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Line x Tester Analysis in Rice (*Oryza sativa* L.)

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One hundred and fifteen crosses from five CMS lines and 23 restorers along with parents were evaluated in line x tester design for grain yield and yield components in rice. Predominance of non additive gene action was observed for all the characters, suggesting the development of hybrids in rice. The lines APMS 6A and PUSA 5A, while IBL-57, SG 27-77, SG 26-120 and KMR-3 were good general combiners for grain yield and attributing traits. The IRRI genotypes *viz*., IR 43, IR 55 and IR 60 were good general combiners for dwarf plant type. The hybrid combinations IR 79156A x IBL-57 , APMS 6A x GQ-25, APMS 6A x 517, IR 58025A x GQ-70, APMS 6A x SG26-120 and PUSA 5A x IR55 were good specific combiners for grain yield and associated components.

Key words: CMS lines, combining ability, hybrid rice, Line x Tester.

To exploit the heterosis in rice, there is an urgent need to test various cytoplasmic male sterile (CMS) lines and restorers for their combining ability. The knowledge of combining ability is useful to assess nicking ability in self pollinated crops and at the same time to elucidate the nature and magnitude of gene action involved. The Line x Tester analysis of combining ability proposed by Kempthorne (1957) is commonly used to find out general and specific combiners and study the gene action governing the inheritance of characters. Hence the present study was undertaken to assess the combining ability of promising CMS and restorer lines in rice using Line x Tester analysis.

Materials and Methods

The material for the present study comprised 115 F_1s of rice generated by crossing five CMS lines (*viz.,* IR 58025A, IR 79145A, APMS 6A, PUSA 5A and CRMS 32A) with 23 restorer lines during *rabi,* 2006-07. The resultant 115 F_1s along with 28 parents and 4 checks of different maturity groups were grown in randomized complete block design with two replications during *kharif*, 2007 at Research Farm, Directorate of Rice Research, Rajendranagar, Hyderabad. Thirty days old seedlings were transplanted with one seedling per hill adopting 20 x 15 cm spacing. Each entry was planted in two rows of 1.8 m length. All the recommended agronomic practices were followed. In each entry, five plants were selected randomly from each replication and data were recorded for plant height, productive tillers per plant, panicle length, panicle weight, filled grains per panicle, spikelet fertility per cent, grain yield per plant and productivity per day. Days to fifty per cent flowering was recorded on plot basis. The mean data were analyzed for combining ability following Kempthorne (1957). The F_1 hybrid performance was evaluated on the basis of the estimate of heterosis (Mutzinger, Mann, and Cockrham, 1952), heterobeltiosis (Fone*sca* and Patterson, 1968) and standard heterosis (Comparison of F_1 with best commercial check hybrid/variety).

Results and Discussion

The analysis of variance for combining ability revealed that sufficient variability existed in the material for all the traits. The variance due to lines was significant for panicle weight and filled grains per panicle (Table 1) indicating their contribution to combining ability. The variance due to testers was significant for plant height and productive tillers. While L x T component of variances were significant for all the traits indicating that lines interacted sufficiently with testers. The estimates of variance due to *GCA* and *SCA* indicated the predominance of *SCA* variance for all the traits studied. Sanjeevkumar *et al.,* (2007), Sarma *et al*. (2007), Venkatesan *et al.* (2007) and Dalvi and Patel (2009) also reported that non additive gene effects were predominant than additive gene effects especially for yield and its component characters. The presence of non additive genetic variance in this study offer scope for exploitation of heterosis for these characters.

