Combining Ability and Gene Action Analysis for Yield and its Components in Rice (*Oryza sativa L.*)

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Abstract

Thirty three hybrids generated from crossing three lines with eleven 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. Among parents IR 58025A, RPHR 203-3 and OR 1898-18RAU 720-12-44 were the best general combiners for grain yield and contributing traits. The best combinations for sca effects are IR 58025A/ OR 1898-18RAU 729-12-44, CRMS 31A/ IR 68830-NDR-1-1, IR 58025A/R 304-34, CRMS32A/ R 1130-102-3-88-1 and CRMS 31A/ RPHR 203-3. Promising hybrids based on per se performance, gca and sca effects are IR 58025A/ OR 1898-18RAU 729-12-44, IR 58025A/ R 304-34, CRMS 31A/ RPHR 203-3 and IR 58025A/CHINIKAPOOR.

Combining ability analysis helps in the identification of parents with high general combining ability (gca) effects and cross combinations with high – specific combining effects (sca) for commercial exploitation of heterosis and isolation of pure lines among the progenies of the heterotic hybrids. Therefore the present investigation has been conducted to determine the combining ability and gene action for yield and its components using line x tester mating design in rice.

Materials and Methods

The experimental material comprised of 33 hybrids obtained from the lines involving three newly evolved CMS lines (CRMS 31A, CRMS 32A, IR 58025A) and eleven testers (WAR 120-1-5-6-2-B-B-3, RPHR 203-3, R 1130-102-3-88-1, IR 68830-NDR-1-1, CR 780-1937, R 1241-1856-1-1, R 304-34, R 1216-6, CHINIKAPOOR, OR1898-18RAU 729-12-44, WAR 89-4-A9-1-B-B-B-2). The set of hybrids were generated in line x tester pattern for the purpose and evaluated along with parents in Randomized Complete Block Design with two replications at Experimental Research Farm under rainfed conditions. Twenty one days old seedlings of hybrids and parents were transplanted in the field. A standard spacing of 20 x 20 cm was adopted for planting and 12 plants were maintained in a single row.

Single seeding per hill was transplanted. Recommended package of practices were followed. Observations were recorded on five randomly selected plants in both the replications for thirteen traits *viz*., Days to 50% flowering, plant height, tillers per plant, productive tillers per plant, panicle length, flag leaf angle, second leaf angle, third leaf angle, leaf area, pollen fertility (%), spikelet fertility (%), harvest index (%) and seed yield per plant. Combining ability analysis was carried out by the method suggested by Kempthorne (1957).

Results and Discussion

The analysis of variance (ANOVA) showed highly significant differences among lines for most of the characters, except plant height, pollen fertility percentage and harvest index (%). The ANOVA for combining ability of the line x tester set revealed that the variances due to lines as well as testers were significant for characters, indicating significant variation among parents used in this study in terms of general combining ability (Table 1). The significant differences were also recorded for parent's vs crosses indicating presence of heterosis for these characters. The significance of line x tester for all the characters provided a direct test, indicating that non- additive variances were important for majority of the characters. The significant mean square of lines and testers indicated prevalence of additive variance for the yield and its components.

The magnitude of specific combining ability (sca) variance was higher than the gca variance for all the characters. The comparative variances due

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to general combining ability and specific combining ability revealed the predominance of non-additive gene action in the expression of these traits. The presence of non-additive genetic variance offers scope for exploitation of heterosis. This was also reported by Manuel and Palanisamy (1989), Sarawgi *et al.* (1991), Manomani and Ranganathan (1998), Kalitha and Upadhaya (2000), Shanthi *et al.* (2003), Rosamma *et al.* (2005), Kumar *et al*.(2007) and Panwar (2005)

The estimates of general combining ability (gca) effects of lines and testers showed that CMS line IR 58025A and testers RPHR 203-3, OR 1898-18, RAU729-12-44 were superior general combiners for seed yield per plant (Table 2). Character-wise estimation of gca effects of lines revealed IR 58025A to be a good general combiner for seed yield per plant and several contributing characters *viz*., panicle length, leaf area, narrow flag leaf angle, second leaf angle, third leaf angle, pollen fertility, spikelet fertility and harvest index. This line was also found to be good general combiner for late duration, semi tall height and moderate combiner for productive tillers per plant. The line CRMS 32A was good general combiner for earliness, short stature, productive tillers per plant and broad flag leaf angle. Broad leaf angle is good for disposal of pollen grains in seed production where no clipping of leaf is required. CRMS 31A recorded the highest *per se* seed yield per plant. This line was identified as good combiner for shorter plant height, productive tillers per plant, narrow flag leaf angle and second leaf angle. Among the testers, OR 1898-18RAU 729-12-44 was found to be best general combiner for seed yield per plant, harvest index, spikelet fertility, pollen fertility, leaf area, narrow flag leaf, second leaf, third leaf angles, productive tillers per plant and panicle length. Testers, RPHR 203-3 and CHINIKAPOOR were also found good general combiners for the characters viz., seed yield per plant, late duration, harvest index, spikelet and pollen fertility.

