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RESEARCH PAPER

Studies on heterosis and combining ability in rice (*Oryza sativa* L.)

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Abstract : Hybrid vigour and combining ability of two lines, 25 testers and their 50 hybrids was studied for grain yield, yield components and quality parameters during *Rabi* 2017-18. A perusal of the results revealed that the expression of heterosis was maximum over mid-parent for grain yield plant^{-1} and number of grains panicle^{-1} (>90%). Grain yield plant^{-1} and number of grains panicle^{-1} had also recorded high levels of heterosis over better parent (>70%). Standard heterosis more than 50 per cent was also recorded for grain yield plant^{-1} and number of grains panicle^{-1} over both varietal and the hybrid check. Further, combining ability analysis revealed pre-ponderant non-additive gene action for all the traits studied. A perusal of the GCA effects revealed MTU 2247-55-2, JMP 16, MTU 2336-70-46-25-44, MTU 2336-62-25-39-16, MTU 2337-216-1-1 and MTU 2331-216-1-1 to be good combiners for grain yield plant^{-1} and quality parameters. Analysis of the specific combining ability effects revealed none of the hybrids to possess consistently high SCA effects for all the characters and the best cross combination was observed to vary from character to character. Further, nine hybrids had recorded high *per se* performance, heterosis and desirable SCA effects for grain yield plant^{-1}. Among these three hybrids, APMS 8A x MTU 2247-55-2, APMS 8A x MTU 2331-216-1-1 and APMS 8A x MTU 2337-216-1-1 involving poor and good combiner parents for grain yield plant^{-1}, had recorded maximum grain yield plant^{-1}, in addition to desirable SCA effects and standard heterosis >50 per cent for grain yield plant^{-1}.

Key Words : Heterosis, Combining ability, Grain yield, Quality, Rice

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INTRODUCTION

Hybrid rice technology is considered one of the promising, practical, sustainable and eco-friendly options to break the yield ceiling witnessed in rice. India is the second country, after China to have commercially exploited heterosis in rice with the release and cultivation of hybrid rice varieties having yield advantage of 1-1.5 t/ha over the existing high yielding varieties. India has released 78 hybrid rice varieties for commercial cultivation. However, widespread use of these hybrids is restricted mainly due to lack of quality hybrids with good yield potential. Therefore, identification of parents with high yield and good quality in addition to good restoration and combining ability for yield and quality traits

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is essential for successful hybrid breeding programme.

Heterosis in rice was first reported by Jones (1926). Later on several workers had reported considerable heterosis for yield and other important economic characters. Further, combining ability study helps in deciding parents, hybrids and the appropriate breeding procedures to be followed for selection of desirable segregants. In this context, the present investigation was undertaken to identify the best combination of parents giving high degree of useful heterosis in addition to identification of parents with better potential to transmit desirable characteristics to the progenies and identify the best specific crosses for grain yield, yield components and quality characters studied. Analysis of quantitative inheritance was also an equally important objective to gain knowledge regarding the nature and magnitude of gene action, which has an important bearing on the choice of most appropriate and efficient breeding procedure.

MATERIAL AND METHODS

The experimental material comprised of two CMS lines namely, APMS 6A and APMS 8A; 25 testers namely, BPT 5204, RP 6112-MS-128-5-2-3-1-4-5, MTU 2244-128-18, MTU 2201-34-3-1, MTU 2049-5-2-1, MTU 2247-55-2, BPT 2659, JMP 16, MTU 1061, RM 168-28-1-1-1, MTU 2336-70-46-25-44, MTU 2347-158-3-1-1, MTU 2336-62-25-39-16, MTU 2284-103-1-7, HR L4, NLR 5815-10-1-1-1, UTR 51, NLR 3445, BPT 2782, MTU 2284-103-1-9, MTU 2345-98-3, MTU 2067-9-1-1-2, RM 138-80-3-1-1-1, MTU 2337-216-1-1 and MTU 2331-216-1-1 obtained from the germplasm collections maintained at Regional Agricultural Research Station, Maruteru, West Godavari district and their 50 hybrids derived from the 2 x 25 line x tester mating. The hybrids and parents were evaluated along with the hybrid check, Arize 6444 Gold and varietal check, MTU 1153 in a Randomized Block Design with two replications for grain yield, yield components and quality characters at Regional Agricultural Research Station, Maruteru.

