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COMBINING ABILITY ANALYSIS USING CMS BREEDING SYSTEM FOR DEVELOPING HYBRIDS IN RICE (*Oriza sativa*)

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Abstract

Using line x tester 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 was 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 percent. 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 percent. The cross combinations APMS 6 A/ET 1-13, CRMS 31 A/ET 1-12, and IR 79156 A/ NP T 80-1 were found to be outstanding with respect to grain yield per plant, head rice recovery percent, and spikelets per panicle. The cross APMS 6 A/NPT 2-2-694-1 was good combiner for head rice recovery percent. These promising lines, testers, and crosses revealed wide scope for enhancing the grain yield in the CMS line or three line breeding system based rice improvement programme to develop rice hybrids.

Keywords: Rice, CMS line, general combining ability (GCA), specific combining ability (SCA), grain yield.

Introduction

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, which are important to decide upon the parents and crosses to be selected for eventual success and also the appropriate breeding

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procedure. The knowledge of combining ability is useful to assess nicking ability in self pollinated crops and an insight into nature and relative magnitude of gene actions involved (Peng and Virmani, 1990). It provides to the breeders an insight into nature and relative magnitude of fixable and non-fixable genetic variances (Cockerham, 1961; Pradhan *et al.,* 2006). Hybrid rice based on Cytoplasmic Male Sterility (CMS) increases grain yield by more than 20% relative to improved inbred rice varieties (Yuan and Virmani, 1994).

Globally there is a potentiality of hybrid rice technology but it's acceptability varies as per the agro-climatic-socio-economic status of the region, therefore, it is the proper time for the exploitation of the heterosis in the developing countries like Bangladesh, India, China, Vietnam, Pakistan by using rice hybrid. Rice itself being a major staple field and food crop for South Asia as well as most important for Bangladesh, India and Pakistan. As per the rice agro-ecological and climatic status of Bangladesh, there is sufficient scope of locally develop, and adopted hybrid for the food security and fruitfulness of the rice farmers. The hybrid rice gives 25-30 percent higher yield over the best inbred check and 5 percent over regional hybrid check under same agronomic management (Bhandari *et al.,* 2011; Ghosh and Hedayetullah, 2011,).

Therefore, present investigation was carried out to estimate combining ability effects for yield and its components involving CMS and restorer lines in rice.

Materials and Method

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. The Line x Testers design was used during Rabi 2009-10 and number of crosses attempted in 21 cross combinations. The generated 21 crosses along with their parents were grown in randomized complete block design during Kharif 2010 with two replications at the Research 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 per hill was planted with the spacing of 20 cm. x 20 cm. All the recommended agronotnic 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 per plant, pollen fertility (%), sterile spikelets per panicle, fertile spikelets per panicle, spikelets fertility percent, panicle length, 1000 — seed weight, grain yield per plant 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 Discussion

Analysis of variance

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).

Therefore, the traits *viz.,* days to 50% flowering (DFF), flag leaf length (cm), flag leaf width (cm), flag leaf area (cm^2), plant height, productive tillers per plant, pollen fertility (%), sterile spikelets per panicle, fertile spikelets per panicle, spikelets per panicle, spikelets fertility (0%), panicle length (cm), 1000- seed weight (g), grain yield per plant (g), and head rice recovery (%) controlled by dominance gene action can be exploited through hybridization programme.

General combining ability effects

The line CRMS 31 A and IR 79156 A were recorded as good combiners for head rice recovery percent. These lines were also good combiners for pollen fertility %, sterile spikelets per panicle, fertile spikelets per panicle, spikelets per panicle, 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 per plant and TOX 98 1-1 1-2-3 was good combiner for grain yield and head rice recovery percent. Whereas, the tester R 1244-1246-1-605-1 was recorded as best general combiner for head rice recovery percent. Beside this, all these testers were recorded also as good general combiners for pollen fertility (%), sterile spikelets per panicle, fertile spikelets per panicle, spikelets per panicle, and spikelets fertility percent. These testers were also good general combiners for important yield attributes *viz.,* NPT 80-1 for productive tillers per plant, 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 tester NPT 80-1 and TOX 98 1-1 1-2-3 were found as good general combiners for grain yield and important yield attributes and can be used for further hybridization programme.

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 (cm2)	Plant height (cm)	Productive tillers per plant	Pollen fertility (%)	Sterile spikelets per panicle	Fertile spikelet per Panicle	Spikelets per panicle	Spikelets fertility (%)	Panicle length (cm)	100 seed weight (g)	Grain yield per plant (g)	Head rice recover (%)
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**
Parents 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	1.703	1.832	4.469*	1.507	2.330	1.739	2.378**	1.536	0.760
Lime x testers	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 $p \leq 0.051$ and 0.01, respectively

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

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 per plant	Pollen fertility (%)	Sterile spikelets per panicle	Fertile spikelets per panicle	Spikelets per panicle	Spikelets fertility (%)	Panicle length (cm)	1000-seed weight (g)	Grain yield per plant	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 $p \leq 0.051$ 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 per plant	Pollen fertility (%)	Sterile spikelets per panicle	Fertile spikelets per panicle	Spikelets per panicle	Spikelets fertility (%)	Panicle length (cm)	1000-seed weight (g)	Grained yield per plant	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**	1.73**	-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**	0.13	-0.83	12.80**	-2.04**	0.72**	8.60**	33.21**	41.81**	-2.07**	2.388**	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**
R1244-1246-1-605-1	-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**

* & **, significant at $p \leq 0.051$ and 0.01, respectively.