The selection of parents with good general combining ability effects is a pre-requisite for a successful breeding programme, especially hybrid breeding. Of the CMS lines evaluated, APMS 6A was good general combiner for grain yield per plant, panicle weight, filled grains per panicle and per day productivity, while PUSA 5A was good general combiner for grain yield per plant, earliness, dwarf plant height and per day productivity (Table 2). The line IR 58025A showed good *gca* for panicle length and CRMS 32A for filled grains per panicle. Among

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Table 1. Analysis of variance for combining ability for grain yield and attributing traits in rice

Source	d.f	Days to 50% flowering	Plant hieght (cm)	Productive tillers	Panicle Weight (g)	Filled grains/ panicle	Spikelet fertility (%)	Panicle Length (cm)	Grain yeild/plant (g)	Productivity/ day (kg/ ha)
Replications	1	22.54**	7.57	0.63	0.32	0.36	45.50	0.01	0.22	0.58
Crosses	114	24.17**	114.84**	3.45**	4.23**	1.32**	4680.47**	145.74**	125.40**	508.91**
Lines	4	10.92	117.43	2.30	4.70	6.02**	23605.54**	283.58	222.08	957.62
Testers	22	27.10	207.76**	5.18**	5.10	1.43	4571.25	155.01	147.72	621.29
Line x Tester	88	24.04**	91.50**	3.07**	4.00**	1.08**	3847.55**	137.15**	115.43**	460.42**
Error	114	3.84	9.89	0.85	0.75	0.19	141.97	5.30	3.57	15.42
s^2gca		0.55	5.49	0.1	0.15	0.13	498.11	7.62	6.48	27.67
s^2sca		10.17	41.3	1.12	1.66	0.45	1853.13	65.55	56.03	222.92
s^2gca/s^2sca		0.05	0.13	0.09	0.09	0.29	0.27	0.12	0.12	0.12

* Significant at 5 % level;** Significant at 1 % level

the testers, IBL-57, SG 27-77, SG26-120 and KMR-3 were good general combiners for grain yield per plant, spikelet fertility, filled grains per panicle and per day productivity.

The specific combining ability (*sca*) effect is an average performance of a cross expressed as deviation from the population mean and is correlated with parental *gca* effects. The high *sca* effect may be associated with high hybrid vigour.

Table 2. General combining ability effect of parents for grain yield and associated traits in rice

Lines	DFF	PHT	PBT	PL	PWT	FG	SF%	GY	PPD
IR 58025A	0.14	1.46**	-0.34*	0.27*	-0.29**	-12.49**	0.02	-0.09	-0.09
IR 79156A	0.57*	0.00	0.22	-0.12	-0.25**	-18.68**	-0.96**	-3.55**	-7.43**
APMS 6A	-0.43	0.33	0.19	0.16	0.59**	37.32**	4.22**	2.39**	4.83**
PUSA 5A	-0.58**	-2.68**	-0.04	-0.51**	-0.12	-11.33**	-2.15**	0.93**	2.08**
CRMS 32A	0.29	0.89**	-0.03	0.20	0.07	5.17**	-1.14**	0.33	0.61
S.E (lines)	0.28	0.44	0.13	0.12	0.06	1.75	0.36	0.27	0.56
Testers									
1096	0.57	3.69**	0.16	0.71**	0.21	6.41	-1.04	-1.33*	-2.88*
1005	2.27**	-0.64	0.33	-0.40	0.34*	41.03**	0.00	-2.18**	-5.36**
619-2	-2.63**	0.74	0.66*	0.95**	0.08	-8.13*	-1.93**	-1.55**	-1.96
612-1	0.87	3.51**	0.30	0.10	0.33*	16.89**	0.12	-1.38*	-3.10**
611-1	0.17	0.20	-0.10	0.00	-0.38**	-15.97**	-9.37**	-3.05**	-6.00**
GQ-25	-1.13	-4.37**	0.83**	-0.32	-0.18	-10.15**	-1.03	3.11**	6.83**
GQ-37-1	-1.83**	0.46	0.93**	-0.80**	-0.31	-7.87*	-1.72*	-0.97	-0.99
GQ-70	0.57	-6.57**	-0.20	-0.55*	-0.19	16.47**	6.90**	-0.71	-1.89
GQ-120	-0.03	7.18**	-0.24	0.48	-0.61**	-29.51**	-0.45	-3.31**	-6.82**
KMR-3	-1.53**	8.59**	0.56	0.71**	0.04	-12.93**	2.00*	4.85**	10.54**
IBL-57	-1.43**	-7.40**	0.63*	-1.19**	0.38**	29.09**	4.07**	8.29**	17.40**
BR827-35	-0.93	0.98	0.16	-0.40	0.04	-12.11**	-2.14**	-1.55**	-2.66*
EPLT-109	-1.53	-5.88**	0.45	-0.93**	-0.04	-21.37**	-6.67**	-4.61**	-8.81**
SC_5 2-2-1	-0.13	1.17	0.08	-0.01	0.32*	-8.67*	-0.65	-0.61	-1.10
SC_5 9-3	0.67	-2.96**	-0.34	-0.24	0.24	4.41	0.82	-0.32	-0.89
SG27-77	0.57	2.27*	-0.27	1.15**	-0.16	7.59**	2.16**	6.98**	13.45**
SG26-120	-3.63**	5.06**	-0.14	0.62*	0.09	10.69**	1.73*	4.49**	10.88**
118	2.47**	2.95**	0.70*	0.33	0.51**	16.67**	3.53**	0.82	0.63
124	2.07**	5.46**	0.43	1.13**	0.59**	22.75**	2.58**	3.04**	5.10**
517	1.67**	-0.10	-0.34	-0.30	0.03	22.03**	5.90**	4.06**	6.88**
IR 43	-0.23	-4.22**	-1.54**	-1.10**	-0.47**	-5.53	0.26	-4.68**	-9.30**
IR 55	2.47**	-3.67**	-1.70**	0.70**	-1.00**	-56.54**	-7.61**	-6.31**	-13.40**
IR 60	0.77	-6.44**	-1.37**	-0.67*	0.12	-5.23	2.52**	-3.08*	-6.56**
S.E (testers)	0.61	0.94	0.29	0.26	0.13	3.76	0.78	0.58	1.21

