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Combining ability analysis using CMS breeding system in rice

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ABSTRACT

Using L x T mating design with three CMS lines and seven elite testers the general combining ability (GCA) of parents and specific combining ability (SCA) of crosses were carried out for grain yield and its attributes. The SCA variance recorded greater than the GCA variance for grain yield and yield components, suggesting the preponderance of dominance and epistatic gene action in expression of these traits. The line CRMS 31 A and IR 79156 A were recorded as good combiners for head rice recovery per cent. The tester NPT 80-1 was good general combiner for grain yield per plant and TOX 981-11-2-3 for both grain yield per plant and head rice recovery per cent. Whereas, the tester R 1244-1246-1-605-1 was recorded as best general combiner for head rice recovery per cent. The cross combinations APMS 6 A/ET 1-13, CRMS 31 A/ET 1-12 and IR 79156 A/ NPT 80-1 were found to be outstanding with respect to grain yield per plant, head rice recovery per cent and spikelets per panicle whereas, APMS 6 A/NPT 2-2-694-1 was good combiner for head rice recovery per cent. Considering the pollen fertility and spikelets fertility per cent of prime importance for development of maintainer lines, crosses APMS 6 A/ NPT 2-2-694-1 and APMS 6 A/ ET 1-13 might be utilized in three line breeding system.

Key words: *rice, CMS line, general combining ability, specific combining ability, line x tester, grain yield*

The successful development of rice hybrids by utilizing the cytoplasmic-genetic male sterility system and fertility restoration system mainly depends upon the availability of stable male sterile lines and economically viable hybrid seed production technology. The success further be hastened by choice of suitable outstanding parents with favourable out-crossing would give heterotic hybrids. The combining ability analysis of parents and their crosses provides information on the components of variance *viz*., additive and dominance variance or their heterotic hybrids. The combining ability analysis of parents and their crosses provides information on the components of variance *viz*., additive and dominance variance or their interaction, which are important to decide upon the parents and crosses to be selected for eventual success and also the appropriate breeding procedure. The knowledge of combining ability is useful to assess nicking ability in self pollinated crops and an insight in to nature and relative magnitude of gene actions involved (Peng and Virmani, 1990). It provides to the breeders an insight in to nature and relative magnitude of fixable and non-fixable genetic variances (Cockerham, 1961; Pradhan *et al*., 2006). Therefore, present investigation was carried out to estimate combining ability effects for yield and its components involving CMS lines and restorer lines in rice.

MATERIALS AND METHODS

The material for present study comprised three CMS lines *viz.,* APMS 6 A, CRMS 31 A, IR 79156 A and seven elite tropical *japonica- indica* and *indica* type of testers *viz.* NPT 2-2-694-1, NPT 9, NPT 80-1, ET 1-12, ET 1-13, TOX 981-11-2-3 and R 1244-1246-1-605-1 through Line x Testers design during dry season 2009-10. The generated 21 crosses along with their parents were grown in randomized complete block design during wet season 2010 with two replications at the Research and Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur. Twenty-one- day old seedlings were transplanted in a single row of 2.4 m length. The single seedling hill^{-1} was planted with the spacing of 20 x 20 cm. All the recommended agronomic

package of practices was followed. In each entry, five plants were randomly selected from each replication and biometrical observations were recorded for days to 50 % flowering, flag leaf length, flag leaf area, plant height, productive tillers par plant, pollen fertility (%), sterile spikelets per panicle, fertile spikelets panicle^{-1}, spikelets panicle^{-1}, spikelets fertility percent, panicle length, 1000-seed weight, grain yield plant^{-1} and head rice recovery per cent following the Standard Evaluation System for Rice (IRRI, 1988). The mean data was analyzed for combining ability following the standard method of Kempthorne (1957).