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).

Specific combining ability effects

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 80-1 were 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 AiNPT 80-1, IR 79156 A/TOX 98 1-1 1-2-3, and IR 79156 A/R 1244-1246-1-605-1 were found as good specific combiners for head rice recovery percent. 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 per plant and head rice recovery percent. These crosses were also recorded as good specific combiners for important yield attributes *viz.,* APMS 6 Al ET 1-13 for spikelets per panicle; APMS 6 A/TOX 98 1-1 1-2-3 for productive tillers per plant, sterile spikelets per panicle, fertile spikelets per panicle, and spikelets fertility percent; APMS 6 A/R 1244-1246-1-605-1 for fertile spikelets per panicle, spikelets fertility percent, and sterile spikelets per panicle; APMS 6 AMPT 2-2-694-1 for days to 50% flowering, panicle length, and 1000-seed weight; APMS 6 A/NPT 9 for pollen fertility percent, 1000-seed weight, fertile spikelets per panicle, and spikelets per panicle; CRMS 31 A/NPT 80-1 for productive tillers per plant, fertile spikelets per panicle, and spikelets per panicle; CRMS 31 A/ET 1-12 for fertile spikelets per panicle, spikelets per panicle, and spikelets fertility percent: CRMS 31 A/ET 1-13 for pollen fertility %, fertile spikelets per panicle, and spikelets fertility percent; IR 79156 Al NPT 2-2-694-1 for productive tillers per plant, pollen fertility %, fertile spikelets per panicle, spikelets per panicle, and spikelets fertility percent; IR 79156 AiNPT 80-1 for pollen fertility %, fertile spikelets per panicle, spikelets per panicle 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 percent.

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).

The line CRMS 31 A and IR 79156 A were recorded as good combiners for head rice recovery percent. These lines were also good combiners for pollen fertility %, sterile spikelets per panicle, fertile spikelets per panicle, spikelets per panicle and spikelets fertility percent. Therefore, the line viz., CRMS 31 A and IR 79156 A can be used for further breeding programme for the enhancement of

pollen fertility percent, fertile spikelets per panicle, spikelets per panicle, and spikelets fertility percent including head rice recovery.

The tester NPT 80-1 was good general combiner for grain yield per plant and TOX 981-11-2-3 for 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 percent. Therefore, the tester viz., NPT 80-1, TOX 981-11-2-3 can be used for the yield with traits viz., flag leaf area (cm^2), plant height (cm), pollen fertility percent, spikelets sterility, fertile spikelets per panicle, spikelets per panicle including grain yield. Whereas, the testers R 1244-1246-1-605-1 and NPT 2-2-694-1 could also be used in breeding programme for head rice recovery percent. The testers ET 1-12, R 1244-1246-1-605-1, TOX 981-11-2- 3, NPT 80-1 could be used for improvement of pollen fertility percent, spikelet fertility percent and spikelets per panicle.

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 percent, and spikelets per panicle whereas, APMS 6 A/NPT 2-2-694-1 was good combiner for head rice recovery percent. The cross APMS 6A/ET 1-13 was good specific combiner of fertile spikelets per panicle and spikelets per panicle. The cross CRMS 31A/ET-1-12 was found good specific combiner for flag leaf length (cm), flag leaf area (cm^2), fertile spikelets per panicle, spikelets per panicle, spikelets fertility percent in addition to head rice recovery and grain yield per plant. The cross IR 79156 A/ NPT 80-1 was good general combiner for fertile spikelets per panicle, spikelets per panicle, panicle length (cm) and 1000-seed weight (g) including grain yield and head rice recovery percent. Therefore, crosses APMS 6 A/ET 1-13, CRMS 31 A/ET 1-12 and IR 79156 A/ NPT 80-1 had sufficient scope for the exploitation of genetic potential under hybridization programme.

These promising lines viz., CRIM 31 A, IR 79156A; testers NPT 80-1, TOX 981-11-2-3 and crosses viz., APMS 6 A/ET 1-13, CRMS 31 A/ET 1-12, IR 79156 A/ NPT 80-1, APMS '6 A/TOX 981-11-2-3, APMS 6 A/R 1244-1246-1-605-1, CRMS 31A/NPT 80-1 revealed wide scope for enhancing the grain yield in three line breeding system based rice improvement programme to develop rice hybrids.

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