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Combining Ability Analysis for Grain Yield and Yield Components in CMS Based Hybrids in Rice (*oryza sativa* L.)

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ABSTRACT

Forty eight hybrids generated from crossing four CMS lines and twelve testers were studied along with parents for combining ability for yield and yield components. The predominance of non-additive gene action was recorded for days to 50 per cent flowering, days to maturity, plant height, total number of productive tillers per plant, panicle length, number of grains per panicle, 200-kernel test weight, harvest index and grain yield per plant. Among parents, APMS 6A, IR 58025A, MTU 1010 and MTU 1001 were found to be good general combiners for yield and yield components. Among crosses IR 58025A x MTU 5249 and PMS 16A x MTU 1061 were identified as most promising heterotic crosses for yield based on *sca* effects, *per se* performance and with more than 20% standard heterosis.

Key words : Cytoplasmic male sterility, General combining ability, Rice, Specific combining ability.

Rice is the most important food crop in the world, which accounts for more than 21% of the calorific needs of the world's population and upto 76% of the calorific intake of the population of South East Asia (Melissa *et al.,* 2009). Hybrid rice technology appears to be the most feasible and readily adoptable to increase the yield level in rice. Several pioneer rice hybrids have shown a yield advantage of around 20% over current three line hybrids on commercial scale. The average yield of rice hybrid is 6.3 t/ha while that of the inbred varieties is 4.5 t/ha (Long ping Yuan, 2004). Therefore, the breeders are making concentratred efforts to evolve better hybrids in the genetic background of newly developed CMS lines. Therefore, the present investigation was conducted to analyze the combining ability of four newly developed CMS lines with 12 restorers for grain yield and its components in rice through a Line x Tester analysis.

MATERIAL AND METHODS

The experimental material comprised of 48 F_1 hybrids of rice derived from a Line x Tester mating design involving four cytoplasmic male sterile lines *viz.,* APMS 6A, APMS 8A, PMS 16A and IR 58025A as lines and 12 restorers viz., MTU 1010, MTU 1075, MTU 1061, PLA 1100, MTU 7029, MTU 1001, MTU 1064, MTU 5249, MTU 4870, BPT 5204, MTU 1078 and MTU 2716 as testers. The F_1 hybrids and parents were grown in a contiguous blocks in randomized block design in three replications at wet land farm of Sri Venkateswara Agricultural College, Tirupati during *rabi* 2010. Twenty four days old seedlings of each genotype were transplanted in three rows of 2.0 m length by adopting a spacing of 22.5 cm between rows and 10 cm between plants within a row *i.e.* at the rate of 20 plants per row. The observations were recorded on agronomic characters *viz.,* days to 50 per cent flowering, days to maturity, plant height, total number of productive tillers per plant, panicle length, number of grains per panicle, 200-kernel test weight, harvest index and grain yield per plant. The combining ability analysis was carried out as per the procedure given by Kempthorne (1957) and Arunachalam (1974).

RESULTS AND DISCUSSION

Analysis of variance for combining ability revealed highly significant differences among the lines, testers and line x tester for all the characters studied, indicating the presence of wide genetic variability among the lines, testers and their interaction effects (Table 1). The line x tester contributed more to the observed variability than the lines and testers for all the characters indicating significant interaction were accounted for total variation among hybrids (Table 2). Higher estimates of s^2sca than s^2gca variance was recorded for all

Table 1. Analysis of variance for combining ability for grain yield and its contributing characters in rice

Source of variation	df	DF	DM	PH	TPTP	PL	NGPP	GY	200-KTW	HI
Replications	2	0.63	0.67	0.37	2.35	0.64	1387.17	26.71	0.15	7.11
Lines	3	106.32**	160.96**	69.23**	7.76**	19.06**	12886.20**	50.64**	0.74**	157.05**
Testers	11	373.09**	189.73**	213.61**	9.16**	7.92**	9703.19**	24.94**	1.05**	129.52**
Line×Tester	33	134.21**	128.31**	112.68**	9.26**	5.03**	4753.71	12.66**	0.66**	62.89**
Error	94	0.46	0.38	0.13	0.07	0.16	139.03	1.09	0.02	0.62

