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Assessment of combining ability and heterosis in rice (*Oryza sativa* L.) under irrigated ecosystem

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ABSTRACT

The study was carried out to estimate the combining ability and heterosis for grain yield and its components in rice hybrids. Crosses were effected in line x tester design by using four CMS lines and five restorers as testers and produced twenty hybrids. Analysis of variance for combining ability revealed that variances of SCA were higher than the GCA variances for the traits studied except for 1000 grain weight and spikelet fertility (%) which indicated the predominance of non-additive gene action in the inheritance of traits. The line IR-68897A and the testers IR-79597-56-1-2-1 and WGL-347 were found to be promising general combiners for grain yield per plant and some of its attributes. Estimation of specific combining ability effects revealed that the crosses APMS-6A x IR-79597-56-1-2-1 and IR-79156A x IR-71218-93-1-4-3 had favourable genes for grain yield per plant. The cross IR-68897A x WGL-347 exhibited superior heterosis for number of productive tillers per plant, panicle length, number of filled grains per panicle, spikelet fertility and grain yield per plant over standard check. The cross combinations such as IR-79156A x IR-71218-93-1-4-3, IR-79156A x WGL-347, IR-68897A x IR-79597-56-1-2-1 and APMS-6A x IR-79597-56-1-2-1 showed positive significant heterosis for grain yield. Based on *sca* effect and standard heterosis the crosses IR-79156A x IR-71218-93-1-4-3 and APMS-6A x IR-79597-56-1-2-1 were found to be promising for grain yield and its components. Hence these cross combinations could be utilized for exploitation of heterosis in rice.

***Key words**: Rice, Gene action, Combining ability, Heterosis*

Introduction

Rice is one of the most important food crops and primary source of food for almost half of the world population. In India it is cultivated in an area of 44.5 m ha with a production of 172.58 mt (INDIASTAT, 2018-19). Plateauing trend in the yield of high yielding varieties necessitates the need to find the alternative means for increasing the yield potential. Among the various strategies contemplated to break the existing yield barriers in rice, hybrid rice technology offers an opportunity to increase the yield of rice under fragile conditions as hybrid rice varieties have a yield advantage of 15- 20% over the conventional high yielding varieties (Virmani, 1996). Breeding approaches for developing hybrids with high yield potential require the expected level of heterosis and combining ability. Combining ability analysis is a powerful tool to assess the combining ability of genotypes and to know the type of gene action involved in the inheritance of traits. The magnitude of heterosis depends on the degree to which parental lines are related. The present investigation was undertaken to assess the combining ability, nature of gene action and extent of heterosis for grain yield and its component traits in rice.

Materials and Methods

The material for the present study consists of four cytoplasmic male sterile lines and five elite testers. The crosses were effected in lines x tester design at Rice Research Centre, Rajendranagar, Hyderabad. The resultant 20 F_1s and their parents along with hybrid check (KRH-2) were evaluated for grain yield and its component characters at Seed Research and Technology Centre, Rajendranagar, Hyderabad. The trial was laid out in randomized block design with three replications. Each entry was transplanted in a row of 4 m length with a spacing of 20 cm between the rows and 15 cm between the plants. A standard package of practices was followed for raising the crop. Data was recorded on 10 plants selected randomly from each entry and replication. Observations were recorded for the traits *viz*., days to 50% flowering, plant height (cm), number of productive tillers per plant, panicle length (cm), number of filled grains per panicle, 1000 grain weight (g), spikelet fertility (%) and grain yield per plant (g). The mean data was subjected to line x tester analysis as per the method suggested by Kempthorne (1957). Heterosis was estimated as the percentage increase or decrease in F_1 over the standard check by following standard procedures.

Results and Discussion

The analysis of variance revealed significant differences among crosses and line x tester for all the characters studied (Table 1). This indicates the presence of appreciable amount of genetic variability in the experimental material under study. The variances due to general combining ability and specific combining ability revealed the predominance of non-additive gene action for days to 50% flowering, plant height, number of productive tillers per plant, panicle length, number of filled grains per panicle and grain yield per plant. These results are in accordance with Savita *et al*. (2015), Satheesh Kumar *et al*. (2016), Sudeepthi *et al*. (2018) and Deepika *et al*. (2019). The presence of higher magnitude of non-additive gene action offers scope for exploiting hybrid vigour through heterosis breeding. Preponderance of additive gene action was recorded for spikelet fertility (%) and 1000 grain weight. Additive gene action for test weight had been reported by Sudeepthi *et al*. (2018).

The estimation of general combining ability (*gca*) effects of parents revealed that the line IR-68897A was found to exhibit significant superiority for days to 50% flowering, number of productive tillers per plant, number of filled grains per panicle and grain yield per plant in desired direction (Table 2). The line IR-58025A possessed favourable genes for dwarf plant type, spikelet fertility (%) and 1000 grain weight while the line IR-79156A showed significantly superior *gca* effect for number of productive tillers per plant, panicle length and 1000 grain weight. Among the testers, IR-79597-56-1-2-1 exhibited favourable *gca* effects for number of productive tillers per plant, panicle length, 1000 grain weight and grain yield per plant. The tester WGL-347 was found to be promising general combiner for the traits such as panicle length, number of filled grains per panicle and grain yield per plant. The tester IR-71218-93-1-4-3 recorded significant *gca* effects for panicle length and 1000 grain weight. And the tester, MTU-1081 identified as good general combiner for