RESULTS AND DISCUSION

The analysis of variance for combining ability revealed that the variances due to treatments, parents, hybrids and lines x testers were highly significant for all the characters under study whereas, the variance due to tester was significant for days to 50 % flowering, fertile spikelets per panicle and 1000-seed weight. On the other hand, variance due to lines were non significant for all the characters which might be due to less number of lines (Table 1). The result revealed sufficient variability present in the material under study. The comparative estimates of variances due to GCA and SCA revealed the importance of SCA variance. The SCA variances were higher than GCA variances for all the traits, suggesting the significance of dominance and epistatic gene action for controlling these traits (Table 2). Preponderance of dominance and epistatic gene action for grain yield and its components was also reported earlier by Sarawgi *et al.* (1991), Munhot *et al.* (2000), Satyanarayana *et al.* (2000), Rita and Motiramani (2005), Venkatesan *et al.* (2007), Dalvi and Patel (2009), Bagheri and Jelodar (2010), and Saidaiah *et al.* (2010).

The line CRMS 31 A and IR 79156 A were recorded as good combiners for head rice recovery per cent. These lines were also good combiners for pollen fertility %, sterile spikelets panicle^{-1}, fertile spikelets panicle^{-1}, spikelets panicle^{-1} and spikelets fertility percent (Table 3). Out of three, no line was found as good general combiner for grain yield per plant. The tester NPT 80-1 was good general combiner for grain yield plant^{-1} and TOX 981-11-2-3 was good combiner for grain yield and head rice recovery per cent. Whereas, the tester R 1244-1246-1-605-1 was recorded as best general combiner for head rice

Table 1. Analysis of variance for line x tester analysis

Source of Variance	Degree of freedom	Days to 50 % flowering	Flag leaf length (cm)	Flag leaf width (cm)	Flag leaf area (cm^2)	Plant height (cm)	Productive tillers plant^{-1}	Pollen fertility (%)	Sterile spikelets Panicle^{-1}	Fertile spikelet Panicle^{-1}	Spikelets panicle^{-1}	Spikelets fertility (%)	Panicle length (cm)	1000 Seed weight (g)	Grain yield plant^{-1} (g)	Head rice recovery (%)
Replication	1	3.562	2.382	0.074	0.021	0.980	2.295	0.409	1.715	2.436	0.097	4.941*	0.156	0.001	1.580	2.852
Treatments	30	87.744**	52.574**	7.683**	6.864**	4.384**	42.309**	555.564**	670.050**	941.149**	1148.665**	875.688**	10.894**	23.795**	508.442**	367.462**
Parents	9	57.654**	49.766**	7.587**	8.664**	3.988**	64.090**	847.652**	570.018**	397.834**	2583.857**	154.354**	9.779**	17.822**	271.868**	443.910**
Hybrids	20	90.456**	49.818**	7.632**	6.297**	4.596**	34.179**	446.325**	739.189**	1207.539**	553.913**	1191.257**	11.878**	27.230**	613.723**	346.650**
Parent vs. hybrids	1	304.307**	132.958**	9.567**	2.024**	3.712	8.886**	111.570**	187.541**	503.186**	126.964**	1056.319**	1.257	8.854*	531.980**	95.673**
Lines	2	0.654	0.233	2.159	3.604	1.348	3.208	2.153	1.550	2.930	0.359	1.689	3.348	0.613	0.155	3.354
Testers	6	6.135**	0.864	2.747	5.550	1.042	0.564	1.702	1.832	4.469*	1.507	2.330	1.739	2.378**	1.536	0.760
Line x Tester	12	36.098**	56.453**	4.654**	2.398**	4.387**	31.354**	336.648**	566.639**	540.580**	509.152**	811.482**	8.155**	19.807**	570.155**	297.964**
Error	31	1.635	0.023	0.023	58.181	168.07	0.41	4.824	23.51	23.04	13.43	1.83	2.24	1.58	0.658	0.80

* & **, significant at p ?0.05 l and 0.01, respectively

recovery per cent. Beside this, all these testers were recorded also good general combiners for pollen fertility (%), sterile spikelets panicle^{-1}, fertile spikelets panicle^{-1}, spikelets panicle^{-1} and spikelets fertility percent. These testers were also good general combiners for important yield attributes *viz.,* NPT 80-1 for productive tillers plant^{-1}, 1000-seed weight and plant height; TOX 981-11-2-3 for panicle length and plant height; R 1244-1246-1-605-1 for 1000-seed weight. The present findings had also been reported earlier by Babu *et al*. (1999), Lavanya (2000), Munhot *et al.* (2000), Satyanarayana *et al.* (2000), Rita and Motiramani (2005), Venkatesan *et al.* (2007), Dalvi and Patel (2009), Bagheri and Jelodar (2010) and Saidaiah *et al.* (2010).

