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Research Article

Combining ability and heterosis studies for grain yield and its components in hybrid rice (*Oryza sativa* L.)

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Abstract
The study was conducted to know the nature of gene action and level of heterosis in rice hybrids. Analysis of variance revealed the prevalence of non-additive gene action for the traits studied except for days to 50% flowering. The CMS lines IR-79156A and IR-58025A and testers WGL-3962, RNR-15038 and RNR-2781 were best combiners for most important yield contributing traits, like number of productive tillers per plant, number of filled grains per panicle and grain yield per plant by exhibiting positive *gca* effects. The hybrids, IR-58025A x RNR-15038, IR-79156A x NWGR-3132, IR-58025A x RNR-2781, IR-79156A x RNR-2781 and APMS-6A x RNR-15038 were considered as potential cross combinations for grain yield and its attributes based on *per se* performance, *sca* effects, *gca* effects of parents and standard heterosis. These hybrids could be further evaluated in multi locational trials for commercial use.

Key words
Hybrid rice, combining ability, heterosis, grain yield

Introduction

Rice is one of the staple food crops for about 65% of the world's population. The present world rice area, production and productivity are 161.6 mha, 480.7 mt and 2.9 tons per ha, respectively (USDA, Rice Outlook, 2015). In India, rice is grown in 44.0 mha with the production of 106.0 mt and productivity of 2.4 tons per ha. The productivity of rice has stagnated. Hybrid rice technology exploits the phenomenon of hybrid vigour to increase the yield potential of rice varieties by 15-25% over current commercial cultivars (Hwa and Yang, 2008). The commercial success of hybrid rice in China has clearly demonstrated the potential of this technology where, at present, hybrid rice is planted in 15.5 m ha. To sustain rice cultivation and to increase the productivity in the country we need to use this technology successfully to exploit the heterosis (Viraktamath *et al.*, 2006). In view of this the present study was undertaken to assess the type of gene action and level of heterosis in rice hybrids to identify best hybrid combinations for commercial utilization.

Material and Methods

The material for the present study comprising of 79 genotypes (5 'B' lines of corresponding male sterile lines, 12 restorer lines, 60 hybrids and two checks viz., KRH-2 (hybrid check) and MTU 1010 (varietal check) were evaluated during *kharif*, 2014 at Agricultural Research Station, PJTSAU, Kampasagar (Latitude 16° 52¹ 0 N and Longitude 79° 34¹ 60 E) for Southern Telangana Agro-climatic Zone of Telanagana State, India. The trial was laid out in randomized block design with three replications. Thirty days old seedlings were transplanted in a row of 4.0 m length with a spacing of 20 x15 cm. Recommended package of practices were followed to raise the healthy crop. The data recorded on five randomly selected plants from each replication for various quantitative traits *viz*., days to 50% flowering, plant height (cm), number of productive tillers per plant, panicle length (cm), number of filled grains per panicle, spikelet fertility (%), 1000 grain weight (g) and grain yield per plant (g). Mean data was subjected to line x tester analysis as per Kempthorne (1957). Standard heterosis over the best check MTU-1010 was estimated as per Liang *et al.* (1971) and expressed in percentage.

Results and Discussion

Analysis of variance for combining ability revealed the presence of significant differences for crosses and line x tester effect for the characters studied (Table-1). The line effect was significant for days to 50% flowering, number of productive tillers per plant, panicle length, spikelet fertility (%) and 1000 grain weight while tester effect showed significant differences for all the traits studied except for number of productive tillers per plant and panicle length. This reveals the existence of wide variability in the material under study and there is a scope for identifying promising parents and hybrid combinations. Variance of specific combining ability was higher than the general combining ability variance for the traits studied except for days to 50% flowering. This indicated the predominance of non-additive gene action in controlling these

traits. Bineeta Devi and Lal (2015), Upadhyay and Jaiswal (2015), Satheesh Kumar *et al* (2016) and Archana Devi *et al* (2017) also reported role of non-additive gene action for grain yield and its component traits.

Estimates of *gca* effects for lines and tester were presented in Table-2. The lines, IR-80555A and IR-68897A were found to be early in flowering which recorded significant negative *gca* effects. Upadhyay and Jaiswal (2015) also reported that the line IR-68897A was the best general combiner for earliness. For the traits number of productive tillers per plant, panicle length and grain yield per plant the line IR-58025A had favorable genes. The line IR-79156A showed significantly superior *gca* effect for plant height, number of productive tillers per plant, number of filled grains per panicle and grain yield per plant. Shivam and Harish (2013) also reported that the lines IR-79156A and IR-58025A were found to be good combiners for grain yield per plant. The testers, RNR-15351, D-4098 and RNR-15028 were observed to be good combiners for development of early duration hybrids with dwarf plant type. The testers WGL-3962, RNR-2781, RNR-15038, were recorded as best general combiners for majority of the yield contributing traits such as number of productive tillers per plant, panicle length, number of filled grains per panicle, spikelet fertility (%), 1000 grain weight and grain yield per plant.