DFF= Days to 50% flowering; PHT =Plant height (cm); PBT = Panicle bearing tillers; PL = Panicle length (cm); PWT= Panicle weight (g) ; FG = Filled grains/ panicle ; SF = Spikelet fertility (%) ; GY = Grain yield/ plant (g) ; and Productivity/ day (kg/ha).

* Significant at 5 % level;** Significant at 1 % level

The hybrid IR 79156A x IBL-57 recorded the highest significant *sca* effects for panicle weight, filled grains per panicle, grain yield per plant and per day productivity besides spikelet fertility percentage (Table 3). In addition , APMS 6A x GQ-25, APMS 6A x 517, IR 58025A x GQ-70, APMS 6A x SG26-120 and PUSA 5A x IR55 were identified as specific combiners for grain yield per plant and could be utilized for heterosis breeding to exploit hybrid vigour.

Table 3. Specific combining ability effect of selected hybrids for grain yield and associated traits in rice

Lines	DFF	PHT	PBT	PL	PWT	FG	SF%	GY	PPD
IR 58025A x GQ-37-1	-0.84	0.41	0.50	1.22*	-0.53	-11.81	-2.80	11.41**	23.18**
IR 58025A x GQ-70	2.76*	0.74	-0.03	-0.47	0.76*	32.95**	4.24*	13.49**	25.35**
IR 58025A x KMR-3	1.86	3.07	0.37	0.45	0.33	1.45	-5.45**	3.95**	6.62*
IR 58025A x IBL-57	-1.74	-1.72	1.80**	0.51	-0.51	-25.97**	1.98	3.33*	7.49**
IR 58025A x BR827-35	-3.24*	-7.29	1.44*	-0.08	0.83**	54.93**	3.01	7.83**	17.15**
IR 58025A x SC5 2-2-1	3.46*	-0.07	0.69	-2.01**	0.04	3.59	3.10	5.56**	9.20**
IR 58025A x SC5 9-3	-1.84	-4.72*	0.44	-1.76**	-0.37	-16.09**	5.88**	2.91*	6.40*
IR 58025A x SG26-120	-6.54**	-0.26	1.07	-1.03	-1.27**	-3.17	4.87**	6.62**	17.39**
IR 58025A x 517	0.16	6.58**	0.77	2.27**	1.54**	84.79**	-2.82	-8.28**	-16.13**
IR 58025A x IR60	3.56*	6.35**	-0.87	1.72**	1.03**	58.15**	1.51	5.19**	8.74**
IR 79156A x 1096	-1.17	-6.34**	-0.45	0.51	-0.18	-2.80	1.96	5.07**	10.71**
IR 79156A x 612-1	4.03**	-12.87**	-1.25	-2.50**	0.98**	41.42**	5.02**	2.78*	4.20
IR 79156A x 611-1	1.23	11.12**	-0.52	2.18**	-0.59*	-40.12**	-4.79**	-7.55**	-15.30**
IR 79156A x GQ-25	0.03	-7.15**	0.70	-0.83	-0.09	-1.74	0.33	-10.53**	-21.30**
IR 79156A x GQ-120	-4.07**	-9.24**	-0.88	-1.89**	0.89**	32.42**	7.36**	-6.61**	-11.99**
IR 79156A x IBL-57	-1.17	2.12	0.08	0.68	1.25**	69.62**	5.02**	16.62**	34.15**
IR 79156A x SG27-77	3.83**	-10.74**	-1.18	-0.10	1.01**	67.22**	5.04**	10.73**	19.29**
IR 79156A x 118	2.43	-0.52	1.52*	1.11	0.12	8.34	-5.51**	10.09**	18.72**
IR 79156A x 517	-4.77**	0.93	-0.45	-2.31**	-0.68*	-74.32**	-1.88	-9.65**	-17.10**
IR 79156A x IR 43	-3.87**	1.15	-0.41	-0.73	0.49	6.64	4.91**	-3.74**	-6.43*
APMS 6A x 1005	3.63**	-7.12**	0.41	-0.22	0.24	86.98**	2.99	3.64**	5.73*