The usefulness of a particular cross in the exploitation of heterosis is judged by specific combining ability effects. IR 58025A/ OR 1898-18RAU 729-12-44 recorded the highest sca value for yield and several attributing traits, followed by some other cross combinations like CRMS 31A/ IR 68830-NDR-1-1, IR 58025A/R 304-34, CRMS 32A/ R 1130-102-3-88-1, CRMS 31A/ RPHR 203-3, CRMS 32A/ R 1216-6 and CRMS 32A/ WAR 89-4-A9-1-B-B-B-2 (Table 3). It is evident that cross combinations, which expressed high sca effects for grain yield, have invariable positive sca effects for one or more exhibited yield related traits also. Secondly to get best specific combination for yield it would be important to give due weightage to yield related traits. Grafius (1959) has already suggested that there may not be separate gene(s) for yield *per se* and yield being end product of multiple gene interactions among various yield components.

Cross combinations, IR 58025A/ OR 1898-18RAU 729-12-44, IR 58025A/ CHINIKAPOOR and IR 58025A/ RPHR 203-3 recorded high x high parental gca effects, suggesting that additive x additive type gene action. Manual and Palanisamy (1989) also reported interaction between positive alleles in crosses involving high x high combiners which can be fixed in subsequent generations if no repulsion phase linkages are involved. Crosses like CRMS 31A/ RPHR 203-3, IR 58025A/ R 304-34, CRMS 32A/ RPHR 203-3, and CRMS 32A/ CHINIKAPOOR showed high x low parental gca effects, indicating the involvement of additive x dominance genetic interaction. Peng and Virmani (1990) also reported about the possibility of interaction between positive alleles from good combiners and negative alleles from poor combiners in high x low crosses and suggested exploitation of heterosis in F_1 generation. Their high yield potential would be unfixable in succeeding generations. Similar results were also obtained by Dubey (1975). The crosses CRMS 31A/ IR 68830-NDR-1-1, CRMS 32A/ R 1130-102-3-88-1, CRMS 32A/ R 1216-6, CRMS 32A/ R 1130-102-3-88-1 and CRMS 31A/ WAR 120-1-5-6-2-B-B-3 recorded low x low parental gca effects indicating over dominance and epistatic interactions.

From the study 11 promising cross combinations are identified based on *per se* performance; gca and sca effects are given (Table 4) and can be exploited in breeding programme.

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Table 1 : Analysis of variance for Line x Tester and combining ability

Source	Degree of freedom	Days to 50% flowering	Plant height (cm)	Tillers per plant	Productive tillers per plant	Panicle length (cm)	Flag leaf angle (degree)	II^{nd} leaf angle (degree)
Replication	1	1.2766*	4.08511	0.1037	0.412	2.1755*	4.67	8.415*
Parents	13	42.154**	993.959**	7.516**	11.92**	8.373**	104.5**	109.7**
Hybrids	32	143.19**	430.531**	13.944**	11.1**	18.666**	182.5**	156.9**
Parent vs hybrids	1	102.94**	993.313**	20.87**	43.65**	74.732**	96.07**	122.9**
Lines	2	104**	22.3008	16.803**	28.42**	7.8414**	37.78**	329.6**
Testers	10	33.809**	675.45**	2.5669	2.767	7.4911**	126.7**	54.15**
Line x tester	20	201.79**	348.89**	19.346**	13.534**	25.336**	224.81**	191.03**
Error	46	0.3092	11.329	0.8461	0.807	0.5375	1.321	1.449
Variance of GCA		-6.096	-6.731	-0.413	-0.326	-0.226	4.825	9.163
Variance of SCA		81.27	251.60	7.26	5.67	8.63	81.92	66.01
Variance of GCA /Variance of SCA		-0.075	-0.027	-0.057	-0.058	-0.026	0.059	0.139