Among the 60 hybrids studied, five and fourteen hybrids showed significant negative specific combining ability for days to 50% flowering and plant height respectively (Table-3). Number of productive tillers per plant is one of the important characters contributing to the grain yield in hybrids. The hybrids, IR-79156A x NWGR-3132, APMS-6A x WGL-3962, IR-68897A x RNR-2456, IR-58025A x RNR-15028, IR-79156A x RNR-2781 and IR-58025A x RNR-15351 were proved to be good specific combiners for this trait. Earlier researchers, Salgotra *et al*. (2009) and Padmavathi *et al*. (2012) also noticed significant positive *sca* effect for this character. Twenty-one hybrids manifested significant positive specific combining ability effects for number of filled grains per panicle among them the most promising hybrids were IR-68897A x WGL-3962, IR-58025A x RNR-15398, IR-68897A x IR-83142-B-57-B and IR-80555A x RNR-2458. Sen and Singh (2011) and Priyanka *et al*. (2014) recorded high *sca* effects in their studies. The hybrid APMS-6A x RNR-2458 was found to be promising for spikelet fertility (%). Twenty hybrids expressed superior *sca* effects for grain yield per plant and the hybrids, IR-79156A x NWGR-3132, IR-58025A x RNR-15038 and APMS-6A x RNR-2781 were found to be promising. Significant positive *sca* effects for grain yield also reported by Priyanka *et al*. (2014).

The significant negative standard heterosis was observed in three hybrids, IR-68897A x IR-83142-B-57-B, IR-80555A x D-4098 and IR-80555A x IR-83142-B-57-B for days to 50% flowering while only one hybrid IR-80555A x RNR-2456 (-11.26%) manifested significant negative standard heterosis over the check for the trait plant height (Table 4). Early maturity combined with short stature is considered as important traits to fit in multiple cropping systems and to withstand lodging. The range of heterosis for number of productive tillers per plant was observed from -31.36 (APMS-6A xRNR-2456) to 59.09 % (IR-79156A x NWGR-3132). Tiwari *et al.* (2011) and Sharma *et al.* (2013) reported both positive and negative standard heterosis in their studies as in the case of present study. For panicle length, 32 hybrids exhibited significant positive standard heterosis and the hybrids *viz*., IR-58025A x RNR-15038, IR-58025A x RNR-2781 and IR-79156A x RNR-2781 showed high level of heterosis. The significant positive standard heterosis was recorded in 44 hybrids for number of filled grains per panicle. Only one hybrid, APMS-6A x RNR-15038 (6.23 %) exhibited significant superiority over the check for spikelet fertility percentage. Twenty-one hybrids showed significant positive standard heterosis over the check ranged from 17.77 (IR-80555A x RNR-15028) to 90.22 per cent (IR-79156A x NWGR-3132) for grain yield per plant. The hybrids IR-79156A x NWGR-3132, IR-58025A x RNR-15038, APMS6A x RNR-2781 and IR-58025A x RNR-2781 were found to be most promising. Positive heterosis for this trait was also reported by Gouri Shankar *et al.* (2010) and Padmavathi *et al.* (2013) in their studies.

Identification of top ranking hybrids based on *per se* performance, *sca* effects, *gca* effects of parents and standard heterosis for grain yield and its components is very important (Table 5). Based on *per se* performance, *sca* effects, *gca* effects of parents and standard heterosis the hybrids IR-58025A x RNR-15038, IR-79156A x NWGR-3132, IR-58025A x RNR-2781, IR-79156A x RNR-2781 and APMS-6A x RNR-15038 were identified as best specific cross combinations for grain yield per plant. Also these crosses were found to be promising for number of productive tillers per plant, panicle length, number of filled grains per panicle and 1000 grain weight. It indicates that these yield attributes played greater role in expression of higher degree of heterosis for grain yield per plant. The parents involved in these cross combinations exhibited high x high or medium x high *gca* effects for grain yield and its component

traits. Priyanka *et al*. (2014) also reported significant positive *sca* effects for grain yield from high x high gca status. Shivam and Harish (2013) also observed that the crosses involving lines with IR-79156A, IR-58025A and APMS-6A found to be superior for grain yield per plant. The potentiality of these hybrid combinations should be further evaluated in multilocation trials for commercial cultivation.