APMS 6A x 612-1	0.03	9.21**	1.78**	0.83	-0.45	-48.78**	-8.50**	7.69*	15.39**
APMS 6A x GQ-25	0.53	-3.51	0.58	-1.65**	1.47**	92.96**	7.97**	15.46**	30.97**
APMS 6A x GQ-70	4.83**	2.14	0.77	-0.67	-0.23	-10.96	-3.16	-5.98**	-13.24**
APMS 6A x KMR-3	-1.07	-3.68	-0.16	-0.62	-0.85**	-49.36**	-4.03*	-16.05**	-32.20**
APMS 6A x IBL-57	-3.17*	2.37	-1.23	-1.72**	0.01	-28.78**	-10.83**	-11.82**	-22.50**
APMS 6A x BR827-35	-2.17	-1.61	-1.09	0.77	-0.12	-32.48**	3.21	-7.16**	-13.68**
APMS 6A x EPLT-109	-0.07	0.99	0.12	-0.51	0.13	-16.82*	5.61**	-3.25*	-6.36**
APMS 6A x SG26-120	2.53	1.42	2.54**	1.77**	-0.03	-18.38*	-6.29**	13.15**	25.37**
APMS 6A x 118	-1.07	-3.18	1.21	0.45	1.67**	75.24**	1.21	3.14*	6.69*
APMS 6A x 517	6.23**	2.45	-1.09	-0.13	-0.14	20.28*	0.39	15.41**	26.74**
APMS 6A x IR 43	-1.37	-6.92**	-0.06	-0.88	0.35	23.14**	4.37*	-5.50**	-10.59**
APMS 6A x IR55	-1.57	0.22	-0.89	1.47**	-0.42	-20.65*	9.20**	-6.22**	-11.91**
PUSA 5A x 1096	0.48	4.09	1.65*	0.93	0.19	7.55	-4.18*	7.76**	15.20**
PUSA 5A x 611-1	4.88**	-10.78**	-0.42	-2.85**	1.20**	82.43**	13.57**	8.31**	14.06**
PUSA 5A x GQ-37-1	2.38	-0.89	0.71	-1.45*	0.98**	56.23**	5.67**	-7.04**	-15.35**
PUSA 5A x GQ-70	-2.02	-2.83	-0.66	-0.77	-0.35	-15.41	-1.42	-12.86**	-25.09**
PUSA 5A x GQ-120	3.08*	6.99**	0.88	0.47	-0.30	-57.83**	-23.37**	-4.93**	-10.64**
PUSA 5A x IBL-57	4.98**	4.84*	-0.32	1.01	-0.48	-18.93*	3.18	-13.03**	-28.15**
PUSA 5A x BR827-35	5.98**	3.21	-2.52**	-1.39**	-1.04**	-52.73**	-10.62**	-4.53**	-11.20**
PUSA 5A x SG27-77	1.48	6.20**	-0.09	2.09**	0.26	28.77**	-1.45	5.61**	10.60**
PUSA 5A x SG26-120	-2.82*	-3.37	-0.06	-0.69	1.30**	23.97**	-6.47**	-10.06**	-19.72**
PUSA 5A x IR 43	-1.22	3.21	0.34	1.23*	0.26	13.89	3.39	11.25**	23.19**
PUSA 5A x IR55	0.08	-6.66**	0.34	-0.70	0.55	14.20	7.27**	13.07**	25.59**
CRMS 32A x 1096	1.61	-2.41	-0.38	-1.64**	-0.10	-10.65	-5.06**	-7.81**	-16.08**
CRMS 32A x 1005	0.91	-10.80**	1.13	-0.41	-0.14	-13.97	1.44	3.37*	6.28*
CRMS 32A x 611-1	-6.99**	-0.48	1.06	0.41	0.38	-28.77**	-1.59	9.72**	22.84**
CRMS 32A x GQ-120	3.71**	0.15	1.69**	-0.67	0.11	38.47**	11.46**	8.67**	15.63**
CRMS 32A x KMR-3	-2.29	1.19	-0.28	-0.15	1.17**	71.69**	6.29**	5.34**	11.88**
CRMS 32A x IBL-57	1.11	-7.61**	-0.34	-0.47	-0.27	4.07	0.64	4.90**	9.01**
CRMS 32A x EPLT-109	1.21	1.96	-0.33	1.64**	0.24	43.53**	13.21**	4.47**	8.58*
CRMS 32A x 124	-1.39	-8.43**	-0.14	-1.22*	0.81**	14.91	-8.09**	2.81*	6.12*
CRMS 32A x 517	2.01	7.43**	-0.04	0.85	-0.02	17.63*	5.17**	2.82*	4.89
S.E.(Crosses)	1.37	2.11	0.64	0.58	0.29	8.40	1.74	1.30	2.70

