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Combining Ability Analysis and Heterosis in Cytoplasmic Male Sterility Based Rice (*Oryza sativa* L.) Hybrids

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Combining ability and heterosis studies were conducted on 52 hybrids developed from crossing four cytoplasmic male sterile lines with 13 restorers in a line x tester fashion. The magnitude of *sca* variance was higher than *gca* variance for all the characters indicating the predominance of non- additive gene action. Among the parental lines and testers, APMS 9A MTU II-110-9-1-1-1-1, MTU II-283-7-1-1, MTU II-143-26-2 and MTU 1071 were good general combiners for grain yield and yield component characters. Better heterotic combiners based on *per se* performance, significant *sca* effects and standard heterosis for grain yield per plant were APMS 9A x MTU II-143-26-2, APMS 6A x MTU II-110-9-1-1-1-1, APMS 10A x MTU II-283-7-1-1 and IR 58025A x MTU II-190-1-1-1-1-1.

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

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In India rice is cultivated in an area of 43.77 million hectares with a production of 95.32 mt and with an average productivity of 2240 kg/ha (2010-11). Rice production can be increased with the use of suitable hybrids. Hybrid rice has an yield advantage of 20-30 per cent over non-hybrid rice cultivars (Lin and Yuan, 1980). Combining ability analysis will be useful in selection of desirable parents based on the performance of the hybrids, nature of gene action involved in the expression of traits and further it helps in exploitation of heterosis. Assessment of heterosis is an important component of hybrid rice breeding programme in India. Hence the present study was carried out to identify good heterotic combinations in rice.

Materials and Methods

Four CMS lines were crossed with 13 restorers in a line x tester mating design during *kharif,* 2010 at Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station (RARS), Maruteru, Andhra Pradesh. Fifty two hybrids along with their parents were raised in a randomized block design at RARS, Warangal with two replications by adopting a spacing of 20x15 cm. All the recommended agronomic practices were followed to raise a good crop. Plants were selected randomly from each replication and observations were recorded on ten randomly selected plants for days to 50% flowering, plant height (cm), number of tillers per plant, panicle length (cm), number of filled grains per panicle, spikelet fertility per cent, test weight *i.e.,*1000 grain weight (g) and grain yield per plant (g). The combining ability analysis was carried out as Kempthorne (1957) and the standard heterosis was calculated over the standard check MTU 1075.

Results and Discussion

The combining ability analysis revealed significant difference among the lines, testers, crosses and line x tester effect for all the characters except for grain yield per plant in lines effect indicating the presence of adequate variability in the experimental material (Table 1). The estimates of *sca* and *gca* variances and their ratios also revealed the predominance of *sca* effect for all the characters indicating the non-additive gene action confirming the earlier findings of Dalvi and Patel (2009), Jayasudhan and Deepaksharma (2009), Kumarbabu e*t al.* (2010), Bagheri and Babaeian (2010) and Saidaiah e*t al.* (2011). From the general combining ability estimates (Table 2) the line APMS 9A was good general combiner for grain yield per plant, spikelet fertility per cent and number of filled grains per panicle while APMS 6A was good general combiner for early flowering, dwarfness and number of filled grains per panicle whereas the testers *viz.,* MTU II-110-9-1-1-1-1, MTU II-283-7-1-1, MTU II-143-26-2 and MTU 1071 were good general combiners for grain yield per plant, spikelet fertility per cent, number of filled grains per panicle and panicle length. In addition to these characters, MTU II-110-9-1-1-1 -1 and MTU II-143-26-2 restorers also showed positive significant *gca* effect for number of ear bearing tillers per plant. Further MTU II -187-6-1-1 was identified as a good general combiner for grain yield per plant, test weight (1000 seed weight) and spikelet fertility per cent. Significant *sca* effects for grain yield per plant was exhibited by 11 crosses

Table 1. Analysis of variance of combining ability for different characters in rice (*Oryza sativa* L.)