From the study it was observed that the lines, IR-58025A and IR-79156A were proved to be superior general combiners for grain yield and its components. The testers WGL-3962, RNR-2781, RNR-15038, NWGR-3132 and RNR-15028 were recorded superior *gca* effects for majority of the yield contributing traits. These lines and testers could be considered as potential donors in improving grain yield per plant and associated components in future breeding programme. Based on *per se* performance, *sca* effects, *gca* effects of parents and standard heterosis the hybrids IR-58025A x RNR-15038, IR-79156A x NWGR-3132, IR-58025A x RNR-2781, IR-79156A x RNR-2781 and APMS-6A x RNR-15038 were identified as best specific cross combinations for grain yield per plant and most of its component traits. These hybrids could be further evaluated in multi locational trials for commercial use.

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Table 1. Analysis of variance for combining ability for yield and its components in rice

Source	df	Days to 50% flowering	Plant height (cm)	No. of productive tillers / plant	Panicle length (cm)	No. of filled grains / panicle	Spikelet fertility (%)	1000 grain weight (g)	Grain yield / plant (g)
Replications	2	24.06	0.88	0.51	21.26**	414.17**	6.58	1.32*	4.19
Crosses	59	61.25**	244.64**	9.58**	11.74**	3715.85**	29.67**	23.58**	189.72**
Line effect	4	188.04**	177.14	25.04*	42.12**	4583.74	50.88*	29.98*	247.72
Tester effect	11	180.60**	494.63*	10.01	12.46	10248.41**	69.83**	82.03**	515.03**
L x T effect	44	19.88**	188.28**	8.07**	8.80**	2003.82**	17.70**	8.39**	103.12**
Error	118	8.39	9.47	1.75	1.73	78.59	5.53	0.28	5.81
Total	179	25.99	86.88	4.325	5.251	1281.218	13.504	7.97	66.41
GCA		27.704	51.280	2.498	4.016	1151.414	8.498	8.743	58.961
SCA		16.235	239.085	8.631	9.479	2570.676	15.368	10.826	130.169
GCA/SCA		1.706	0.214	0.289	0.424	0.448	0.553	0.808	0.453

*Significant at 5 % level, ** Significant at 1 %

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Table 2. Estimation of general combining ability effects for grain yield and its components in rice

Parent / Cross	Days to 50% flowering	Plant height (cm)	No. of productive tillers / plant	Panicle length (cm)	No. of filled grains / panicle	Spikelet fertility (%)	1000 grain weight (g)	Grain yield / plant (g)
LINES								
IR-58025 A	-0.84	1.83**	0.90**	1.43**	1.07	-1.01*	0.06	3.29**
IR-79156 A	4.38**	-1.45*	0.52*	-0.09	12.44**	0.47	0.11	2.15**
IR-80555 A	-1.86**	-0.60	-1.36**	-1.35**	-8.56**	-1.39**	0.92**	-1.84**
IR-68897 A	-2.74**	-2.52**	0.02	-0.15	-14.05**	1.90**	0.97**	-3.33**
APMS-6A	1.06*	2.74**	-0.08	0.16	9.09**	0.02	-2.05**	-0.28
SE (Lines)	**0.46**	**0.49**	**0.21**	**0.22**	**1.45**	**0.41**	**0.09**	**0.39**
TESTERS								
RNR-15351	-1.85*	-5.79**	-0.06	-0.28	-6.72**	-1.85**	-2.57**	-5.59**
WGL-3962	0.22	2.16**	0.81*	0.77*	9.09**	2.18**	1.19**	3.17**
IR-83142-B-57-B	-5.72**	1.58*	-0.65*	-0.29	-41.01**	-0.87	4.12**	-6.68**
RNR-15398	0.35	6.39**	-1.18**	0.50	-14.14**	-1.83**	-1.89**	-4.85**
D-4098	-1.78*	-9.88**	-0.35	-2.09**	-47.81**	-0.39	3.43**	-6.77**
NWGR-3132	1.15	-0.49	0.29	1.013**	16.59**	-0.77	0.56**	2.14**
RNR-15028	-2.85**	-4.89**	-0.85 *	-1.29**	4.76*	2.22**	-0.45**	1.11
RNR-15038	-0.15	2.58*	1.18**	1.39**	37.63**	4.08**	0.29*	8.39**
RNR-2458	4.22**	2.39*	-0.60	-0.69*	-5.37*	-2.09**	-4.23**	-4.17**
RNR-2456	5.12**	3.32**	0.61	-0.58	9.47**	-0.83	-2.53**	1.92**
RNR-17462	2.55**	9.46**	-0.46	-0.20	0.26	-2.33**	-0.08	0.14
RNR-2781	-1.25	-6.83**	1.27**	1.74**	37.25**	2.47**	2.16**	11.19**
SE (Testers)	**0.72**	**0.77**	**0.33**	**0.34**	**2.25**	**0.64**	**0.13**	**0.61**