The crosses APMS 6 A/ET 1-13, APMS 6 A/ TOX 981-11-2-3, APMS 6 A/R 1244-1246-1-605-1; CRMS 31 A/NPT 80-1, CRMS 31 A/ET 1-12; IR 79156 A/NPT 80-1were recorded as good specific combiners for grain yield per plant (Table 4). The crosses APMS 6 A/NPT 2-2-694-1, APMS 6 A/NPT 9, APMS 6 A/ ET 1-13; CRMS 31 A/ET 1-12, CRMS 31 A/ET 1-13; IR 79156 A/NPT 2-2-694-1, IR 79156 A/NPT 80-1, IR 79156 A/TOX 981-11-2-3 and IR 79156 A/R 1244-1246-1-605-1 were found as good specific combiners for head rice recovery per cent. The crosses APMS 6 A/ET -1-13, CRMS 31 A/ET 1-12 and IR 79156 A/ NPT 80-1 were registered as good specific combiners for both grain yield plant^{-1} and head rice recovery per cent. These crosses were also recorded as good specific combiners for important yield attributes *viz.,* APMS 6 A/ ET 1-13 for spikelets per panicle; APMS 6 A/TOX 981-11-2-3 for productive tillers plant^{-1}, sterile spikelets panicle^{-1}, fertile spikelets panicle^{-1} and spikelets fertility per cent; APMS 6 A/R 1244-1246-1-605-1 for fertile spikelets panicle^{-1}, spikelets fertility per cent and sterile spikelets panicle^{-1}; APMS 6 A/NPT 2-2-694-1 for days to 50% flowering, panicle length and 1000-seed weight; APMS 6 A/NPT 9 for pollen fertility per cent, 1000-seed weight, fertile spikelets panicle^{-1} and spikelets panicle^{-1}; CRMS 31 A/NPT 80-1 for productive tillers plant^{-1}, fertile spikelets panicle^{-1} and spikelets panicle^{-1}; CRMS 31 A/ET 1-12 for fertile spikelets panicle^{-1}, spikelets panicle^{-1} and spikelets fertility per cent; CRMS 31 A/ET 1-13 for pollen fertility %, fertile spikelets panicle^{-1} and spikelets fertility per cent; IR 79156 A/ NPT 2-2-694-1 for productive tillers plant^{-1}, pollen fertility %, fertile spikelets panicle^{-1}, spikelets panicle^{-1} and spikelets fertility percent; IR 79156 A/NPT 80-1 for pollen fertility %, fertile spikelets panicle^{-1}, spikelets panicle^{-1} and panicle length; IR 79156 A/TOX 981-11-2-3 for pollen fertility (%); IR 79156 A/R 1244-1246-1-605-1 for pollen fertility (%) and spikelets fertility per cent. The present finding was also supported by Sao and Motiramani (2006), Venkatesan *et al.* (2007), Dalvi and Patel (2009), Jayashudha and Sharma (2009), Bagheri and Jelodar (2010) and Saidaiah *et al.* (2010).

Table 2. General combining ability and specific combining ability variance

Characters	GCA Variance	SCA Variance	GCA/SCA Ratio
Days to 50% flowering	004.94	028.69	0.172
Flag leaf length(cm)	-000.07	039.86	-1.756
Flag leaf width(cm)	000.00	000.04	0.000
Flag leaf area(cm^2)	012.54	040.68	0.308
Plant height(cm)	005.67	284.66	0.019
Productive tillers/Plant	000.13	006.29	0.020
Pollen fertility (%)	036.01	809.58	0.044
Sterile spikelets/Panicle	280.62	6647.87	0.042
Fertile spikelets/Panicle	865.36	6216.96	0.139
Spikelets/Panicle	066.90	3411.12	0.019
Spikelets fertility (%)	043.86	740.39	0.059
Panicle length(cm)	000.53	008.02	0.066
1000Seed weight(g)	000.77	014.86	0.052
Grain yield/plant (g)	3.45	187.29	0.018
Head rice recovery (%)	003.28	119.31	0.027

