained by Jayashudha and Sharma (2009). The flag leaf length influenced to the photosynthetic area followed by photosynthesis. The SCA variance was found higher than the GCA variance, indicating the role of non-additive gene action. Similar finding was also supported by Saidaiah *et al.* (2010) for flag leaf length. The hybrid IR58025A/R1060-1674-1-1 (10.30), CRMS31/OR2310-12 (8.51) and CRMS31A/JHITPITI (7.82) recorded as good specific combiners for flag leaf area. Saidaiah *et al.* (2010) also reported high SCA variance than GCA variance for flag leaf area. The hybrid CRMS31A/JHITPITI (1.19), IR58025A/R1060-1674-1-

Table 6: Top ranking parents with respect to per se performance and GCA effects and Top ranking parents with respect to per se performance and SCA effects in rice

S. no.	Best performing hybrid (per se performance)	Status of parent	Hybrid with high SCA effect	GCA of the parents	SCA effect
1	IR79156A X OR2310-12	A X P	CRMS31A X R1060-1674-1-1	P X G	-4.94
2	IR79156A X R1060-1674-1-1	P X G	IR58025A X JHITPITI	G X P	-19.00
3	IR79156A X OR2310-12	G X G	CRMS31A X PR111	P X P	4.39
4	IR79156A X OR2310-12	G X G	CRMS31A X JHITPITI	P X G	7.82
5	IR79156A X OR2310-12	G X G	CRMS31A X JHITPITI	A X G	1.19
6	IR58025A X PR111	A X A	IR58025A X PR111	A X A	1.51
7	IR58025A X PR111	P X P	IR58025A X PR111	P X P	28.68
8	IR58025A X PR111	P X P	IR58025A X R-1213-3	P X A	1.30
9	IR58025A X PR111	P X P	IR58025A X PR-111	P X P	24.30
10	IR58025A X PR111	G X P	IR79156A X PR111	P X P	62.39
11	IR58025A X PR111	P X P	IR58025A X PR-111	P X P	-88.99
12	IR58025A X PR111	G X P	IR58025A X PR-111	G X P	28.85
13	IR58025A X PR111	A X P	IR58025A X PR-111	A X P	9.63
14	IR58025A X PR111	P X P	IR79156A X P-1460	A X P	2.14
15	IR58025A X PR111	G X P	IR79156A X OR2310-12	G X P	11.04

1. Days to 50% flowering, 2. Plant height (cm), 3.Flag leaf length (cm), 4.Flag leaf area (cm^2), 5.Leaf area index, 6. Productive tillers/Plant, 7.Pollen fertility (%), 8. Panicle length/plant ; 9. Biological yield/plant, 10. Filledspikelet/Panicle, 11.Sterile spikelet/Panicle, 12.Spikelets fertility (%),13.Grain yield/plant, 14.1000 grain weight (g),15. Harvest index

1and IR79156A/ OR2310-12 (0.54) recorded as good specific combiners for leaf area index. Saidaiah *et al*. (2010) also reported high specific combining ability (SCA) variance than general combining ability (GCA) variance for leaf area index. Among the hybrids IR58025A/PR-111 (1.51), CRMS31A/ R1060-1674-1-1 (1.27) and IR79156A/R-1213-3 (1.02) were recorded as good specific combiners for productive tiller per plant. More productive tillers per plant are a desirable trait of rice hybrids with increased yield per plant. The pollen fertility highly significant positive SCA effects were recorded by cross IR58025A/PR-111 (28.68) followed by IR79156A/ JHITPITI (14.62), IR79156A/R1060-1674-1-1 (8.71), IR79156A / OR2310-12 (8.40) and CRMS31A/PR-111 (5.88). On the other hand, negatively significant specific combining ability (SCA) effect was recorded by IR79156A/PR-111 (-34.56) followed by IR58025A/OR2310-12 (-13.27), CRMS31A/JHITPITI (-9.58), IR58025A/R1060-1674-1-1 (-7.92) and IR58025A/ JHITPITI (-5.03) for pollen fertility per cent indicating their use in hybridization programme for development of new maintainers. Among all the crosses the hybrids IR58025A/PR-111 (49.29), IR79156A/PR-111 (62.39) and CRMS31A/R-1213-3 (78.76) were recognized as good specific combiners for fertile spikelets per panicle. Similar results were also supported by Kumer *et al*. (2010). The hybrids IR58025A/PR-111 (28.85) showed highly significant positive SCA effects followed by IR79156A/ JHITPITI (12.57) and IR79156A/OR2310-12 12 (16.17) found as good specific combiners for fertility restoration. Similar results were reported by Hariprasanna *et al*. (2006), Kumar *et al*. (2006), Sharma (2006), and Jayasudha and Sharma (2009). Among the cross combinations IR79156A/OR2310 (11.04), IR58025A/PR-111(7.65), IR58025A/P-1460 (7.38), IR79156A/ R1060-1674-1-1(6.89), IR79156A/JHITPITI (5.84) found highest positive significant harvest index.

Out of 18 hybrids positive significant SCA effect for grain yield per plant were exhibited by 9 hybrids. Among which IR58025A/PR-111 (9.63) showed highly significant positive SCA effects followed by IR79156A/R1060-1674-1-1(5.83), IR79156A/JHITPITI (5.72), IR58025A/P-1460(4.39) and IR58025A/R-1213-3 (1.28) for grain yield per plant. Similar findings were also supported by Sharma (2006), Singh *et al*. (2007), and Bagheri and Jelodar (2010) for grain yield per plant. Out of 9 hybrids, IR58025A/PR-111, IR79156A/R1060-1674-1-1 and IR79156A/JHITPITI were the top three hybrids recorded high per se performance and significant positive SCA effects for grain yield per plant were presented in Table 6. The hybrid, IR58025A/P-1460 and IR79156A/R1060-1674-1-1 had both the parent with significant positive GCA possessing additive x additive type of gene action. The hybrid IR58025A/PR-111, IR79156A/JHITPITI and IR58025A/R-1213-3 has only one parent with significant positive GCA effects indicating the involvement additive and dominance interaction.

The hybrids possessed high SCA effects were irrespective of GCA effects of the parents involved Table 6. A combination of good general combiner was not necessarily for best cross combinations, nor poor x poor hybrids always poor combinations. This indicates involvement of non-additive gene effects along with inter allelic interaction in SCA effects. Better performance of hybrids having poor x poor or average x poor general combiner indicated dominance X dominance. Hybrids, where poor x poor and poor x average general combiners, produced high SCA effects may be attributed to the non-additive gene effects due to genetic diversity in the form of heterozygous loci for specific trait; similar findings also reported by Dalvi and Patel (2009) and Bhati *et al*. (2015).

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