* Significant at 5 % level, ** significant at 1 % level

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Table 3. Estimation of specific combining ability effects for grain yield and its components in rice

Crosses	Days to 50% flowering	Plant height (cm)	No. of productive tillers / plant	Panicle length (cm)	No. of filled grains / panicle	Spikelet fertility (%)	1000 grain weight (g)	Grain yield / plant (g)
IR-58025A x RNR-15351	2.24	-1.68	1.77*	0.96	-39.83**	0.08	1.11**	-3.42*
IR-58025A x WGL-3962	1.17	-2.36	-0.01	-1.64*	2.95	1.56	1.02**	-0.01
IR-58025A x IR-83142-B-57-B	3.77*	6.59**	-0.06	0.04	-20.39**	-1.23	0.18	-4.36**
IR-58025A x RNR-15398	0.04	4.18*	0.89	0.55	37.89**	1.00	-0.50	5.69**
IR-58025A x D-4098	0.51	-1.80	-1.84*	0.36	-12.82*	0.44	-0.72*	-2.19
IR-58025A x NWGR-3132	0.57	-0.64	-1.73*	-0.89	-7.07	-0.68	0.61*	-7.21**
IR-58025A x RNR-15028	1.91	19.69**	2.41**	1.57*	23.62**	1.74	-0.70*	6.26**
IR-58025A x RNR-15038	-4.23*	-2.62	1.22	0.48	29.18**	2.80*	1.41**	9.03**
IR-58025A x RNR-2458	-1.16	-9.48**	-0.79	1.51*	-15.63**	-2.20	-0.51	-1.91
IR 58025 A x RNR-2456	-0.29	0.55	-1.10	-2.21**	-4.64	1.00	-0.43	-0.96
IR-58025A x RNR-17462	-1.83	2.05	0.16	-0.92	13.12*	0.11	0.51	2.00
IR-58025A x RNR-2781	-3.69*	-3.38	1.33	1.43	12.24*	1.19	0.38	4.67**
IR-79156 A x RNR-15351	-3.18 *	-1.13	-1.89*	-2.35*	4.06	1.15	-2.40**	-2.46
IR-79156 A x WGL-3962	-2.91	-0.01	-2.36**	0.63	-35.26**	2.09	-0.19	-5.94**
IR-79156 A x IR-83142-B-57-B	7.02**	-1.82	-1.39	-2.13**	-13.03*	-7.76**	-0.48	-10.43**
IR-79156 A x RNR-15398	-2.38	-3.41	-1.18	-3.17**	-25.43**	-2.24	-0.03	-2.87*
IR-79156 A x D-4098	1.42	3.89*	-0.18	-1.52*	29.90**	-0.39	-7.39**	1.92
IR-79156 A x NWGR-3132	-1.84	-3.82*	3.99**	2.28**	21.57*	1.04	0.82**	14.83**
IR-79156 A x RNR-15028	-0.18	-1.75	-1.14	-0.43	-0.96	1.27	0.24	-6.64**
IR-79156 A x RNR-15038	-1.64	-0.34	1.04	1.63*	26.75**	-0.28	0.82**	5.30**
IR-79156 A x RNR-2458	1.09	-8.54**	-1.95**	-1.60*	-30.76**	-0.28	1.23**	-3.21 *
IR-79156 A x RNR-2456	2.29	6.18**	1.07	2.28**	12.60*	-2.13	0.51	3.58**
IR-79156 A x RNR-17462	2.76	8.70 **	1.29	1.66*	26.43**	1.75	1.03**	3.79**
IR-79156 A x RNR-2781	-1.34	6.48**	2.03**	2.49**	3.37	3.73*	0.48	5.00**