The line CRMS 31 A and IR 79156 A were recorded as good combiners for head rice recovery per cent. These lines were also good combiners for pollen fertility %, sterile spikelets per panicle, fertile spikelets per panicle, spikelets per panicle and spikelets fertility percent. The tester NPT 80-1 was good general combiner for grain yield plant^{-1} and TOX 981-11-2-3 for grain yield plant^{-1} and head rice recovery per cent. Whereas, the tester R 1244-1246-1-605-1 was recorded as best general combiner for head rice recovery per cent. The cross combinations APMS 6 A/ET 1-13, CRMS 31 A/ET 1-12 and IR 79156 A/ NPT 80-1 were found to be outstanding with respect to grain yield plant^{-1}, head rice recovery per cent and spikelets panicle^{-1} whereas, APMS 6 A/NPT 2-2-694-1 was good combiner for head rice recovery per cent. These promising lines, testers and crosses revealed wide scope for enhancing the grain yield in the CMS line or three

Table 3. Estimates of general combining ability (GCA) effects

Parents	Days to 50 % flowering	Flag leaf length (cm)	Flag leaf width (cm)	Flag leaf area (cm^2)	Plant height (cm)	Productive tillers $plant^{-1}$	Pollen fertility (%)	Sterile spikelets $panicle^{-1}$	Fertile spikelets $panicle^{-1}$	Spikelets $panicle^{-1}$	Spikelets fertility (%)	Panicle length (cm)	1000 Seed weight (g)	Grain yield $plant^{-1}$ (g)	Head rice recovery (%)
Lines															
APMS 6 A	-1.88	0.80	-0.02	1.96	-8.77**	-1.10	-18.25**	43.12**	-58.31**	-15.19**	-15.42**	-1.53	-0.74	-2.03	-8.67**
CRMS 31 A	0.62	-1.33	-0.12	-6.73**	0.74	-0.89	8.96**	-30.52**	36.69**	6.17**	8.49**	2.38	1.35	-0.03	5.34**
IR 79156 A	1.26	0.53	0.14	4.77**	8.03**	1.99	9.28**	-12.60**	21.62**	9.02**	6.93**	-0.86	-0.61	2.05	3.33**
SE (Lines)	0.34	0.32	0.04	2.04	3.46**	0.17	0.59	1.30	1.28	0.98	0.36	0.40	0.34	0.22	0.24
Testers															
NPT 2-2-694-1	0.02	2.33**	-0.03	2.08**	3.35**	0.62	-28.18**	37.43**	-118.60**	-81.17**	-30.93**	-0.15	-4.61**	-6.02**	8.37**
NPT 9	4.36**	-1.07	-0.09	-6.06**	22.90**	-0.71	-15.81**	110.10**	-131.26**	-21.17**	-30.87**	1.81**	-0.83	-8.49**	-6.86**
NPT 80-1	6.36**	-3.42**	0.04	2.55**	-13.09**	1.97**	8.35**	-51.74**	92.07**	40.33**	19.96**	-4.47**	6.10**	18.52**	-2.46**
ET 1-12	-9.98**	6.34**	0.41	22.07**	-5.23**	-0.47	25.35**	-25.40**	55.40**	30.00**	11.52**	2.27**	-1.31	-8.66**	-3.39**
ET 1-13	-6.64**	0.57	0.12	1.15	-4.85**	-1.53	-21.93**	39.26**	-44.76**	-5.50**	-11.62**	-0.40	-1.41	-0.13	-3.77**
TOX 981-11-2-3	11.36**	-2.28**	-0.20	-10.30**	-3.25**	0.12	14.19**	-54.90**	75.07**	20.17**	21.27**	1.64**	-1.16	6.78**	4.02**
R 1244-1246-1-605-1	-5.48**	-2.47**	-0.25	-11.50**	0.16	0.01	18.02**	-54.74**	72.07**	17.33**	20.67**	-0.71	3.21**	-2.00	4.11**
SE (Testers)	0.52	0.49	0.06	3.11	5.29	0.26	0.90	1.98	1.96	1.50	0.55	0.61	0.51	0.33	0.37