The sowings were undertaken in nursery during the second fortnight of November 2017 and transplanting of the seedlings was affected 25 days after sowing, depending on growth of the seedlings. The normal, healthy and vigorous seedlings of each genotype were transplanted in a six-row plot of 4.5-meter length, with a spacing of 20 x 15 cm and the crop was raised following recommended package of practices. Data were recorded on five randomly selected plants in each replication for the characters, namely, plant height, ear bearing tillers plant^{-1}, panicle length, number of grains panicle^{-1}, spikelet fertility percentage and grain yield plant^{-1} for all the genotypes. However, days to 50 per cent flowering was recorded on plot basis, while observations on 1000-seed weight, L/B ratio, hulling percentage, milling percentage and head rice recovery percentage were obtained from a random grain sample drawn from each genotype in each replication. Heterosis over mid-parent, better parent, varietal check MTU 1153 and the hybrid check, Arize 6444 Gold were obtained for each hybrid and for each character, as per the procedures outlined by Liang *et al.* (1971) and their significance was tested using t-test suggested by Snedecor and Cochran (1967). The estimates of combining ability variances and effects were obtained using line x tester analysis, suggested by Kempthorne (1957).

RESULTS AND DISCUSSION

The range of relative heterosis, heterobeltiosis and standard heterosis recorded for the different traits studied are presented in Table 1. A perusal of these results revealed high levels of relative heterosis (136.57% and 96.98%), heterobeltiosis (104.26% and 79.09%) and standard heterosis (63.61% and 53.69%) for grain yield plant^{-1} followed by number of grains panicle^{-1}. Similar high levels of relative heterosis, heterobeltiosis and standard heterosis for grain yield plant^{-1} (Borah *et al.*, 2017) and number of grains panicle^{-1} (Devi *et al.*, 2014) were reported earlier. A perusal of the results also revealed several heterotic hybrids with significant and desirable heterosis for grain yield plant^{-1} and other yield attributes. Further, Virmani (1996) reported that 20 to 30 per cent standard heterosis is sufficient to offset the extra cost of hybrid seed. In the present investigation, the hybrids, APMS 8A x MTU 2247-55-2, APMS 8A x MTU 2331-216-1-1 and APMS 8A x MTU 2337-216-1-1 had recorded significant and positive standard heterosis more than 50 per cent over both the checks studied for grain yield plant^{-1} and hence, are identified as potential hybrids for commercial exploitation.

The expression of heterosis in terms of number of hybrids with significant and desirable heterosis (Table 1) was most evident for number of grains panicle^{-1}, followed by days to 50 per cent flowering and grain yield plant^{-1}. Thirty hybrids had recorded significant and positive heterosis over mid-parent, better parent and standard checks for number of grains panicle^{-1}. Of these, APMS 8A x MTU 2244-128-18 had recorded more than

40 per cent significant and desirable heterosis over mid-parent, better parent and standard checks. Further, 10 hybrids had recorded desirable and significant heterosis over mid-parent, better parent and the standard checks for days to 50 per cent flowering. Of these, APMS 6A x MTU 2336-70-46-25-44 and APMS 6A x MTU 2284-103-1-7 had recorded heterosis more than 10 per cent in the desired direction over mid-parent, better parent and the standard checks. For grain yield plant^{-1}, nine hybrids had recorded significant and positive heterosis over mid-parent, better parent and standard checks. Of these APMS 8A x MTU 2247-55-2 had recorded more than 50 per cent significant and desirable heterosis over mid-parent, better parent and the standard checks. The results are in broad conformity with the reports of Borah *et al.* (2017).

For plant height, only one hybrid APMS 8A x MTU 2049-5-2-1 had recorded more than 18 per cent significant and desirable heterosis over mid-parent, better parent and the standard varietal check. Similar lack of hybrids with significant and negative heterosis over standard hybrid check for plant height were reported earlier by Dar *et al.* (2015). Further, only one hybrid APMS 6A x BPT 5204 had recorded more than 30 per cent significant and desirable heterosis over mid-parent, better parent and the standard varietal check for ear bearing tillers plant^{-1}, while two hybrids, APMS 6A x JMP 16 and APMS 6A x MTU 2331-216-1-1 had recorded more than 15 per cent significant and desirable heterosis over mid-parent, better parent and the standard varietal check for panicle length. These findings are in broad agreement with the results reported by Haque *et al.* (2014).