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Table 3. Contd.,

Crosses	Days to 50% flowering	Plant height (cm)	No. of productive tillers / plant	Panicle length (cm)	No. of filled grains / panicle	Spikelet fertility (%)	1000 grain weight (g)	Grain yield / plant (g)
IR-80555 A x RNR-15351	-1.44	0.79	0.44	-1.73*	1.64	-2.79	0.97**	2.46
IR-80555 A x WGL-3962	-2.08	4.72**	-1.47*	1.04	12.86*	-3.26*	-0.79**	2.85*
IR-80555 A x IR-83142-B-57-B	-0.48	-9.53**	1.19	3.24**	-11.98*	0.02	0.46	5.85**
IR-80555 A x RNR-15398	0.79	-9.05**	-0.37	0.51	-7.38	-1.56	-0.57	-2.28
IR-80555 A x D-4098	-1.08	0.77	0.29	-0.01	-8.41	0.62	1.44**	2.75*
IR-80555 A x NWGR-3132	0.32	-7.33**	-0.07	-1.88*	2.31	2.69	0.92**	-0.82
IR-80555 A x RNR-15028	-2.01	-6.27**	-0.13	1.45	11.82*	2.23	1.06**	3.11*
IR-80555 A x RNR-15038	1.52	-0.76	0.04	-1.29	-21.29**	-2.17	-1.01**	-8.23**
IR-80555 A x RNR-2458	3.26*	21.15**	1.36	1.38	33.99**	-1.74	-6.15**	3.06*
IR-80555 A x RNR-2456	1.46	-10.87**	-0.01	-0.62	-27.25**	-1.17	-0.09	-7.31**
IR-80555 A x RNR-17462	0.26	2.81	-0.11	-3.18**	-11.63*	0.35	0.81**	1.35
IR-80555 A x RNR-2781	-0.61	-1.96	-2.75**	0.08	7.42	3.01*	2.95**	-5.25**
IR-68897 A x RNR-15351	1.54	4.21*	-1.87*	-0.66	28.39**	0.44	0.74 *	4.56**
IR-68897 A x WGL-3962	2.81	2.33	0.57	0.91	22.43**	0.69	-1.23**	3.56**
IR-68897 A x IR-83142-B-57-B	-0.26	-1.35	-0.38	0.41	35.45**	3.98**	-1.69**	2.00
IR-68897 A x RNR-15398	3.68*	-4.37*	0.69	0.96	15.87**	2.72	1.89**	1.87
IR-68897 A x D-4098	1.14	-0.23	1.07	0.49	-3.34	1.08	-0.83**	-3.04*
IR-68897 A x NWGR-3132	-2.46	-8.84**	-1.69*	0.01	-8.34	0.27	-1.36**	-5.48**
IR-68897 A x RNR-15028	0.54	-1.03	-0.62	-0.65	-56.44**	-5.40**	0.17	-7.68**
IR-68897 A x RNR-15038	-3.26*	-6.81**	-2.32**	-2.46**	-25.82**	-0.34	1.44**	-7.47**
IR-68897 A x RNR-2458	-2.52	-2.10	0.78	0.90	-37.87**	-4.44**	0.39	-2.79*
IR-68897 A x RNR-2456	-4.66*	4.14*	2.54**	0.51	22.54**	1.35	1.67**	7.69**
IR-68897 A x RNR-17462	2.14	12.57**	-0.13	1.16	-17.48**	-1.38	-0.93**	-1.72
IR-68897 A x RNR-2781	1.28	1.49	1.36	-1.57*	4.61	1.03	-0.27	0.51
APMS-6A x RNR-15351	0.74	-2.19	-0.04	2.54**	5.74	1.13	-0.41	-1.14
APMS-6A x WGL-3962	1.01	-4.67**	3.28**	-0.95	-22.99**	-4.87**	1.19**	-8.45**

Table 3. Contd.,

Crosses	Days to 50% flowering	Plant height (cm)	No. of productive tillers / plant	Panicle length (cm)	No. of filled grains / panicle	Spikelet fertility (%)	1000 grain weight (g)	Grain yield / plant (g)
APMS-6A x IR-83142-B-57-B	-1.06	6.13**	0.47	-1.55*	9.95	-0.83	1.54**	2.35
APMS-6A x RNR-15398	-2.13	10.93**	-0.03	0.15	-20.95**	0.08	-0.79**	-2.41
APMS-6A x D-4098	-1.99	-2.63	-0.74	0.68	-13.98**	-1.75	0.84**	0.56
APMS-6A x NWGR-3132	3.41*	6.82**	-0.52	0.48	1.52	-3.32*	-0.99**	-1.79
APMS-6A x RNR-15028	-0.26	-10.65**	-0.51	-1.93*	21.95**	0.16	-0.76*	4.96**
APMS-6A x RNR-15038	-0.39	10.53**	1.41	2.33**	1.17	4.17**	0.54	4.37**
APMS-6A x RNR-2458	-0.66	-1.03	0.61	-2.19**	12.86*	4.49**	1.40**	4.85**
APMS-6A x RNR-2456	1.21	-0.01	-2.50**	-0.66	-3.25	0.94	-1.67**	-3.01*
APMS-6A x RNR-17462	3.47*	-15.0**	-1.22	-0.97	-10.44*	-0.83	-1.52**	-7.58**
APMS-6A x RNR-2781	-3.33*	1.79	-0.21	2.06**	18.43**	0.63	0.62	7.28**
SE (Sij - Skl)	2.26	2.44	1.03	1.06	7.10	2.03	0.42	1.91
SE (Sij – Sik)	1.60	1.73	0.73	0.75	5.03	1.47	0.30	1.35