"& **, significant at p ? 0.05 l and 0.01, respectively

Table 4. Estimates of specific combining ability (SCA) effects

Hybrids	Days to 50 % flowering	Flag leaf length (cm)	Flag leaf width (cm)	Flag leaf area (cm^2)	Plant height (cm)	Productive tillers $plant^{-1}$	Pollen fertility (%)	Sterile spikelets $panicle^{-1}$	Fertile spikelets $panicle^{-1}$	Spikelets $panicle^{-1}$	Spikelets fertility (%)	Panicle length (cm)	1000 Seed weight (g)	Grain yield $plant^{-1}$ (g)	Head rice recovery (%)
APMS 6A/ NPT 2-2-694-1	-5.45**	2.79**	0.24	10.23**	14.01**	-1.52**	-12.57**	7.71**	-7.19**	0.52	-9.57**	1.57**	4.56**	3.49	1.79**
NPT 9	3.21**	1.43**	-0.15	-1.64**	12.61**	0.43	12.41**	56.55**	10.98**	67.52**	-9.23**	0.73	3.08**	5.39	11.47**
NPT 80-1	-7.79**	3.53**	-0.32	-0.40	-32.89**	-1.66**	-1.75**	-35.12**	-51.36**	-86.48**	5.70**	-1.43**	-6.07**	-29.57**	-8.51**
ET 1-12	4.55**	-6.73**	0.18	-0.32	10.74**	-1.44**	27.25**	-46.95**	39.31**	-7.64**	16.17**	0.75**	-0.89**	-4.15	-2.89**
ET 1-13	6.21**	-3.59**	0.12	-8.51**	10.11**	0.87	-18.82**	97.38**	-84.02**	13.36**	-30.81**	-0.43	-0.52	7.13**	8.65**
TOX 981-11-2-3	1.71**	-0.11	-0.09	-0.41	-20.24**	2.73**	-0.09	-38.45**	55.14**	16.69**	13.95**	-0.97	0.02	9.68**	-0.22
R 1244-1246-1-605-1	-2.45**	2.68**	0.02	1.06	5.66**	0.59	-6.42**	-41.12**	37.14**	-3.98**	13.79**	-0.20	-0.18	8.04**	-10.30**
CRMS 31A/ NPT 2-2-694-1	3.05**	0.41	0.09	4.37**	-2.06**	-2.35**	-39.68**	81.36**	-102.69**	-21.33**	-33.72**	-0.841	-4.78**	1.49	-12.21**
NPT 9	-3.79**	-7.88**	0.02	-6.40**	-22.11**	0.16	30.20**	-157.31**	62.98**	-94.33**	42.15**	1.817**	3.62**	-6.70	-3.29**
NPT 80-1	4.21**	-0.83**	0.29	1.23	20.09**	3.70**	1.04	26.52**	18.14**	44.67**	-3.63**	-0.903**	0.01	15.57**	-0.76
ET 1-12	-2.95**	12.66**	-0.20	8.88**	0.17	-1.83**	1.04	13.19**	62.31**	75.50**	2.51**	-0.018	0.73	13.34**	12.91**
ET 1-13	-7.29**	2.28**	-0.31	-2.51**	-18.56**	0.80	2.82**	-41.48**	4.48**	-37.00**	12.16**	-2.716**	0.16	-6.02	4.57**
TOX 981-11-2-3	4.21**	0.65	0.04	-1.06	21.19**	-0.38	-5.80**	55.19**	-52.86**	2.33**	-15.39**	5.492**	-0.44	-15.18**	-7.00**
R 1244-1246-1-605-1	4.21**	0.65	0.04	-1.06	21.19**	-0.38	-5.80**	55.19**	-52.86**	2.33**	-15.39**	5.492**	-0.44	-15.18**	-7.00**
IR 79156 A/ NPT 2-2-694-1	2.40**	-3.20**	-0.33	-14.60**	-11.95**	3.87**	52.25**	-89.07**	109.88**	20.81**	43.30**	-0.726	0.22	-4.98	10.42**
NPT 9	0.57	6.45**	0.13	8.04**	9.50**	-0.59	-42.62**	100.76**	-73.95**	26.81**	-32.93**	-2.542**	-6.71**	1.31	-8.19**
NPT 80-1	3.57**	-2.70**	0.03	-0.83	12.80**	-2.04**	0.72**	8.60**	33.21**	41.81**	-2.07**	2.338**	6.06**	14.00**	9.27**
ET 1-12	-16.44**	-12.70**	-0.31	-18.77**	-31.88**	1.53**	-39.69**	15.82**	-137.07**	-121.25**	-29.69**	-5.295**	-3.53**	-16.27**	-17.14**
ET 1-13	1.07	1.31**	0.19	11.02**	8.45**	-1.67**	16.00**	-55.90**	79.55**	23.64**	18.65**	3.149**	0.36	-1.10	-13.23**
TOX 981-11-2-3	-5.93**	-0.54	0.05	1.48	-0.95	-2.35**	5.88**	-16.74**	-2.29**	-19.02**	1.44	-4.517**	0.42	5.50	7.22**
R 1244-1246-1-605-1	-5.93**	-0.54	0.05	1.48**	-0.95**	-2.35**	5.88**	-16.74**	-2.29**	-19.02**	1.44**	-4.517**	0.42	5.50	7.22**