Table 1 : Relative heterosis, heterobeltiosis and standard heterosis for grain yield, yield components and quality characters in rice

Character	Relative heterosis		Heterobeltiosis		Standard heterosis over MTU 1153		Standard heterosis over Arize 6444 Gold	
	Range	No. of desirable heterotic hybrids	Range	No. of desirable heterotic hybrids	Range	No. of desirable heterotic hybrids	Range	No. of desirable heterotic hybrids
Grain yield plant^{-1}	-44.33** to 136.57**	25	-56.32** to 104.26**	19	-45.45** to 116.51**	22	-58.78** to 63.61**	11
Days to 50% flowering	-17.02** to 8.03**	29	-21.24** to 1.48	40	-10.88** to 16.06**	10	-18.87** to 5.66**	31
Plant height	-18.03** to 8.95	2	-25.29** to 3.02	10	-18.05** to 0.36	21	-9.43 to 10.91	--
Ear bearing tillers plant^{-1}	-47.79** to 35.20**	2	-54.11** to 31.44**	1	-24.99 to 46.16**	8	-34.57** to 27.48*	4
Panicle length	-10.14* to 25.54**	24	-12.39* to 19.10**	10	-5.23 to 23.02**	14	-14.58** to 10.88	--
Number of grains panicle^{-1}	-1.18 to 96.98**	49	-21.02** to 79.09**	40	-20.20** to 85.93**	44	-34.03** to 53.69**	31
Spikelet fertility percentage	-43.81** to 20.19**	10	-44.56** to 8.61*	12	-51.34** to 1.48	--	-43.87** to 9.97*	5
1000-seed weight	-32.11** to 10.44	--	-40.06** to 6.63	--	-31.85** to 3.21	--	-31.39** to 3.90	--
L/B ratio	-17.38* to 19.56**	2	-18.09* to 19.34*	1	-11.89 to 23.40**	1	-21.38** to 10.10	--
Hulling (%)	-8.53* to 8.66**	1	-9.93* to 2.20	--	-7.13 to 5.49	--	-8.81* to 3.59	--
Milling (%)	-9.11* to 20.88**	4	-10.43* to 6.69	--	-6.21 to 8.46	--	-8.50 to 5.82	--
HRR (%)	-15.47** to 32.65**	19	-16.73** to 11.54*	1	-16.46** to 9.90	--	-13.61* to 13.65*	6

* and **indicate significane of values at P=0.05 and 0.01, respectively

However, only one hybrid APMS 8A x MTU 2337-216-1-1 had recorded more than eight per cent significant and desirable heterosis over mid-parent, better parent and the standard hybrid check for spikelet fertility percentage. Results of similar trend were reported earlier by Borah *et al.* (2017).

In the present study, none of the hybrids had exhibited significant and positive heterosis over mid-parent, better parent and standard checks for 1000-seed weight. Further, only one hybrid APMS 8A x RP 6112-MS-138-5-2-3-1-4-5 had recorded more than 15 per cent significant and desirable heterosis over mid-parent, better parent and the standard varietal check for L/B ratio. For hulling percentage, only one hybrid had exhibited significant and positive heterosis over mid-parent. However, for milling percentage, four hybrids had exhibited significant and positive heterosis over mid-parent. A perusal of these results for hulling and milling percentage studied in the present investigation revealed that none of the hybrids studied had significant and desirable heterobeltiosis and standard heterosis. Viraktamath (1987) also observed that there was no significant superiority of rice hybrids over better parent and standard parent regarding hulling and milling recovery. In contrast, the feasibility of developing heterotic rice hybrids for yield and head rice recovery were reported by Kumar (2004). In the present study also, significant and desirable relative heterosis, heterobeltiosis and standard heterosis over the hybrid check were recorded for APMS 6A x NLR 5815-10-1-1-1 for head rice recovery. The hybrid had also recorded significant and desirable relative heterosis (58.89%), heterobeltiosis (25.19%) and standard heterosis over the varietal check, MTU 1153 (21.38%) for grain yield plant^{-1} and hence, is identified as a potential high yielding hybrid with good head rice recovery and scope for commercial exploitation.