* Significant at 5 % level, ** significant at 1 % level

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Table 4. Estimation of standard heterosis (over MTU 1010) for yield and its components in rice

Crosses	Days to 50% flowering	Plant height (cm)	No. of productive tillers / plant	Panicle length (cm)	No. of filled grains / panicle	Spikelet fertility (%)	1000 grain weight (g)	Grain yield / plant (g)
IR-58025A x RNR-15351	6.55**	3.83	38.07**	20.24**	-7.18	-5.24*	-24.32**	-17.25*
IR-58025A x WGL-3962	7.59**	12.49**	27.42*	12.67*	36.86**	1.06	-9.09**	35.43**
IR-58025A x IR-83142-B-57-B	-4.14	22.45**	9.47	15.66**	-18.34**	-5.61*	-0.42	-26.00**
IR-58025A x RNR-15398	6.55**	25.32**	14.40	22.03**	45.66**	-4.16	-28.22**	25.41**
IR-58025A x D-4098	0.69	-1.19	-8.09	16.80**	-17.76**	-3.16	-7.04**	-17.00*
IR-58025A x NWGR-3132	7.93**	11.38**	0.79	9.05	34.97**	-4.86*	-13.39**	-0.17
IR-58025A x RNR-15028	5.17*	30.37**	36.33**	18.27**	49.14**	1.31	-23.05**	53.61**
IR-58025A x RNR-15038	14.83**	12.68**	29.74*	22.66**	70.51**	1.02	-26.45**	84.14**
IR-58025A x RNR-2458	9.31**	4.27	1.38	20.89**	12.03*	-4.49	-22.68**	-4.53
IR 58025 A x RNR-2456	6.21**	5.24	11.95	6.63	31.44**	-3.02	-30.55**	25.90**
IR-58025A x RNR-17462	6.90**	13.21**	14.36	11.38*	37.87**	-5.74*	-16.51**	31.04**
IR-58025A x RNR-2781	6.21**	12.65**	38.54**	26.38**	58.51**	-5.67*	-17.61**	70.52**
IR-79156 A x RNR-15351	-1.38	0.58	-14.79	2.65	34.35**	-4.02	-36.58**	-18.06*
IR-79156 A x WGL-3962	1.03	11.38**	-10.06	16.33**	16.68**	1.67	-11.80**	4.80
IR-79156 A x IR-83142-B-57-B	4.14	8.52**	-5.72	-2.31	-4.27	-6.42**	-0.83	-46.02**
IR-79156 A x RNR-15398	1.72	12.37**	-19.53	-3.57	6.61	-7.87**	-23.93**	-16.61*
IR-79156 A x D-4098	-0.69	1.69	18.66	0.24	29.39**	-4.10	-10.06**	-4.18
IR-79156 A x NWGR-3132	3.10	3.67	59.09**	17.14**	57.52**	-2.90	-10.21**	90.22**
IR-79156 A x RNR-15028	0.69	0.89	-15.19	1.12	39.20**	0.77	-16.82**	-7.12
IR-79156 A x RNR-15038	6.90**	11.49**	34.67**	24.24**	84.74**	1.12	-18.64**	76.02**
IR-79156 A x RNR-2458	9.31 **	1.49	-21.89	-1.71	9.19	-5.92*	-14.00**	-15.13
IR-79156 A x RNR-2456	6.55 **	8.04**	28.21*	17.78**	52.94**	-6.60**	-24.32**	40.58**
IR-79156 A x RNR-17462	9.31**	30.46**	18.34	16.57**	56.41**	-3.88	-12.04**	33.83**
IR-79156 A x RNR-2781	5.17 *	15.21**	28.64*	25.28**	53.42**	-0.45	-12.06**	63.18**