line breeding system based rice improvement programme to develop rice hybrids.

Considering the pollen fertility and spikelets fertility per cent of prime importance for development of maintainer lines, crosses APMS 6 A/ NPT 2-2-694-1 and APMS 6 A/ ET 1-13 might be utilized in three line breeding system as these are also found as good combiners for economic characters of either grain yield per plant or head rice recovery per cent or combination of both in addition to pollen and spikelets fertility per cent.

REFERENCES

Babu MS, Satyanarayana PV, Madhuri J and Kumer RV 1999. Combining ability analysis for identifying elite parents for heterotic rice hybrids. Oryza 37 (1): 19-22

Bagheri N and Jelodar NB 2010. Heterosis and combining ability for yield and related yield traits in hybrid rice. International Journal of Biology 2 (2): 222-231

Cockerham CC 1961. Implication of genetic variances in hybrid breeding programme. Crop Science 8: 720-722

Dalvi VV and Patel DV 2009. Combining ability analysis for yield in hybrid rice. Oryza 46 (2): 97-102

IRRI 1988. Standard Evaluation System for Rice. International Rice Research Institute, Los Banos, Metro city Manila, Philippines. pp 35

Jayashudha S and Sharma D 2009. Combining ability and gene action analysis for grain yield and its components in rice (*Oryza sativa* L.). Journal of Rice Research 2(7): 105-111

Kempthorne O 1957. An Introduction to Genetic Statistics. The Iowa State University Press. John Wiley and Sons, Inc: New York. pp 545

Lavanya C 2000. Combining ability for yield and its components in hybrid rice. Oryza 37 (1): 11-14

Munhot MK, Sarawgi AK and Rastogi NK 2000. Gene action and combining ability for yield, grain quality and other related characters in rice. Oryza 37 (1): 1-6

Peng, JY and Virmani SS 1990. Combining ability for yield and yield related traits in relation to breeding in rice. Oryza 46(1): 1-10

Pradhan SK, Boss LK and Meher J 2006. Studies on gene action and combining ability analysis in Basmati rice. Journal of Centeral European Agriculture 7(2): 267-272

Rita B and Motiramani NK 2005. Study on gene action and combining ability in rice. Oryza 42(2): 153-155

Saidaiah P, Kumer SS and Ramesha MS 2010. Combining ability studies for development of new hybrids in rice over environment. Journal of Agricultural Sciences 2(2): 225-233

Sao A and Motiramani NK 2006. Combining ability analysis for yield and yield contributing traits using cytoplasmic male sterility-fertility restoration system in rice hybrids. Jordan Journal of Agricultural Sciences 2 (1): 29-34

Sarawgi AK, Shrivastava MN and Chowdhary BP 1991. Partial diallel cross analysis of yield and its related characters in rice (*Oryza sativa* L.) under irrigated and rainfed situations. Indian Journal of Genetics and Plant Breeding 51(1): 30-36

Satyanarayana PV, Reddy MSS, Kumar I and Madhuri J 2000. Combining ability studies on yield and yield components in rice. Oryza 37(1): 22-25

Venkatesan M, Anbuselvam YE, langaimannan R and Karthikeyan P 2007. Combining ability for yield and physiological characters in rice. Crop Improvement 44 (4): 296-299