Source of variation	df	Days to 50% flowering	Plant height (cm)	No. of tillers per plant	Panicle length (cm)	No. of filled grains per panicle	Spikelet fertility (%)	Test weight (g)	Grain yield per plant (g)
Replication	1	2.78	1.64	0.24	0.10	57.16	6.45	0.12	9.00
Crosses	51	96.90**	233.71**	4.57**	4.09**	6668.10**	158.31**	5.16**	212.43**
Lines	3	246.57**	377.04*	8.85**	7.16*	10668.67*	236.22*	23.27**	129.92
Testers	12	221.57**	543.61**	11.18**	10.19**	15424.50**	369.58**	8.35*	486.07*
Lines ×Testers	36	42.87**	118.46**	2.01**	1.80**	3415.92**	81.39**	2.58**	128.09**
ERROR	51	2.09	14.69	0.71	0.56	522.01	10.77	0.32	16.17
s_2GCA		1.06	2.25	0.05	0.04	63.55	1.50	0.05	1.65
s_2SCA		20.39	51.89	0.65	0.62	1446.96	35.31	1.13	55.96
s_2GCA/ s_2SCA		0.05	0.04	0.08	0.07	0.04	0.04	0.04	0.03

*significant at 5% level — s_2GCA = Variance of General combining ability

**significant at 1% level — s_2SCA = Variance of Specific combining ability

viz., APMS 6A x MTU II-110-9-1-1-1-1, APMS 6A x MTU II-124-41-1-1, APMS 6A x WGL 285, APMS 9A x MTU II 218-5-1, APMS 9A x MTU II-110-11-1-1-1-6, APMS 9A x MTU II-143-26-2, APMS 10A x MTU II-290-42-1, APMS 10A x MTU II-283-7-1-1, IR58025A x MTU II-190-1-1-1-1-1, IR58025A x MTU II-301-2-1 and IR 58025A x WGL 285 (Table 3). The best

Table 2. General combining ability effects of lines and testers for yield and yield component traits in rice (*Oryza sativa* L.)

CMS lines	Days to 50% flowering	Plant height (cm)	No. of ear bearing tillers per plant	Panicle length (cm)	No. of filled grains per panicle	Spikelet fertility (%)	Test weight (g)	Grain yield per plant (g)
APMS 6A	-4.61**	-2.06**	-0.44**	-0.63**	12.33**	0.26	-0.41**	1.15
APMS 9A	1.24**	3.65**	0.29	-0.22	13.59**	3.30**	-0.98**	2.13**
APMS 10A	1.82**	2.71**	0.68**	0.54**	-29.67**	-4.01**	1.24**	-0.27
IR58025A	1.55**	-4.31**	-0.53**	0.31*	3.75	0.45	0.14	-3.01**
S.E (lines)	0.28	0.75**	0.16	0.15	4.48	0.64	0.11	0.79
Restorer lines								
MTU 1071	5.21**	6.25**	0.18	2.14**	26.59**	2.50*	-0.62**	3.1*
MTU II 218-5-1	-4.66**	-7.68**	-0.46	-1.32**	-27.73**	0.19	0.13	-8.08**
MTU II-110-9-1-1-1-1	5.09**	4.95**	2.13**	1.46**	26.26**	3.09**	-1.19**	12.02**
MTU II-110-11-1-1-1-6	2.34**	-4.65**	-0.62*	-0.44	27.99**	3.19**	-0.08	-0.05
MTU II -187-6-1-1	4.84**	0.18	-0.10	-0.51	-28.56**	3.66**	1.71**	3.07*
MTU II-190-1-1-1-1-1	2.21**	8.80**	0.77*	0.71**	50.39**	2.54*	-1.52**	1.9
MTU II-143-26-2	-0.41	10.43**	1.15**	0.91**	20.39*	3.73**	0.27	9.05**
MTU II-124-41-1-1	-8.91**	-7.07**	-1.57**	-0.81**	-1.73	0.39	0.75**	-4.3**
MTU II-178-28-1-1-1	-2.79**	-1.15	-0.55	-0.48	-4.27	2.28	0.15	-1.85
MTU II-290-42-1	5.09**	-0.95	1.53**	-0.57*	-9.31	-0.12	1.7**	-0.05
MTU II-301-2-1	-9.79**	-13.25**	-1.7**	-1.49**	-93.71**	-20.43**	0.05	-15.18**
MTU II-283-7-1-1	3.46**	13.23**	0.45	1.08**	67.81**	5.47**	0.01	9.20**
WGL 285	-1.66**	-9.07**	-1.22**	-0.68*	-54.13**	-6.47**	-1.37**	-8.83**
S.E (testers)	0.51	1.35	0.30	0.27	8.08	1.16	0.20	1.42