DF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TPTP: Total number of Productive Tillers per Plant; PL: Panicle Length; NGPP: Number of Grains Per Panicle; GY: Grain Yield per plant; 200 KTW: 200-Kernel Test Weight; HI: Harvest Index

Table 2. Proportional contribution of Lines, Testers and Lines x Testers interaction towards total variance in respect of grain yield and its components in rice

Traits	Proportional contribution (%) of		
	Lines	Testers	Line x Tester
Days to 50% flowering	3.60	46.36	50.03
Days to maturity	7.10	30.67	62.23
Plant height	3.31	37.44	59.25
Total number of productive tillers per plant	5.41	23.44	71.14
Panicle length	18.42	28.05	53.52
Number of grains per panicle	12.79	35.31	51.90
Grain yield per plant	18.00	32.51	49.49
200-Kernel test weight	18.00	32.51	49.49
Harvest Index	11.86	35.88	52.26

Table 3. Estimates for *gca* and *sca* variances for grain yield and yield components in rice

Traits	s^2gca	s^2sca	s^2gca/s^2sca	s^2A	s^2D	s^2A / s^2D
Days to 50% flowering	0.7571	44.5861	0.0170	1.5142	44.5861	0.0340
Days to maturity	0.2302	42.6429	0.0054	0.4604	42.6429	0.0108
Plant height	0.2916	37.5162	0.0078	0.5832	37.5162	0.0155
Total number of productive tillers per plant	0.0017	3.0644	0.0006	0.0034	3.0644	0.0011
Panicle length	0.0220	1.6240	0.0135	0.0440	1.6240	0.0271
Number of grains per panicle	23.4648	1538.2234	0.0153	46.9296	1538.2243	0.0305
Grain yield per plant	0.0741	3.8546	0.0192	0.1482	3.8546	0.0384
200-Kernel test weight	0.0013	0.2151	0.0060	0.0026	0.2151	0.0121
Harvest Index	0.3022	20.7537	0.0146	0.6044	20.7537	0.0291

Table 4.General combining ability effects of Lines and Testers for grain yield and its components in rice

Parents	DF	DM	PH	TPTP	PL	NGPP	GY	200-KTW	HI
Lines									
APMS 6A	-2.10**	-3.11**	-0.18**	0.42**	-0.10**	1.62	1.11**	0.15**	2.32**
APMS 8A	0.63**	1.11**	-1.12**	-0.66**	-0.92**	11.19	-1.29**	-0.12**	-2.77**
PMS 16A	1.96**	1.50**	1.9**	0.04**	0.84**	14.38	-0.72**	-0.13**	0.22**
IR 58025A	-0.49**	0.50**	-0.701**	0.20**	0.19**	-27.19**	0.90**	0.10**	0.21**
SE (g_i)	0.11	0.10	0.060	0.04	0.07	1.97	0.17	0.02	0.13
Testers									
MTU 1010	-11.65**	-7.06**	3.51**	1.58**	0.67**	-11.40**	2.27**	0.16**	5.02**
MTU 1075	-2.82**	-4.06**	3.63**	0.01	1.31**	34.72	-0.345**	-0.27**	-1.17**
MTU 1061	-2.90**	-1.64**	0.69**	-0.81**	-0.05**	-33.49**	-1.88**	0.14**	-2.26**
PLA 1100	1.93**	1.53**	4.76**	-0.23**	0.30**	9.70	-1.41**	-0.10**	-2.91**
MTU 7029	6.43**	4.94**	-5.02**	-0.16**	-0.04**	23.00	0.55*	-0.02**	3.57**
MTU 1001	-6.65**	-5.56**	-8.12**	1.16**	-0.21**	-11.38**	-0.56**	0.35**	2.84**
MTU 1064	2.01**	1.94**	-2.19**	-0.003**	-0.61**	-27.54**	-0.58**	0.26**	-6.25**
MTU 5249	5.35**	0.94**	-1.64**	0.68**	-1.09**	10.25	0.17	0.21**	-2.28**
MTU 4870	0.51**	1.61**	-2.15**	-1.79**	-0.94**	-11.43**	-1.20**	-0.18**	-0.07**
BPT 5204	-2.82**	-0.39**	-2.14**	-0.21**	-0.93**	-31.00**	-0.21**	-0.66**	-0.91**
MTU 1078	6.60**	1.61**	5.31**	-0.34**	1.24**	59.53*	3.14**	-0.20**	1.01**
MTU 2716	4.01**	6.11**	3.36**	0.12**	0.35**	-11.91**	-0.04**	0.31**	3.43**
SE (g_j)	0.20	0.18	0.11	0.08	0.12	3.40	0.30	0.04	0.23

