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Combining ability analysis for yield and other associated traits in rice (*Oryza sativa* L.)

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Abstract
The present investigation entitled "Combining ability analysis for grain yield and other associated traits in Rice (*Oryza sativa* L.)" was undertaken with the objective to study the combining ability from three standard CMS lines and twelve restorer as parental material. Thirty six hybrids were developed by crossing three CMS and seven restorer lines in L x T mating design for 8 quantitative characters, *viz*., days to 50 percent flowering, days to maturity, plant height at maturity, productive tillers per plant, tillers per square meter, Thousand grain weight, grains per panicle, yield per plant and Hybrids were evaluated in randomized block design (RBD) with three replications. Among the three testers studied, IR-58025 A was found to be the good general combiners for most of the characters studied, which indicated the usefulness of such exotic male sterile line for involving in crossing with the local restorers. Among the restorers, IR61614, HR1005, RPHR51 and RPHR612 are found to be good general combiners for quantitative characters. Specific combinations like IR-58025 A x IR66, RTN6- A x BR827-35, IR-58025 A x RPHR2, were identified as better hybrids.

Keywords: combining ability, GCA, SCA, rice, *Oryza sativa* L.

Introduction
The concept of general and specific combining ability helps the breeder to assess the general combining ability effects of the parents and specific combining ability effects of the hybrids (Sprague and Tatum, 1942) [11]. Genetic constitution and divergence among the parents involved in hybridization governs the nature of gene action in that hybrid. It is therefore, necessary to assess the genetic potential of the parents in hybrid combination through systematic studies in relation to general and specific combining abilities, which are due to additive and non-additive gene effects, respectively. The evaluation of performance of CMS lines, restorers and their crosses is a pre-requisite for evaluating better hybrids. The assessment of performance of lines/ restorer helps in selecting better hybrids. Hence, in the present investigation, the performance of the lines and hybrids were studied for yield and its yield contributing characters.

Materials and Methods
In present study, twelve restorers and three CMS lines *viz*., IR-58025-A, RTN6-A and RTN17-A were used to generate 36 crosses. The resulting 36 hybrids, 15 parents were studied in randomized block design with three replications during kharif 2013 at Agriculture Research Station Vadgaon Maval, Pune. Each plot consisted of single row of 3.0 meter length with a spacing of 20 cm. between rows and 15 cm. within plant.
The recommended dose of fertilizer was applied @ 100:50:50 kg NPK/ha splits to 50 per cent of N and full dose of P and K at transplanting, 25 per cent of N at 30 DAT and 25 per cent of N at 60 DAT. The recommended cultural practices including weeding, fertigation and plant protection measures were followed as per recommendation Parents and crosses for combining ability for eight quantitative characters *viz*., days to 50 percent flowering, days to maturity, plant height at maturity, productive tillers per plant, tillers per square meter, Thousand grain weight, grains per panicle, yield per plant.
In this regard the line x tester analysis method given by Kempthrone (1957) and modified by Arunachalum (1972) is very widely used for estimation of combining ability effects and variances.

Results and Discussions
Analysis of variance for eight characters among parents hybrids
The analysis of variance for yield and component characters is presented in Table 1. The variance due to parents was highly significant for all the characters.

Male, female, hybrids and parents vs. hybrids were highly significant for all the character studied.

General combining ability effects

The importance of general combining ability in selection of parents for hybridization has been emphasized by many workers in rice. The potentiality of any line to be used as a parent in hybridization depends on its performance of F1 hybrid derived from it and its own gca effect.

The estimates of general combining ability effects are presented in Table 2. It is quite evident that none of the female and male parents exhibited significant gca effect for all characters. The line IR58025-A had the highest gca effect for the plant height at maturity, grains per panicle and days to 50 per cent flowering The line RTN17-A had the highest gca effect for days to maturity, tillers per plant and tillers per square meter.