Table 3. Hybrids showing *per se* performance, *sca* effect and standard heterosis for grain yield per plant

Hybrids	*Per se* performance	*sca* effect	Standard heterosis
APMS 6A x MTU 1071	42.40	0.85	30.46*
APMS 6A x MTU II 218-5-1	27.10	-3.28	-16.62
APMS 6A x MTU II-110-9-1-1-1-1	57.20	6.72*	76.00**
APMS 6A x MTU II-110-11-1-1-1-6	28.40	-10.00**	-12.62
APMS 6A x MTU II -187-6-1-1	46.00	4.47	41.54**
APMS 6A x MTU II-190-1-1-1-1-1	32.80	-7.55**	0.92
APMS 6A x MTU II-143-26-2	52.60	5.10	61.85**
APMS 6A x MTU II-124-41-1-1	41.00	6.85*	26.15*
APMS 6A x MTU II-178-28-1-1-1	39.80	3.20	22.46
APMS 6A x MTU II-290-42-1	36.00	-2.40	10.77
APMS 6A x MTU II-301-2-1	12.00	-11.28**	-63.08**
APMS 6A x MTU II-283-7-1-1	47.80	0.15	47.08**
APMS 6A x WGL 285	36.80	7.17*	13.23
APMS 9A x MTU 1071	46.20	3.67	42.15**

c o n t d .

Hybrids	*Per se* performance	*sca* effect	Standard heterosis
APMS 9A x MTU II 218-5-1	38.60	7.25*	18.77
APMS 9A x MTU II-110-9-1-1-1-1	54.60	3.15	68.00**
APMS 9A x MTU II-110-11-1-1-1-6	48.60	9.22**	49.54**
APMS 9A x MTU II -187-6-1-1	39.70	-2.80	22.15
APMS 9A x MTU II-190-1-1-1-1-1	33.20	-8.13**	2.15
APMS 9A x MTU II-143-26-2	59.40	10.92**	82.77**
APMS 9A x MTU II-124-41-1-1	30.60	-4.53	-5.85
APMS 9A x MTU II-178-28-1-1-1	33.20	-4.38	2.15
APMS 9A x MTU II-290-42-1	33.80	-5.58	4.00
APMS 9A x MTU II-301-2-1	25.20	0.95	-22.46
APMS 9A x MTU II-283-7-1-1	49.60	0.97	52.62**
APMS 9A x WGL 285	19.90	-10.70**	-38.77**
APMS 10A x MTU 1071	37.80	-2.33	16.31
APMS 10A x MTU II 218-5-1	31.80	2.85	-2.15
APMS 10A x MTU II-110-9-1-1-1-1	40.50	-8.55**	24.62
APMS 10A x MTU II-110-11-1-1-1-6	32.60	-4.38	0.31
APMS 10A x MTU II -187-6-1-1	39.80	-0.30	22.46
APMS 10A x MTU II-190-1-1-1-1-1	37.60	-1.33	15.69
APMS 10A x MTU II-143-26-2	44.60	-1.48	37.23**
APMS 10A x MTU II-124-41-1-1	29.20	-3.53	-10.15
APMS 10A x MTU II-178-28-1-1-1	36.40	1.22	12.00

c o n t d .

Hybrids	*Per se* performance	*sca* effect	Standard heterosis
APMS 10A x MTU II-290-42-1	49.80	12.82**	53.23**
APMS 10A x MTU II-301-2-1	26.50	4.65	-18.46
APMS 10A x MTU II-283-7-1-1	54.00	7.77**	66.15**
APMS 10A x WGL 285	20.80	-7.40*	-36.00**
IR58025A x MTU 1071	35.20	-2.19	8.31
IR58025A x MTU II 218-5-1	19.40	-6.82*	-40.31**
IR58025A x MTU II-110-9-1-1-1-1	45.00	-1.32	38.46**
IR58025A x MTU II-110-11-1-1-1-6	39.40	5.16	21.23
IR58025A x MTU II -187-6-1-1	36.00	-1.37	10.77
IR58025A x MTU II-190-1-1-1-1-1	53.20	17.01**	63.69**
IR58025A x MTU II-143-26-2	28.80	-14.54**	-11.38
IR58025A x MTU II-124-41-1-1	31.20	1.21	-4.00
IR58025A x MTU II-178-28-1-1-1	32.40	-0.04	-0.31
IR58025A x MTU II-290-42-1	29.40	-4.84	-9.54
IR58025A x MTU II-301-2-1	24.80	5.68*	-23.69
IR58025A x MTU II-283-7-1-1	34.60	-8.89**	6.46
IR58025A x WGL 285	36.40	10.93**	12.00

**significant at 1% level *significant at 5% level

combiners for each character was identified based on *per se* performance, significant positive *sca* effect and standard heterosis (Table 4).