Analysis of variance for combining ability (Table 2) revealed significant mean sum of squares for parents, hybrids and parents vs. hybrids components of variation for all the characters studied, except hulling percentage for parents, plant height for hybrids and milling percentage for parents vs. hybrids component of variation. The results thus indicated the existence of significant differences among the parents and hybrids in addition to significant levels of heterosis for majority of the characters studied. Further, partitioning of the hybrids component of variation into lines, testers and line x testers also revealed significant mean squares for

Table 2: Combining ability ANOVA for grain yield, yield attributes and quality parameters in rice

Source of variation	d.f.	Days to 50% flowering	Plant height	Ear bearing tillers plant^{-1}	Panicle length	Number of grains panicle^{-1}	Spikelet fertility (%)	Grain yield plant^{-1}	1000-Seed weight	L/B ratio	Hulling (%)	Milling (%)	HRR (%)
Replications	1	71.59	389.17	0.91	0.34	271.62	2.72	0.02	0.48	0.07	1.45	0.77	2.65
Parents	26	60.34**	156.36**	11.32**	12.40**	5338.96**	145.49**	35.69**	9.16**	0.09*	9.94	57.15**	127.97**
Hybrids	49	104.77**	38.38	4.50**	6.44**	5557.09**	761.54**	182.85**	36.27**	0.61**	469.44**	361.72**	334.54**
Lines	1	49.00**	28.73	5.00	22.71**	8281.00**	35.64	85.19**	14.40*	0.04	0.01	2.84	2.28
Testers	24	44.79**	152.39**	11.63**	12.30**	4835.55**	147.63**	24.81**	6.42**	0.09*	8.82	60.14**	131.98**
Line x tester	24	77.94**	36.89	2.92**	3.05	3291.55**	636.48**	113.48**	31.85**	0.55**	452.17**	339.80**	318.04**
Parents vs hybrids	1	3704.27**	2025.44**	88.28**	281.52**	602360.38**	1699.92**	1932.52**	38.72**	0.31*	225.29**	0.82	1087.90**
Error	76	5.63	42.36	1.28	2.34	243.62	13.47	3.93	2.62	0.05	11.82	12.05	11.74
σ^2 GCA		2.28	-0.70	0.21	0.10	1264.51	23.21	4.68	0.78	0.01	9.39	8.96	8.69
σ^2SCA		35.68	-5.29	0.82	0.36	1524.01	311.61	54.80	14.64	0.25	220.27	163.97	153.25
σ^2 GCA/ σ^2 SCA		0.06	0.13	0.26	0.29	0.83	0.07	0.09	0.05	0.04	0.04	0.05	0.06

* and** indicate significance of values at P=0.05 and 0.01, respectively

grain yield plant^{-1}, days to 50 per cent flowering, number of grains panicle^{-1} and 1000-seed weight indicating the importance of both additive and non-additive gene actions. A perusal of the results on GCA:SCA variance ratio however, indicated pre-ponderant non-additive gene action for grain yield plant^{-1}, days to 50 per cent flowering, plant height, ear bearing tiller plant $^{-1}$, panicle length, spikelet fertility percentage and 1000-Seed weight (Madhuri *et al.*, 2017), number of grains panicle^{-1} (Sudeepthi *et al.*, 2017), L/B ratio, hulling percentage, milling percentage and head rice recovery percentage (Thakare *et al.*, 2013), similar to the reports of earlier workers. Non- additive gene action is also highly desirable in the present context for exploitation of heterosis, as lines used in the present investigation are cytoplasmic male sterile lines.

A perusal of the results on categorization of the parents based on *per se* performance and GCA effects

Table 3 : Characterization of parents based on per se performance and GCA effects for grain yield, yield attributes and quality characters