Among the restorers IR61614 was the best combiner, with higher gca effect for five characters *viz*., days to 50 per cent flowering, tillers per plant, tillers per square meter, thousand seed weight and seed yield per plant. The tester RPHR1005 for plant height at maturity, IR40750 for days to 50 per cent flowering and days to maturity. From the above studies IR61614 and RPHR1005 were found to be best general combiner for yield and most important yield contributing characters. The above results are in agreement with reports of Shreedhar and Kulkarni (1997) [12], Lavanya (2000) [4], Shanti *et al*. (2004), Panwar *et al*. (2005) [6], Savery and Ganesan (2003) [7] and Dhakar and Vyas (2006) [2].

Specific combining ability

Specific combining ability effects are presented in the Table 3. Out of the thirty six crosses, the most promising crosses exhibiting high sca effects were selected for each character and the gca status of the parents of each of such hybrid has been presented as either low or high. From the table 9, it can be seen that none of the hybrids combined higher sca effects for all the economic traits.

In rice negative SCA effects are considered to be desirable for days to 50 per cent flowering, days to maturity and plant height. Among thirty six crosses, seven hybrids for days to 50 per cent flowering, eleven hybrids for days to maturity and nine hybrids for plant height exhibited highly significant sca effects in desirable direction. Similarly positive and significant sca effects were observed in two hybrids for tillers per plant, two hybrids for tillers per square meter, two hybrids for grains per panicle, four hybrids for thousand seeds weight, two hybrid for seed yield per plant with highly significant sca effect.

The high SCA effects was found in hybrid RTN-6A x IR61614, RTN17-A x RPHR-51 and RTN17-A x RPHR2 for days to 50 per cent flowering, RTN6-A x IR66, RTN17-A x RPHR2, IR58025-A x RPHR1096, RTN17-A x RPHR-51 for days to maturity, RTN17-A x RPHR2, IR58025-A x RPHR619, RTN6-A x IR40750, IR58025-A x IR40750 for plant height at maturity, RTN6-A x RPHR 51, RTN6-A x RPHR1096, RTN17-A x RPHR619 for productive tillers per plant and productive tillers per square meter, IR58025-A x RPHR2, IR58025-A x IR62037, RTN17-A x RPHR1096 for grains per panicle, RTN17-A x IR66, IR58025-A x IR60199, RTN-6A x RPHR1005 for thousand seeds weight and IR58025-A x RPHR2, RTN6-A x BR827-35, IR58025-A x IR61614 for yield per plant with highest SCA effects.

For all the character studied, the crosses with significant SCA effects in the desirable direction involved parents with high x high or high x low or low x low gca effects indicating high performance of these crosses due to additive, dominance and epistastic gene interaction. The ideal cross combination to be exploited is one having high magnitude of sca, in addition to gca in both or at least in one of the parents. Therefore, the hybrid RTN17-A x RPHR-51, RTN17-A x RPHR2, RTN6-A x IR66 for early maturity and RTN6-A x BR827-35, RTN6-A x RPHR 51, RTN17-A x RPHR1096 for yield and yield contributing characters can be exploited through heterosis breeding. These findings are in agreement to those of Singh *et al*. (1993) [9], Singh *et al*. (1996) [10], Munhot *et al*. (2000) [5], Savery and Ganeshan *et al*. (2003) [7] reveals that the hybrids with high sca effects were produced.

Table 1: Analysis of variance for combining ability for eight characters in rice

Mean sum of squares									
Character/ source of variation	**D.F.**	**Days to 50% flowering (No.)**	**Days to maturity (No.)**	**Plant height at maturity (cm)**	**Productive tillers per plant (No.)**	**Productive tillers per sq. m (No.)**	**Grains per panicle (No)**	**Thousand seeds weight (g)**	**Yield per plant (g)**
Replication	2	24.19*	17.95*	39.27**	88.918*	102,199.62**	211.56**	23.561*	1,667.48**
Male (M)	11	27.26*	84.83	410.82**	2.417*	2,760.17**	14,938.07**	71.013*	380.69**
Female (F)	2	13.00*	15.73*	1,425.60**	1.562	1,877.98**	1,479.27**	10.211*	142.57**
F x M	22	22.41*	41.82*	772.85**	4.620*	5,344.27**	1,820.87**	9.877*	158.96**
Error	70	1.18	0.74	16.09	1.521	1,772.46	1,107.872	1.869	43.48