Four heterotic combiners were identified as promising for grain yield based on *per se* and significant *sca* effects *viz.,*APMS 9A x MTU II-143-26-2 (High x High), APMS 6A x MTU II-110-9-1-1-1-1 (Low x High), APMS 10A x MTU II-283-7-1-1 (Low x High) and IR 58025A x MTU II-190-1-1-1-1-1 (Low x Low). The crosses between high × high general combiners revealed additive and additive × additive genetic component of variance where the characters could be easily improved through simple selection procedures in recombination breeding while the cross combinations involving low × high resulted in superior cross combinations due to complementary gene action with both additive and non-additive gene actions. The cross between two low combiners revealed the presence of non-additive interallelic interaction. Superiority of low × low cross combination was mainly due to nicking ability of their parents. Similar findings were observed by Dalvi and Patel (2009), Jayasudhan and Deepak Sharma (2009), Kumar Babu e*t al.* (2010), Bagheri and Babaeian (2010) and Saidaiah *et al.* (2010).

Table 4. The best heterotic hybrids identified for yield and yield components based on *per se* performance, significant positive *sca* effect and standard heterosis

Character	hybrids	Per se performance	sca effect	Standard heterosis
Days to 50% flowering	APMS 6A x MTU II 218-5-1	87.50	-4.69**	-20.81**
	APMS 6A x MTU II-124-41-1-1	90.00	-3.74**	-18.55**
	APMS 6A x WGL 285	90.50	-4.64**	-18.1**
	IR 58025A x MTU II-301-2-1	90.50	-2.67**	-18.1**
	IR 58025A x MTU II-124-41-1-1	91.00	-3.05**	-17.65**
Plant height (cm)	IR 58025A x MTU II-290-42-1	85.50	-17.27**	-16.09**
	APMS 6A x MTU II-110-11-1-1-1-6	88.50	-12.82**	-13.15**
	IR 58025A x MTU II-301-2-1	89.80	-0.67	-11.87**
	APMS 6A x WGL 285	91.00	-5.89	-10.7**
No. of ear bearing tillers per plant	APMS 10A x MTU II-290-42-1	15.1	2.49*	48.04**
Panicle length (cm)	APMS 10A x MTU 1071	32.02	1.75**	29.66**
	APMS 9A x MTU II-283-7-1-1	29.96	1.50**	21.32**
No. of filled grains per panicle	APMS 9A x MTU II-283-7-1-1	409.80	31.99**	31.64**
	APMS 6A x MTU II-190-1-1-1-1-1	400.20	41.07**	28.56**
	APMS 9A x MTU II-110-11-1-1-1-6	398.60	60.61**	28.04**
	IR 58025A x MTU II-190-1-1-1-1-1	398.50	47.95**	28.01**
Test weight (g)	APMS 10A x MTU II-290-42-1	23.01	1.79*	17.52**
	APMS 10A x MTU II-124-41-1-1	21.12	0.85*	7.89**
Grain yield per plant	APMS 9A x MTU II-143-26-2	59.40	10.92**	82.77**
	APMS 6A x MTU II-110-9-1-1-1-1	57.20	6.72*	76.00**
	APMS 10A x MTU II-283-7-1-1	54.00	7.77**	66.15**
	IR 58025A x MTU II-190-1-1-1-1-1	53.20	17.01**	63.69**

**significant at 1% level *significant at 5% level

Hence these four crosses *viz.,* APMS 9A x MTU II-143-26-2, APMS 6A x MTU II-110-9-1-1-1-1, APMS 10A x MTU II-283-7-1-1 and IR 58025A x MTU II-190-1-1- 1-1-1 can be exploited successfully in hybrid rice breeding programme.

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