Line/Tester	Days to 50% flowering		Plant height		Ear bearing tillers plant-1		Panicle length		Number of grains panicle-1		Spikelet fertility (%)		Grain yield plant-1		1000-seed weight		L/B ratio		Hulling (%)		Milling (%)		HRR (%)	
	per se	GCA	per se	GCA	per se	GCA	per se	GCA	per se	GCA	per se	GCA	per se	GCA	per se	GCA	per se	GCA	per se	GCA	per se	GCA	per se	GCA
Lines																								
APMS 6A	H	L	H	L	L	L	L	L	L	L	H	H	L	L	L	L	H	L	L	L	L	L	L	L
APMS 8A	L	L	L	L	H	L	H	L	H	H	L	L	H	L	H	L	L	L	H	L	H	H	H	H
Testers																								
BPT 5204	L	L	H	L	L	H	L	L	L	H	H	H	L	H	L	L	H	L	H	L	H	L	H	L
RP6112-MS-128-5-2-3-1-4-5	L	L	H	L	H	L	L	L	L	L	H	H	H	L	L	L	H	H	H	L	H	L	H	L
MTU 2244-128-18	L	L	H	L	H	L	H	L	H	H	L	H	L	L	L	L	L	L	H	L	H	L	H	L
MTU 2201-34-3-1	L	L	H	L	H	L	L	L	L	H	H	L	H	L	H	L	H	L	H	L	L	L	L	L
MTU 2049-5-2-1	L	L	L	L	L	L	H	L	L	L	L	L	L	L	H	L	L	L	H	L	H	L	H	L
MTU 2247-55-2	L	L	H	L	H	H	L	H	L	L	H	H	H	H	H	H	L	L	L	H	L	L	L	L
BPT 2659	L	L	L	L	H	L	H	L	H	L	L	H	L	H	H	H	L	L	H	H	H	H	H	H
JMP 16	H	H	L	L	L	L	H	H	H	H	L	H	H	H	L	H	L	L	H	H	H	H	H	H
MTU 1061	L	L	L	L	H	H	H	L	L	L	H	L	H	L	L	L	L	L	L	L	L	L	H	L
RM 168-28-1-1-1	H	H	L	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	L	L	L	H	L	L
MTU 2336-70-46-25-44	H	H	L	L	H	L	L	L	L	L	H	H	H	H	H	H	H	L	H	H	H	H	H	L
MTU 2347-158-3-1-1	L	L	L	L	H	H	H	L	H	L	L	L	L	L	H	L	L	L	L	L	L	L	L	L
MTU 2336-62-25-39-16	L	H	L	L	L	L	H	L	H	H	H	H	H	H	H	L	H	L	L	L	L	L	L	L
MTU 2284-103-1-7	H	H	H	L	L	L	H	L	H	H	L	L	H	L	L	L	H	L	H	H	H	H	H	H
HR L4	L	L	L	L	H	L	H	L	H	H	H	L	L	L	L	H	L	L	H	L	H	L	H	L
NLR 5815-10-1-1-1	H	H	H	L	L	L	L	L	L	L	H	L	L	L	H	L	H	L	H	H	L	H	L	H
UTR 51	H	L	H	L	L	L	L	L	L	L	H	L	L	L	L	L	H	L	H	H	H	L	L	L
NLR 3445	H	H	H	L	L	L	L	L	L	L	H	H	L	H	L	L	H	L	L	H	L	H	H	H
BPT 2782	H	L	H	L	L	L	H	L	L	H	L	H	L	L	H	L	L	L	H	L	H	L	H	H
MTU 2284-103-1-9	L	H	L	L	L	L	L	L	L	H	L	L	L	L	L	H	H	L	L	L	H	L	H	L
MTU 2345-98-3	H	L	L	L	H	L	H	H	L	H	L	H	H	L	L	H	H	L	L	L	L	H	L	H
MTU 2067-9-1-1-2	H	H	L	L	L	L	H	L	L	L	L	H	L	H	H	H	L	L	H	H	H	H	H	H
RM 138-80-3-1-1-1	H	H	L	L	H	L	H	H	H	L	L	L	H	L	H	H	H	H	L	L	L	L	L	L
MTU 2337-216-1-1	L	L	H	L	H	L	H	H	H	H	L	H	H	H	L	H	L	H	L	H	H	H	H	H
MTU 2331-216-1-1	L	L	L	L	H	H	H	H	H	H	L	H	H	H	H	H	H	H	H	H	L	H	H	H

is presented in Table 3. The results revealed the absence of association between *per se* performance and GCA effects of the parents for grain yield and yield components and quality characters. Similar results were reported by earlier workers (Satheeshkumar *et al.*, 2016). The results revealed APMS 8A to be a good combiner with high *per se* performance for number of grains panicle^{-1}, milling percentage and head rice recovery percentage and hence, may be utilized in hybrid breeding programmes. It had also resulted in the best yielding and heterotic hybrids identified in the present investigation, namely, APMS 8A x MTU 2247-55-2, APMS 8A x MTU 2331-216-1-1 and APMS 8A x MTU 2337-216-1-1. Further, the testers, MTU 2247-55-2, JMP 16, MTU 2336-70-46-25-44, MTU 2336-62-25-39-16, MTU 2337-216-1-1 and MTU 2331-216-1-1 had recorded high *per se* performance and desirable GCA effects for grain yield plant^{-1}. Among these, JMP 16, MTU 2336-70-46-25-44, MTU 2337-216-1-1 and MTU 2331-216-1-1 had also recorded high *per se* performance and desirable GCA effects for few yield attributes and quality characters studied indicating their importance in hybrid breeding programmes.