** and * indicates significant at 1% and 5% respectively.

Table 2: Estimates of general combining ability (GCA) effects of lines and testers for eight characters in rice

Sr. No.	**Source**	**Days to 50% flowering (No.)**	**Days to maturity (No.)**	**Plant height at maturity (cm.)**	**Productive tillers per plant (No.)**	**Productive tillers per sq. m (No.)**	**Grains per panicle (No.)**	**Thousand seeds weight (g.)**	**Yield per plant (g.)**
Female parent (Lines)									
1.	IR58025A	0.50*	-0.12	6.98**	-0.17	-5.88	6.12	0.48	-2.20
2.	RTN6A	-0.68**	-0.59**	-1.73**	-0.062	-2.19	-6.66	-0.57*	0.53
3.	RTN17A	0.17	0.71**	-5.25**	0.23	8.06	0.53	0.09	1.67
GCA Lines	CD (0.05%)	0.41	0.32	1.51	O.46	15.88	12.55	0.52	2.48
CD (0.01%)		0.55	0.43	2.02	0.62	21.22	16.77	0.69	3.32
Male parent (Testers)									
1.	IR40750	-3.05**	-4.64**	-2.89	-0.61	-19.60	17.46	-0.89	8.69**
2.	IR66	0.72	-1.65**	-5.31**	0.01	0.072	-40.31**	-0.96	-1.08
3.	IR60199	-0.94	-1.87**	2.04	0.25	8.38	-32.46*	-1.08	-7.18**

4.	IR61614	1.39**	2.01**	-0.35	0.65	22.02	67.02**	4.28**	8.73**
5.	BR827-35	0.16	0.68	-2.02	0.89	28.38	-39.78**	-1.44*	-5.04
6.	IR62307	2.39**	5.35**	2.19	-0.48	-16.550	-14.05	-1.57*	-9.99**
7.	RPHR1005	-1.39**	-1.98**	-8.56**	0.46	15.561	-27.36	-2.60**	-2.008
8.	RPHR51	-1.72**	-4.65**	-2.74	-0.01	-0.31	55.37**	3.96**	5.49
9.	RPHR619	1.61**	1.35**	1.49	-0.35	-12.02	-23.336	-2.33**	0.581
10.	RPHR2	-1.83**	2.02**	16.47**	-0.03	-1.06	2.786	-0.33	-3.931
11.	RPHR1096	1.83**	0.019	6.83**	-0.89	-30.58	-27.59	-2.31**	-3.031
12.	RPHR612	0.83	3.35**	-7.17**	0.17	5.69	62.23**	5.26**	8.76**
GCA Testers	CD (0.05%)	0.96	0.75	3.54	1.09	37.42	29.44	1.20	5.83
CD (0.01%)		1.28	1.01	4.74	1.46	49.78	39.35	1.61	7.79

** and * indicates significant at 1% and 5% respectively

Table 3: Estimates of specific combining ability (SCA) effects of hybrids for eight characters in rice