DF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TPTP: Total number of Productive Tillers per Plant; PL: Panicle Length; NGPP: Number of Grains Per Panicle; GY: Grain Yield per plant; 200 KTW: 200-Kernel Test Weight; HI: Harvest Index

Table 5. Specific combining ability effects of 48 F_1 hybrids for grain yield and its components in rice

S.No	F_1 hybrid	DF	DM	PH	TPTP	PL	NGPP	GY	200 KTW	HI
1	APMS6A X MTU1010	-2.40**	-7.56**	0.41	-1.99**	1.14**	48.74**	-1.23*	-0.22**	1.19*
2	APMS6A X MTU1075	0.10	-0.22	17.03**	0.65**	2.56**	40.99**	2.10**	0.16*	-3.84**
3	APMS6A X MTU1061	0.85*	2.03**	-1.90**	2.23**	0.02	35.33**	-1.40*	0.86**	1.28**
4	APMS6A X PLA 1100	10.01**	5.86**	9.60**	-1.02**	0.92**	1.71	-1.90**	-0.71**	0.26
5	APMS6A X MTU7029	-5.15**	-1.56**	0.11	1.68**	0.49*	-14.97*	3.72**	-0.14	4.06**
6	APMS6A X MTU 1001	2.93**	6.94**	1.71**	1.30**	-0.73**	-27.05**	-1.75**	-0.60**	-0.43
7	APMS6A X MTU 1064	-4.74**	-2.56**	-1.61**	-2.91**	-0.64**	-27.15**	-0.21	-0.14	3.12**
8	APMS6A X MTU 5249	-0.07	10.78**	-7.03**	-0.66**	-1.41**	-64.67**	-0.95	0.35**	0.97*
9	APMS6A X MTU 4870	-2.24**	0.44	-7.62**	-0.43**	-1.49**	32.97**	0.90	-0.25**	-2.59**
10	APMS6A X BPT 5204	5.10**	-4.89**	-8.13**	1.57**	-1.04**	-17.09*	1.39*	0.16*	-5.36**
11	APMS6A X MTU 1078	-4.32**	-10.22**	2.04**	1.06**	-1.02**	7.91	1.45*	0.07	1.89**
12	APMS6A X MTU 2716	-0.07	0.94**	-4.60**	-1.47**	1.21**	-16.72*	-2.11**	0.46**	-0.54
13	APMS8A X MTU 1010	-5.13**	-8.78**	8.85**	1.88**	-2.67**	-50.02**	1.88**	-0.18*	10.94**
14	APMS8A X MTU 1075	-2.96**	-0.78*	-11.28**	1.29**	-2.18**	-15.34*	1.66**	0.08	6.10**
15	APMS8A X MTU 1061	-0.88*	4.14**	5.62**	-0.33*	0.73**	14.26*	-1.23*	-0.50**	-2.51**
16	APMS8A X PLA 1100	4.63**	-1.03**	0.22	-1.11**	-0.12	7.38	1.06	-0.26**	0.67
17	APMS8A X MTU 7029	-9.54**	-2.44**	-2.86**	-0.41**	-0.06	-25.97**	-1.25*	0.62**	-3.61**
18	APMS8A X MTU 1001	-2.13**	6.39**	-0.49*	-1.46**	-0.51*	4.79	0.35	0.56**	-0.72
19	APMS8A X MTU 1064	-1.46**	-4.44**	0.61**	1.50**	0.23	18.39**	-0.24	0.12	-0.92*
20	APMS8A X MTU 5249	7.21**	-4.11**	-1.50**	-1.92**	1.17**	-34.77**	-2.11**	0.14	0.81
21	APMS8A X MTU 4870	3.04**	2.89**	2.00**	1.35**	2.01**	23.14**	1.13	-0.71**	1.78**
22	APMS8A X BPT5204	2.71**	5.56**	3.02**	-0.43**	0.36	51.68**	-0.99	0.16*	-2.09**
23	APMS8A X MTU 1078	1.96**	2.22**	-3.37**	0.60**	0.49*	0.48	-0.72	-0.23**	-6.66**
24	APMS8A X MTU 2716	2.54**	0.39	-0.83**	-0.96**	0.55*	6.02	0.45	0.20**	-3.79**