Source	Degree of freedom	Third leaf angle (degree)	Leaf area (cm2)	Pollen fertility %	Spikelet fertility%	Harvest Index (%)	Seed yield per plant(gm)
Replication	1	16.362*	12.149	2.383	0.2128	0.0957	-1.486E-11
Parents	13	101.48**	382.75**	2870**	490.62**	81.711**	66.57182**
Hybrids	32	105.68**	364.76**	998.1**	1260.8**	432.35**	228.714**
Parent vs hybrids	1	20.107**	101.02**	769**	4472.7**	1560**	438.9102**
Lines	2	236.56**	762.03**	0.0002	2031.1**	1.4407	79.3350**
Testers	10	72.877**	327.48**	187.3**	208.37**	99.03**	48.8377**
Line x tester	20	108.99**	343.67**	1483.34**	1710.01**	642.09**	333.59**
Error	46	1.0937	3.6997	2.254	1.4162	1.4288	0.6619
Variance of GCA		-0.453	2.754	12.061	-16.643	-7.873	-3.816
Variance of SCA		50.29	189.14	387.52	586.95	211.78	120.70
Variance of GCA /Variance of SCA		-0.009	0.014	0.031	-0.028	-0.037	-0.031

*** =significant of p=0.05 level, **= significant of p=0.01 level**

Table 2: **General combining ability (GCA) effect of different parents for characters under study**

Parents	1	2	3	4	5	6	7	8	9	10	11	12	13
Lines													
CRMS 31A	0.2*	-2.45**	0.52**	0.38**	-0.42**	-3.21**	-0.88**	0.87**	-5.77**	-3.75**	-0.14	-0.01	-1.26**
CRMS 32A	-1.21**	-3.4**	0.13	0.2	-0.22	3.7**	4.42**	1.19**	2.5**	-0.12	-3.32**	-2.34**	-1.85**
IR 58025A	1.02**	5.86**	-0.65**	-0.58**	0.64**	-0.49**	-3.55**	-2.06**	3.27**	3.87**	3.46**	2.34**	3.12**
SE (Lines)	0.08	0.24	0.15	0.14	0.12	0.19	0.2	0.16	0.32	0.25	0.2	0.18	0.12
Testers													
WAR 120-1-5-6-2-B-B-3	-6.21**	-3**	0.55	0.56	0.92**	-8.83**	-2.25**	-5.24**	-0.71	13.98**	18.39**	3.57**	-0.33
RPHR 203-3	0.62**	5.9**	1.22**	0.9**	-0.29	-5.94**	-2.69**	-4.3**	-0.3	12.53**	17.36**	21.46**	11.17**
R 1130-102-3-88-1	2.12**	-1.83**	-1.17**	-1.1**	-2.44**	-1.78**	-3.86**	-1.08**	-18.15**	-32.5**	-28.7**	-10.82**	-5.38**
IR 68830-NDR-1-1	0.29	8.97**	2.11**	1.84**	3.33**	1.45**	-2.02**	-0.35	7.19**	18.97**	-16.46**	-7.16**	-2.27**
CR 780-1937	-5.71**	7.09**	0.61	0.68*	3.42**	4.95**	6.81**	0.92*	-3.09**	3.87**	6.66**	0.84*	-5.72**
R 1241-1856-1-1	6.29**	-12.71**	-1.45**	-1.77**	-1.92**	-0.61	0.36	2.59**	3.14**	-19.77**	-15.69**	-9.6**	-7.55**
R 304-34	6.95**	-5.65**	1.05**	1.12**	-0.16	-5.55**	-4.42**	-3.8**	4.04**	-15.89**	-16.54**	-8.93**	-1.66**
R 1216-6	0.12	-3.8**	0.22	0.29	-1.73**	9.22**	8.59**	2.04**	-3.25**	13.2**	17.98**	3.12**	-0.16
Chinikapoor	1.12**	2.64**	-2.39**	-1.99**	-0.31	6.06**	0.26	8.43**	0.58	3.1**	6.22**	0.57	1.56**
OR 1898-18RAU 729-12-44	1.12**	4.67**	0.77*	0.62	0.18	-3.72**	-7.41**	-4.91**	5.71**	3.39**	6.6**	3.79**	10.23**
WAR 89-4-A9-1-B-B-B-2	-6.71**	-2.27**	-1.5**	-1.16**	-0.99**	4.78**	6.64**	5.7**	4.85**	-0.88	4.16**	3.18**	0.12
SE (Testers)	0.17	0.53	0.34	0.32	0.27	0.42	0.44	0.36	0.71	0.57	0.44	0.41	0.28

*** =significant of p=0.05 level,**
**** = significant of p=0.01 level**

1.Days to 50% flowering, 2.Plant height (cm), 3.Tillers per plant, 4.Productive tillers per plant, 5.Panicle length (cm), 6.Flag leaf angle(degree), 7.Second leaf angle (degree), 8.Third leaf angle (degree), 9.Leaf area (cm^2), 10.Pollen fertility% 11.Spikelet fertility %, 12.Harvest index (%), 13. Seed yield/plant (gm).