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Table 4. Contd.,

Crosses	Days to 50% flowering	Plant height (cm)	No. of productive tillers / plant	Panicle length (cm)	No. of filled grains / panicle	Spikelet fertility (%)	1000 grain weight (g)	Grain yield / plant (g)
IR-80555 A x RNR-15351	-2.07	3.87	34.28**	-6.45	16.75**	-7.27**	-18.10**	-14.03
IR-80555 A x WGL-3962	-0.69	18.03**	3.20	12.21*	37.07**	1.13	-9.78**	25.58**
IR-80555 A x IR-83142-B-57-B	-5.17*	0.34	17.36	17.75**	-19.26**	-2.93	7.57**	4.60
IR-80555 A x RNR-15398	2.41	8.71**	-7.30	13.14*	4.39	-5.83*	-21.65**	-31.30**
IR-80555 A x D-4098	-5.86*	-1.02	10.30	1.47	-21.69**	-1.70	8.73**	-17.87*
IR-80555 A x NWGR-3132	2.76	16.96**	13.61	-9.31	34.78**	0.24	-5.31**	7.27
IR-80555 A x RNR-15028	-3.79	-3.48	-0.59	4.12	33.03**	3.12	-8.91**	17.77*
IR-80555 A x RNR-15038	7.59**	12.00**	25.40*	3.87	32.85**	0.22	-21.69**	0.22
IR-80555 A x RNR-2458	8.97**	37.87**	19.92	6.71	55.53**	-6.33**	-47.21**	-5.24
IR-80555 A x RNR-2456	3.10	-11.26**	18.11	-2.52	7.21	-4.24	-22.32**	-23.77**
IR-80555 A x RNR-17462	4.14	24.45**	4.26	-13.17*	12.02*	-4.21	-8.44**	5.99
IR-80555 A x RNR-2781	3.45	11.45**	-6.51	12.21*	54.14**	4.31	9.74**	25.25**
IR-68897 A x RNR-15351	0.00	5.66	-15.46	8.52	32.73**	-1.51	-18.86**	-9.24
IR-68897 A x WGL-3962	3.45	12.89**	23.71	21.31**	55.16**	3.39	-11.40**	58.96**
IR-68897 A x IR-83142-B-57-B	-5.86*	7.81**	-4.77	13.68**	12.26*	3.67	-1.19	-25.01**
IR-68897 A x RNR-15398	4.48	9.95**	1.58	20.24**	17.74**	1.12	-11.26**	-17.67*
IR-68897 A x D-4098	-4.48	-4.51	15.98	13.64**	-22.00**	0.90	-0.48	-47.20**
IR-68897 A x NWGR-3132	-1.03	-3.57	-9.15	9.65	22.65**	-0.46	-14.54**	-19.25*
IR-68897 A x RNR-15028	-2.07	0.48	-9.94	3.58	-22.40**	-3.52	-12.42**	-33.23**
IR-68897 A x RNR-15038	1.72	2.51	-6.00	7.88	25.32**	4.38	-11.36**	-0.84
IR-68897 A x RNR-2458	2.07	7.88**	9.47	14.13**	-16.05**	-7.35**	-19.85**	-34.90**
IR-68897 A x RNR-2456	-4.14	4.33	44.65**	12.75*	40.49**	0.70	-14.80**	36.79**
IR-68897 A x RNR-17462	5.17*	33.78**	0.47	17.75**	3.49	-4.13	-15.45**	-11.62
IR-68897 A x RNR-2781	4.48	13.28**	38.50**	13.90**	47.90**	4.11	-3.39	45.86**
APMS-6A x RNR-15351	3.10	4.31	-10.18	17.88**	33.11**	-2.86	-31.79**	-24.99**
APMS-6A x WGL-3962	5.52*	10.82**	39.45**	5.98	23.39**	-5.10*	-9.55**	-18.72*

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Table 4. Contd.,

Crosses	Days to 50% flowering	Plant height (cm)	No. of productive tillers / plant	Panicle length (cm)	No. of filled grains / panicle	Spikelet fertility (%)	1000 grain weight (g)	Grain yield / plant (g)
APMS-6A x IR-83142-B-57-B	-2.76	23.00**	-19.13	-2.13	10.49	-3.98	4.07*	-14.61
APMS-6A x RNR-15398	2.41	34.46**	-23.20	10.01	7.47	-4.03	-30.56**	-27.27**
APMS-6A x D-4098	-3.79	-1.09	-21.89	8.34	-12.60*	-4.48	3.62*	-22.74**
APMS-6A x NWGR-3132	8.97**	21.35**	-11.64	5.71	47.46**	-6.71**	-21.18**	5.64
APMS-6A x RNR-15028	1.03	-4.71	-25.05*	-8.89	53.91**	0.68	-24.42**	30.34**
APMS-6A x RNR-15038	8.62**	29.43**	21.78	25.04**	63.01**	6.23**	-28.57**	59.29**
APMS-6A x RNR-2458	7.93**	15.43**	-8.88	-7.21	54.14**	1.85	-23.84**	7.10
APMS-6A x RNR-2456	5.86*	5.66	-31.36*	0.77	38.51**	-1.91	-36.83**	-0.59
APMS-6A x RNR-17462	3.45	7.17*	-28.72*	12.11*	26.19**	-5.65*	-25.69**	-18.73*
APMS-6A x RNR-2781	10.69**	19.89**	11.64	14.36**	61.01**	1.51	-8.19**	74.72**