* Significant at 5 % level;** Significant at 1 % level

High magnitude of *sca* effects in these hybrids resulted from the combination high x high (APMS 6A with GQ-25, SG 26-120 and 517); high x low (PUSA 5A with 1096, 611-1, IR43 and IR 55); medium x medium (IR 58025A with GQ37-1 and GQ-70); medium x low (CRMS 32A with 611-1 and GQ-120) *gca* effects of parents. Similar results were reported by Dalvi and Patel (2009). Shivani *et al.* (2009) and Salgotra *et al.* (2009) also reported about interaction between positive and positive alleles in crosses involving high x high combiners which can be fixed in subsequent generations if no repulsion phase linkages are involved. In crosses with high x low or medium x low *gca* effects, the high positive *sca* effects may be due to the dominant x recessive interaction, expected to produce desirable segregants in subsequent generations (Lingham, 1961).

Yield compensation is a cumulative function of various components, the contribution of these components are through component compensation mechanism (Adams, 1967). Meagre hybrid vigour for a component may result in significant hybrid vigour for yield *per se.* In the present study, the cross combinations *viz.,* 79156A x IBL-57, APMS 6A x GQ-25, APMS 6A x 517 and IR 58025A x GQ-70 were identified to be the best and could be exploited further. In these crosses, heterosis was realized for more than one component *viz.,* panicle weight, filled grains per panicle, grain yield per plant and per day productivity.

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