Table 3 Specific combining ability (SCA) effect of hybrids for different characters

Hybrids	1	2	3	4	5	6	7	8	9	10	11	12	13
CRMS 31A/													
WAR 120-1-5-6-2-B-B-3	-4.7**	-0.96	-0.85	-1.16**	-0.36	6.05**	1.49*	2.07**	-19.35**	8.78**	6.09**	1.45*	3.87**
RPHR 203-3	-1.03**	15.77**	-1.35**	-1.16**	3.15**	12.16**	12.94**	12.14**	-5.14**	7.3**	3.85**	5.23**	9.71**
R 1130-102-3-88-1	-14.53**	33.05**	3.04**	2.01**	4.43**	7.65**	6.1***	5.41**	-7.62**	-10.22**	-16.23**	-1.83**	-3.07**
IR 68830-NDR-1-1	3.3**	-13.53**	2.59**	3.4**	-2.44**	-5.4**	-8.23**	-7.65**	8.55**	6.85**	44**	23.84**	18.48**
CR 780-1937	-1.2**	-21.51**	-4.91**	-3.77**	-5.09**	1.1**	-0.07	-4.76**	-20.27**	6.67**	5.46**	5.67**	1.93**
R 1241-1856-1-1	9.8**	1.47	-1.02*	-0.32	-0.35	-5.18**	-1.79**	-2.26**	-5.31**	20.92**	16.95**	-8.88**	-1.07**
R 304-34	3.64**	3.06**	3.65**	3.45**	-0.47	0.6	14.99**	9.97**	-1.1	-22.81**	-20.85**	-11.72**	-7.96**
R 1216-6	-2.53**	-8.16**	0.15	-0.38	-0.93*	-4.18**	-5.51**	-3.37**	10.46**	5.72**	5.44**	6.4**	-0.29
Chinikapoor	2.47**	-1.83*	-1.24**	-1.6**	1.66**	-2.17**	-1.85**	-3.09**	16.91**	13.04**	1.15	-4.22**	-5.52**
OR 1898-18RAU 729-12-44	8.47**	-5.91**	2.26**	1.28**	0.89*	-9.57**	-13.68**	-5.59**	14.9**	-24.36**	-29.16**	-8.95**	-15.67**
WAR 89-4-A9-1-B-B-B-2	-3.7**	-1.45	-2.3**	-1.77**	-0.51	-1.07	-4.4**	-2.87**	7.98**	-11.91**	-16.71**	-6.99**	-0.4
CRMS 32A/													
WAR 120-1-5-6-2-B-B-3	-5.79**	16.06**	1.87**	1.69**	1.52**	-3.86**	3.36**	2.76**	21.3**	-13.4**	-11.95**	-13.05**	-3.04**
RPHR 203-3	10.38**	-5.01**	1.37**	1.53**	-1.77**	-17.6**	-11.21**	-7.19**	9.65**	3.57**	8.09**	5.23**	-0.2
R 1130-102-3-88-1	9.38**	-13.03**	0.76	1.19**	0.07	-1.75**	0.97	6.09**	2.57*	38.5**	44.1**	19.01**	13.19**
IR 68830-NDR-1-1	-7.29**	2.31**	1.32**	0.41	0.66	-0.47	4.13**	5.7**	-18.3**	-2.06**	-29.68**	-14.5**	-7.59**
CR 780-1937	0.71**	-9.7**	2.49**	2.41**	-2**	13.19**	5.3**	4.92**	5.21**	-15.89**	-16**	-15.66**	-3.15**
R 1241-1856-1-1	-11.79**	-1.22	-1.79**	-1.81**	0.25	1.41*	-2.09**	-2.58**	7.61**	-22.64**	-18.36**	-5.05**	-2.31**
R 304-34	-1.95**	5.37**	-3.62**	-3.53**	2.5**	-8.47**	-8.48**	-4.52**	8.61**	-6.48**	-14.98**	-9.38**	-7.37**
R 1216-6	10.88**	10.24**	-0.46	-0.2	1.29**	11.91**	2.86**	-5.35**	-10.63**	-4.71**	-2.48**	6.39**	8.13**
Chinikapoor	-2.62**	0.52	0.32	0.58	-0.57	-1.25*	-0.31	2.42**	-2.41*	-13.25**	-0.98	11.12**	3.08**
OR 1898-18RAU 729-12-44	-12.12**	6.06**	-1.85**	-1.53**	0.14	3.52**	2.69**	-0.91	-9.18**	13.13**	16.61**	1.07	-6.6**
WAR 89-4-A9-1-B-B-B-2	10.21**	-11.62**	-0.4	-0.75	-2.09**	3.36**	2.8**	-1.35**	-14.43**	23.21**	25.61**	14.84**	5.85**
IR 58025A/													
WAR 120-1-5-6-2-B-B-3	10.48**	-15.1**	-1.02*	-0.54	-1.16**	-2.18**	-4.84**	-4.83**	-1.95	4.62**	5.86**	11.6**	-0.84**
RPHR 203-3	-9.35**	-10.77**	-0.02	-0.37	-1.37**	5.43**	-1.73**	-4.95**	-4.51**	-10.88**	-11.94**	-10.46**	-9.51**
R 1130-102-3-88-1	5.15**	-20.03**	-3.8**	-3.2**	-4.5**	-5.9**	-7.07**	-11.5**	5.05**	-28.28**	-27.87**	-17.18**	-10.12**
IR 68830-NDR-1-1	3.98**	11.21**	-3.91**	-3.81**	1.78**	5.87**	4.1**	1.95**	9.75****	-4.79**	-14.32**	-9.34**	-10.89**
CR 780-1937	0.48	31.21**	2.42**	1.35**	7.09**	-14.3**	-5.23**	-0.17	15.06*	9.22**	10.54**	9.99**	1.22**
R 1241-1856-1-1	1.98**	-0.25	2.81**	2.13**	0.09	3.76**	3.88**	4.84**	-2.3*	1.71*	1.4*	13.94**	3.39**
R 304-34	-1.68**	-8.43**	-0.02	0.08	-2.03**	7.87**	-6.51**	-5.44**	-7.51**	29.29**	35.83**	21.1**	15.33**
R 1216-6	-8.35**	-2.07**	0.31	0.58	-0.36	-7.74**	2.66**	8.72**	0.17	-1.02	-2.96**	-12.79**	-7.84**
Chinikapoor	0.15	1.31	0.93*	1.02*	-1.09**	3.43**	2.16**	0.67	-14.5**	0.2	-0.17	-6.9**	2.44**
OR 1898-18RAU 729-12-44	3.65**	-0.14	-0.41	0.24	-1.04**	6.04**	10.99**	6.5**	-5.72**	11.23**	12.55**	7.88**	22.27**
WAR 89-4-A9-1-B-B-B-2	-6.52**	13.07**	2.7**	2.52**	2.6**	-2.29**	1.6**	4.22**	6.45**	-11.31**	-8.91**	-7.84**	-5.45**
SE	0.24	0.75	0.48	0.45	0.38	0.59	0.62	0.5	1	0.8	0.62	0.58	0.39