* Significant at 5 % level, ** significant at 1 % level

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Table 5. Top ranking hybrids based on *per se* performance, *sca* effects, *gca* effects of parents and standard heterosis for grain yield and its components in hybrid rice

Cross / Characters	Mean	*sca* effects	*gca* effects		*gca* status of parents	Standard heterosis (MTU 1010)
			Female	Male		
IR-58025A x RNR-15038						
Days to 50% flowering	107.56	-3.66**	-0.72*	-0.92*	H x H	10.50**
Plant height (cm)	105.44	1.92	2.61**	0.06	L x M	8.36
No. of productive tillers / plant	13.5	2.12**	0.87**	1.66**	H x H	53.33**
Panicle length (cm)	26.54	0.88*	0.80**	1.42**	H x H	26.24**
No. of filled grains / panicle	240.54	18.64**	0.19	41.94**	M x H	79.94**
Spikelet fertility (%)	88.55	1.83*	-0.58**	3.63**	L x H	0.4
1000 grain weight (g)	17.8	1.16**	0.12*	0.32**	H x H	-27.15**
Grain yield / plant (g)	47.37	5.70**	3.14**	8.48**	H x H	74.70**
IR-79156 A x NWGR-3132						
Days to 50% flowering	99.78	-1.48	4.39**	0.91*	L x L	2.51
Plant height (cm)	87.83	-8.67**	-2.20**	-2.15**	H x H	-9.74
No. of productive tillers / plant	13.01	2.92**	0.42**	-0.13	H x M	47.73**
Panicle length (cm)	25.6	2.30**	-0.05	0.93**	M x H	21.75**
No. of filled grains / panicle	214.27	12.93**	8.34**	13.24**	H x H	60.29**
Spikelet fertility (%)	87.57	2.01**	0.62**	-0.42	H x M	-0.71
1000 grain weight (g)	21.55	0.79**	0.09	0.44**	M x H	-11.83**
Grain yield / plant (g)	44.83	13.30**	0.04	1.48**	M x H	65.32**
IR-58025A x RNR-2781						
Days to 50% flowering	103.67	-2.77**	-0.72*	-1.27**	H x H	6.50 **
Plant height (cm)	106.98	-3.45**	2.61**	-1.38*	L x H	9.94
No. of productive tillers / plant	13.22	1.26**	0.87**	1.73**	H x H	50.15 **
Panicle length (cm)	26.4	1.06*	0.80**	1.63**	H x H	25.55 **
No. of filled grains / panicle	216.55	8.42*	0.19	36.81**	M x H	61.99 **
Spikelet fertility (%)	84.94	1.72*	-0.58**	2.78**	L x H	-3.70 *
1000 grain weight (g)	20.4	0.73**	0.12*	2.22**	H x H	-16.51 **
Grain yield / plant (g)	44.51	2.14**	3.14**	11.80**	H x H	64.13 **
IR-79156 A x RNR-2781						
Days to 50% flowering	101.44	-2.32*	4.39**	-1.27**	L x H	4.22**
Plant height (cm)	112.43	-6.83**	-2.20**	-1.38*	H x H	15.54*
No. of productive tillers / plant	12.68	1.22**	0.42**	1.73**	H x H	43.98**
Panicle length (cm)	26.39	1.67**	-0.05	1.63**	M x H	25.51**
No. of filled grains / panicle	216.28	9.26**	8.34**	36.81**	H x H	61.79**
Spikelet fertility (%)	86.85	1.86*	0.62**	2.78**	H x H	-1.53
1000 grain weight (g)	21.45	0.63**	0.09	2.22**	M x H	-12.21**
Grain yield / plant (g)	44.12	2.26**	0.04	11.80**	M x H	62.70**
APMS-6A x RNR-15038						
Days to 50% flowering	104.33	-0.09	0.89**	-0.92*	L x H	7.19 **
Plant height (cm)	108.15	7.19**	0.04	0.06	M x M	11.14
No. of productive tillers / plant	11.86	1.01*	0.23	1.66**	M x H	34.63**
Panicle length (cm)	27.01	1.81**	0.43**	1.42**	H x H	28.44**
No. of filled grains / panicle	244	13.59**	8.70**	41.94**	H x H	82.53**
Spikelet fertility (%)	91.16	1.65*	0.02	3.63**	M x H	3.35*
1000 grain weight (g)	17.55	0.59**	-2.06**	0.32**	L x H	-28.18**
Grain yield / plant (g)	42.42	3.86**	0.56*	8.48**	H x H	56.45**

* Significant at 5 % level, ** significant at 1 % level