Sr. No.	Crosses	Days to 50% flowering (No.)	Days to maturity (No.)	Plant height at maturity (cm.)	Productive tillers per plant (No.)	Productive tillers per sq. m (No.)	Grains per panicle (No.)	Thousand seeds weight (g)	Yield per plant (g.)
1	IR58025A x IR40750	-0.72	-2.21**	-10.76**	1.29	42.93	4.61	1.48	0.39
2	IR58025A x IR66	0.16	1.45**	-4.020	0.75	25.53	-44.91*	-2.05*	-11.74**
3	IR58025A x IR60199	-0.83	0.009	-4.965	0.74	25.15	0.17	2.83**	-7.24
4	IR58025A x IR61614	-0.50	-0.21	-8.40**	1.10	37.58	-8.18	-0.50	5.89
5	IR58025A x BR827-35	0.056	-0.55	8.52**	0.15	5.08	-23.24	-0.15	-13.14**
6	IR58025A x IR62037	-0.83	2.79**	-5.15*	-1.91*	-64.38*	35.16	0.16	1.44
7	IR58025A x RPHR1005	1.61*	-1.88**	-0.73	-0.44	-14.89	14.67	-0.71	2.16
8	IR58025A x RPHR51	2.61**	1.79**	-3.69	-0.71	-23.96	-2.84	-0.28	2.76
9	IR58025A x RPHR619	-0.72	0.78	-19.98**	-0.36	-12.25	19.61	0.909	1.70
10	IR58025A x RPHR2	2.38**	5.12**	35.03**	-0.12	-3.939	46.69*	-1.84*	13.35**
11	IR58025A x RPHR1096	-0.94	-4.88**	21.11**	-0.85	-28.81	-35.83	-0.11	5.05
12	IR58025A x RPHR612	-2.29**	-2.21**	-6.95**	0.35	11.97	-5.89	0.29	-0.61
13	RTN6A x IR40750	-2.56**	-2.74**	-11.86**	-1.32	-45.77	-15.51	-1.47	2.76
14	RTN6A x IR66	-2.00**	-6.74**	-5.15*	-0.36	-12.17	23.17	-2.10*	7.59
15	RTN6A x IR60199	-0.00	0.48	3.71	-2.21**	-74.88**	-0.651	-2.18*	5.59
16	RTN6A x IR61614	-3.00**	-2.07**	9.63*	-0.34	-11.34	4.40	-0.35	-5.14
17	RTN6A x BR827-35	0.89	1.59**	-9.44*	-0.69	-23.48	22.07	0.740	12.96**
18	RTN6A x IR62037	0.67	0.26	-3.05	0.66	22.57	-11.26	1.07	-0.73
19	RTN6A x RPHR1005	1.11	0.59	3.10	1.05	35.81	1.98	2.24*	-3.57
20	RTN6A x RPHR51	3.11**	2.59	2.48	1.88*	64.14*	-0.928	0.27	-6.24
21	RTN6A x RPHR619	-0.89	-0.41	18.35**	-0.17	-5.75	-23.17	1.23	-5.99
22	RTN6A x RPHR2	2.56**	1.59**	2.87	-0.494	-16.70	-17.39	-0.32	-6.49
23	RTN6A x RPHR1096	0.22	4.59**	-7.35**	1.87*	63.82*	11.18	0.67	-1.75
24	RTN6A x RPHR612	-0.11	0.26**	-3.28	0.11	3.74	6.09	0.34	0.96
25	RTN17A x IR40750	3.28**	4.95**	22.63**	0.023	2.84	10.89	-0.005	-3.15
26	RTN17A x IR66	1.83**	5.28**	9.17**	-0.39	-13.35	21.73	4.16**	4.15
27	RTN17A x IR60199	0.83	-0.49	1.26	1.47	49.73	0.48	-0.65	1.65
28	RTN17A x IR61614	3.50**	2.29**	-1.29	-0.77	-26.24	3.77	0.85	-0.75
29	RTN17A x BR827-35	-0.94	-1.05	0.92	0.55	18.41	1.17	-0.59	0.18
30	RTN17A x IR62037	0.17	-3.05**	8.21**	1.23	41.79	-23.89	-1.16	-0.77
31	RTN17A x RPHR1005	-2.72**	1.29*	-2.37	-0.61	-20.91	-16.65	-1.53	1.35
32	RTN17 A x RPHR51	-5.72**	-4.38**	1.21	-1.17	-40.18	3.77	0.073	3.48
33	RTN17A x RPHR619	1.61	-0.38	1.64	0.534	17.99	3.56	-2.19*	4.29
34	RTN 17 A x RPHR2	-4.94**	-6.71**	-37.96**	0.612	20.64	-29.29	2.17*	-6.86
35	RTN17A x RPHR1096	0.72	0.29	-13.76**	-1.021	-35.00	24.65	-0.56	-3.29
36	RTN17A x RPHR612	2.39**	1.95**	10.24**	-0.46	-15.71	-0.206	-0.63	-0.35
C. D. @ 5 %		1.36	1.07	5.01	1.54	52.66	41.64	1.70	8.24
C. D. @ 1 %		1.81	1.43	6.71	2.06	70.39	55.66	2.28	11.025

** and * indicates significant at 1% and 5% respectively.

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