Table 5. Cont…

S.No	F_1 hybrid	DF	DM	PH	TPTP	PL	NGPP	GY	200 KTW	HI
25	PMS 16A X MTU1010	-3.46**	11.83**	-4.68**	-0.75**	0.37	-39.11**	-0.70	0.28**	-1.71**
26	PMS 16A X MTU1075	2.04**	0.83*	-0.90**	-0.81**	-0.18	32.54**	-2.34**	-0.02	-2.20**
27	PMS 16A X MTU1061	0.46	-13.58**	2.89**	-1.56**	0.61*	-53.49**	3.84**	0.04	2.96**
28	PMS 16A X PLA1100	-9.04**	-7.08**	-6.88**	2.99**	-0.70**	-6.28	1.29*	0.73**	-3.53**
29	PMS 16A X MTU7029	7.79**	0.83*	0.83**	-1.81**	-0.65**	37.91**	0.47	-0.05	3.08**
30	PMS 16A X MTU1001	-5.46**	-4.67**	-7.14**	-1.26**	1.28**	-7.80	-0.89	0.26**	0.74
31	PMS 16A X MTU1064	10.21**	7.17**	0.83**	2.70**	0.68**	37.23**	2.57**	-0.22**	2.41**
32	PMS 16A X MTU5249	7.88**	3.83**	5.92**	0.05	0.75**	45.74**	-1.34*	-0.93**	-6.03**
33	PMS 16A X MTU4870	-2.63**	-2.83**	3.70**	0.42**	1.02**	-1.22	-0.87	0.46**	3.26**
34	PMS 16A X BPT 5204	-11.96**	-1.50**	0.59**	-1.72**	-0.83**	-69.74**	-0.40	0.10	3.01**
35	PMS 16A X MTU1078	1.29**	4.17**	-0.27	-1.23**	-0.45	23.56**	-1.99**	-0.07	-0.18
36	PMS 16A X MTU2716	2.88**	1.00**	5.12**	2.98**	-1.89**	0.67	0.36	-0.59**	-1.81**
37	IR58025A X MTU1010	10.99**	4.50**	-4.58**	0.86**	1.16**	40.39**	0.05	0.12	-10.42**
38	IR58025A X MTU1075	0.82*	0.17	-4.85**	-1.13**	-0.19	-58.19**	-1.41*	-0.22**	-0.05
39	IR58025A X MTU1061	-0.43	7.42**	-6.61**	-0.35*	-1.36**	3.91	-1.21*	-0.41**	-1.73**
40	IR58025A X PLA 1100	-5.60**	2.25**	-2.95**	-0.86**	-0.10	-2.81	-0.45	0.25**	2.60**
41	IR58025A X MTU7029	6.90**	3.17**	1.93**	0.54**	0.22	3.04	-2.94**	-0.43**	-3.53**
42	IR58025A X MTU1001	4.65**	-8.67**	5.93**	1.42**	-0.05	30.07**	2.29**	-0.22**	0.42
43	IR58025A X MTU1064	-4.01**	-0.17	0.16	-1.29**	-0.27	-28.47**	-2.12**	0.23**	-4.61**
44	IR58025A X MTU5249	-15.01**	-10.50**	2.61**	2.53**	-0.51*	53.71**	4.39**	0.44**	4.25**
45	IR58025A X MTU4870	1.82**	-0.50	1.93**	-1.34**	-1.54**	-54.89**	1.16	0.49**	-2.46**
46	IR58025A X BPT 5204	4.15**	0.83*	4.52**	0.59**	1.52**	35.16**	0.00	-0.42**	4.44**
47	IR58025A X MTU1078	1.07**	3.83**	1.60**	-0.42**	0.98**	-31.94**	1.25*	0.23**	4.95**
48	IR58025A X MTU2716	-5.35**	-2.33**	0.32	-0.55**	0.13	10.03	1.30*	-0.07	6.14**
	SE (S_{ij})	0.389	0.357	0.209	0.153	0.232	6.808	0.604	0.074	0.456