Table 4 : Specific combining ability of rice hybrids for grain yield, yield attributes and quality parameters

Character	Number of hybrids with significant and desirable SCA effects	Best hybrid combination
Grain yield plant^{-1}	13	APMS 8A x MTU 2337-216-1-1
Days to 50 per cent flowering	8	APMS 6A x MTU 2347-158-3-1-1
Plant height	--	--
Ear bearing tillers plant^{-1}	2	APMS 8A x MTU 2337-216-1-1
Panicle length	--	--
Number of grains panicle^{-1}	12	APMS 8A x MTU 2049-5-2-1
Spikelet fertility percentage	9	APMS 6A x MTU 2049-5-2-1
1000-seed weight	3	APMS 6A x MTU 2049-5-2-1
L/B ratio	2	APMS 6A x MTU 2049-5-2-1
Hulling (%)	2	APMS 6A x MTU 2049-5-2-1
Milling (%)	2	APMS 6A x MTU 2049-5-2-1
HRR (%)	3	APMS 8A x HR L4

Table 5 : Best heterotic combinations identified for grain yield based on *per se* performance, *sca* effect and heterosis

Cross combination	*Per se* performance	SCA effect	Characterization of parents with respect to GCA effect	Relative heterosis	Better parent heterosis	Standard heterosis		Desirable SCA effects observed for
						MTU 1153	Arize 6444 gold	
APMS 8A x MTU 2247-55-2	44.06	10.35**	Low x High	97.53**	52.14**	116.51**	63.61**	Days to 50% flowering, spikelet fertility percentage
APMS 8A x MTU 2331-216-1-1	42.83	4.29**	Low x High	94.42**	47.89**	110.47**	59.04**	--
APMS 8A x MTU 2337-216-1-1	41.13	13.06**	Low x High	68.47**	38.57**	102.11**	52.73**	Ear bearing tillers plant^{-1}, number of grains panicle^{-1}
APMS 6A x BPT 2659	39.30	4.75**	Low x High	136.57**	104.26**	98.03**	49.65**	Ear bearing tillers plant^{-1}
APMS 8A x MTU 2067-9-1-1-2	38.05	4.55**	Low x High	74.82**	31.39**	86.98**	41.29**	--
APMS 6A x JMP 16	37.95	2.83**	Low x High	100.42**	92.35**	86.49**	40.92**	--
APMS 8A x NLR 3445	34.92	3.39**	Low x High	68.45**	20.58**	71.60**	29.67**	--
APMS 6A x MTU 2336-62-25-39-16	33.35	7.02**	Low x High	84.10**	69.03**	63.88**	23.84**	Spikelet fertility percentage
APMS 6A x MTU 2336-70-46-25-44	31.35	4.80**	Low x High	49.89**	41.86**	54.05**	16.41*	--

* and**indicate significance of values at P=0.05 and 0.01, respectively

A study on the specific combining ability effects for grain yield, yield components and the quality traits also revealed significant and desirable SCA effects for several hybrids studied in the present investigation (Table 4). However, out of the 50 hybrids studied, none had exhibited consistently high SCA effects for all the characters and the best cross combination was observed to vary from character to character. Similar, results were reported earlier (Kumar, 2004). Further, nine hybrids (APMS 8A x MTU 2247-55-2, APMS 8A x MTU 2331-216-1-1, APMS 8A x MTU 2337-216-1-1, APMS 6A x BPT 2659, APMS 8A x MTU 2067-9-1-1-2, APMS 6A x JMP 16, APMS 8A x NLR 3445, APMS 6A x MTU 2336-62-25-39-16 and APMS 6A x MTU 2336-70-46-25-44) had recorded high *per se* performance, heterosis and desirable SCA effects for grain yield plant^{-1} (Table 5). A characterization of the parents of these hybrids with respect to their GCA effects revealed low and high GCA parents. Similar production of superior hybrids involving low and high GCA parents were reported earlier (Annadurai and Nadarajan, 2001). The production of superior hybrids from parents with low and high GCA effects was attributed to the favourable effect of additive x non-additive or dominance x recessive gene interactions (Kumar, 2004).

A perusal of the results on *per se* performance, heterosis and specific combining ability revealed the superiority of APMS 8A x MTU 2247-55-2 hybrid, which had recorded maximum grain yield plant^{1} (44.06 g), more than 50 per cent heterosis over mid-parent, better parent and the standard checks studied, in addition to desirable SCA effects for days to 50 per cent flowering and spikelet fertility percentage. Further, the hybrids, APMS 8A x MTU 2331-216-1-1 and APMS 8A x MTU 2337-216-1-1 had also recorded high grain yield plant^{-1} (>40.0 g) and standard heterosis (>50%) in addition to desirable SCA effects. Hence, these hybrids are identified as potential and high yielding heterotic hybrids.

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