*** = significant of p=0.05 level,**
**** = significant of p=0.01 level**

1.Days to 50% flowering, 2.Plant height (cm), 3.Tillers per plant, 4.Productive tillers per plant, 5.Panicle length (cm), 6.Flag leaf angle(degree), 7.Second leaf angle (degree), 8.Third leaf angle (degree), 9. Leaf area (cm^2), 10.Pollen fertility% 11.Spikelet fertility %, 12.Harvest index (%), 13. Seed yield/plant (gm).

Table 4: Promising hybrids based on *per se* performance, SCA and GCA effects.

Cross combination	Per se performance (yield per plant in g)	SCA effects	GCA effects (females)	GCA effects (males)
IR 58025A/OR 1898-18 RAU 729-12-44	50.50	22.27**	3.12**(H)	10.23**(H)
CRMS31A/RPHR 203-3	34.50	9.71**	-1.26**(L)	11.17**(H)
IR 58025A/R 304-34	31.67	15.33**	3.12**(H)	-1.66**(L)
CRMS 31A/IR 68830-NDR-1-1	29.83	18.48**	-1.26**(L)	-2.27**(L)
CRMS 32A/RPHR 203-3	24.00	-0.20	-1.85**(L)	11.17**(H)
IR 58025A/ Chinikapoor	22.00	2.44**	3.12**(H)	1.56**(H)
CRMS 32A/R 1216-6	20.99	8.13**	-1.85**(L)	-0.16(L)
CRMR 32A/R 1130-102-3-88-1	20.83	13.19**	-1.85**(L)	-5.38**(L)
IR 58025A/RPHR 203-3	19.67	-9.51**	3.12**(H)	11.17**(H)
CRMS 32A/ Chinikapoor	17.67	3.08**	-1.85**(L)	1.56**(H)
CRMS 31A/WAR 120-1-5-6-2-B-B-3	17.17	3.87**	-1.26**(L)	-0.33(L)