DF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TPTP: Total number of Productive Tillers per Plant; PL: Panicle Length; NGPP: Number of Grains Per Panicle; GY: Grain Yield per plant; 200-KTW: 200-Kernel Test Weight; HI: Harvest Index the traits indicating the predominance of non- additive gene action in the traits (Table 3). The preponderance of non- additive gene action offers a good scope for exploitation of hybrid vigour in improving these traits. Similar results were also reported by Bisne and Motiramani (2005) for days to 50 % flowering, Ramalingam *et al.,* (1993) for days to maturity, Sharma *et al*., (1996) for plant height, Sanjeev Kumar *et al.,* (2007) for panicle length and Karthikeyan *et al.* (2009) for total number of productive tillers per plant and grain yield per plant. The estimate of degree of dominance for these traits was found less than one indicating the genetic control of partial dominance type of gene effects in them.

The estimates of *gca* effects revealed significance among the parental lines for different traits. Among lines, IR 58025A was found to be the best general combiner for early flowering and early maturity, 200 kernel test weight and number of grains per panicle, whereas PMS 16A for panicle length, total number of productive tillers per plant and harvest index (Table 4). The other line APMS 6A was found as good general combiner for dwarf height and grain yield per plant. Similarly among testers, MTU 1010 was found to be a superior combiner for early flowering and early maturity, 200 kernel test weight and total number of productive tillers per plant, whereas MTU 1075 for panicle length and number of grains per panicle. The remaining testers *viz*., BPT 5204 and MTU 1001 were found to be good general combiners for grain yield and harvest index, respectively.

In the present study, positive significant *sca* effects for grain yield per plant were exhibited by 13 crosses (Table 5). The promising specific crosses along with high *per se* performance for grain yield per plant were IR 58025A x MTU 5249, PMS 16A x MTU 1061, APMS 6A x MTU 7029, PMS 16A x MTU 1064, IR 58025A x MTU 1001 and

APMS 6A x MTU 1075 in the decreasing order of *sca* effects. These promising crosses involved one parent with high *gca* effect and other having either high or low combining ability effect indicating the presence of additive x dominance and /or additive x additive gene effects in sizeable amount in these crosses. Similar type of results were also reported by Anand Kumar *et al.,* (2006) and Pradhan and Singh (2008) for grain yield.

The promising specific combinations for grain yield per plant along with other traits were IR 58025A x MTU 5249 and PMS 16A x MTU 1061. The cross combinations *viz*.,

IR 58025A x MTU 5249 and PMS 16A x BPT 5204 had exhibited low *sca* effect for days to 50% flowering (Table 5). Negative estimates of *sca* are desirable for plant height and were recorded in the crosses APMS 8A x MTU 1075 and IR 58025A x MTU 1061. Similarly,

PMS 16A x PLA 1100 and IR 58025A x MTU 5249 registered high *sca* effects for total number of productive tillers per plant. Promising specific combiners identified for panicle length were APMS 8A x MTU 4870 and PMS 16A x MTU 1001. The cross combinations

IR 58025A x MTU 5249 and APMS 8A x BPT 5204 had exhibited high *sca* effects for number of grains per panicle. Further, the hybrids APMS 6A x MTU 1061 and PMS 16A x MTU 2716 had exhibited high *sca* effects for 200-kernel test weight, whereas IR 58025A x MTU 2716 and APMS 8A x MTU 1075 had exhibited high *sca* effects for harvest index.

Considering both *per se* performance and *gca* effects, APMS 6A, IR 58025A, MTU 1010 and MTU 1001 were adjudged as good general combiners for grain yield and most of yield components. Among crosses IR 58025A x MTU 5249 and PMS 16A x MTU 1061 were identified as most promising crosses for grain yield based on their *sca* effects, *per se* performance and with more than 20% standard heterosis and therefore could be profitably exploited for the production of hybrids in rice after thorough testing in a wide range of locations and seasons.

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