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

Source of variation	df	Days to 50% flowering	Plant height	No. of productive tillers/plant	Panicle length	No. of filled grains/panicle	Spikelet fertility (%)	1000 grain weight	Grain yield/ plant
Replications	2	3.171	31.648	3.892	1.545	293.234	9.350	2.097	54.117
Treatments	28	29.82**	210.87**	13.34**	11.82**	6376.85**	36.02**	43.51	222.170**
Crosses	19	20.052**	119.29**	13.97**	8.96**	6694.78**	25.43**	46.22**	186.410**
Line	3	72.55*	69.57	34.28	6.98	2092.93	77.25*	48.16	438.860*
Tester	4	3.48	138.51	9.06	21.37*	15329.87	20.62	126.32**	240.870
Line x Tester	12	12.4**	125.31**	10.53**	5.32**	4966.89**	14.08*	19.03**	105.15*
Error	38	2.383	10.700	2.009	0.740	219.643	5.685	0.258	43.969
Total	59	8.118	46.378	5.925	3.416	2307.353	12.168	15.121	90.185
ó^{2}gca		10.558	27.106	5.823	3.972	2508.260	13.025	25.775	89.516
ó^{2}sca		13.433	150.338	11.347	6.071	6294.463	12.151	25.040	89.862
ó^{2}gca / ó^{2}sca		0.786	0.180	0.513	0.654	0.398	1.072	1.029	0.996

* Significant at 5 per cent level ** Significant at 1 per cent level

number of filled grains per panicle and spikelet fertility (%).

Among the 20 crosses studied, the two crosses IR-79156A x WGL-347 and APMS-6A x MTU-1081 expressed significant *sca* effects for days to 50 % flowering in desirable direction (Table 3). For the trait plant height five crosses exhibited favourable *sca* effects. Likewise, two hybrids (IR-79156A x IR-71218-93-1-4-3 and IR-68897A x IR-79597-56-1-2-1) for number of productive tillers per plant, four hybrids for panicle length, six hybrids for number of filled grains per panicles, seven hybrids for 1000 grain weight and only one hybrid (APMS-6A x MGD-103) for spikelet fertility (%) were found to be promising with positive significant *sca* effect. Out of 20 crosses evaluated, only two crosses, APMS-6A x IR-79597-56-1-2-1 and IR-79156A x IR-71218-93-1-4-3 exhibited positive significant *sca* effect for grain yield per plant. The cross APMS-6A x IR-79597-56-1-2-1 which was found to be the best specific combiner for grain yield per plant also showed better *sca* effects for number of filled grains per panicle and 1000 grain weight. It is evident that cross combinations, which expressed high *sca* effects for grain yield have invariably exhibited positive *sca* effects for one or more yield related traits. Predominance of non-additive gene action for grain yield and its components was also reported by Saidaiah *et al*. (2011), Tiwari *et al*. (2011) and Sudeepthi *et al*. (2018).

Heterosis for grain yield per plant is mainly because of simultaneous manifestation of heterosis for yield component traits. For the trait days to 50% flowering none of the cross registered standard heterosis in desirable direction (Table 4). All the crosses exhibited heterosis in preferred way except only one cross (IR-68897A x WGL-347) for the trait plant height. Among the 20 crosses studied, three crosses such as IR-68897A x IR-79597-56-1-2-1, IR-68897A x WGL-347 and IR-79156A x IR-71218-93-1-4-3 exhibited positive significant heterosis for number of productive tillers per plant. A wide range of heterosis (25.24 to 163.30 %) was observed for number of filled grains per panicle. Eighteen crosses expressed significant heterosis over check and higher magnitude of heterosis was recorded in the cross IR-68897A x WGL-347 (163.30%). The positive significant heterosis was found in two cross combinations *viz*., IR-79156A x WGL-347 and IR-68897A x WGL-347 for spikelet fertility (%) over standard check (KRH-2). The range of significant positive heterosis varied from 40.57 (IR-68897A x MTU-1081) to 68.78 per cent (IR-68897A x WGL-347) for grain yield per plant. The cross IR-68897A x WGL-347 showed higher magnitude of standard heterosis for grain yield per plant also exhibited significant heterosis for number of productive tillers per plant, panicle length, number of filled grains per panicle and spikelet fertility. The crosses *viz*., IR-79156A x IR-71218-93-1-4-3, IR-79156A x WGL-347, IR-68897A x IR-79597-56-1-2-1 and APMS-6A x IR-79597-56-1-2-1 also found to be promising for grain yield and some its components over standard check.

Table 2. Estimation of general combining ability effect of lines and testers in rice

Parents	Days to 50% flowering	Plant height	No. of productive tillers per plant	Panicle length	No. of filled grains per panicle	Spikelet fertility (%)	1000 grain weight	Grain yield/ plant
Lines								
IR-58025A	-0.15	-2.98**	-2.19**	-0.33	5.20	1.66**	1.24**	-3.05
IR-79156A	0.85*	0.44	0.92*	0.76**	-2.26	0.81	1.10**	3.4
IR-68897A	-2.95**	0.39	1.07**	0.34	12.35**	0.89	0.26	5.60**
APMS-6A	2.25**	2.15*	0.21	-0.77**	-15.29**	-3.35**	-2.61**	-5.96**
SE (Lines)	0.56	1.29	0.52	0.32	5.73	0.81	0.18	2.24
Testers								
IR-79597-56-1-2-1	-0.32	0.78	1.16**	0.92**	-42.05**	-1.73*	3.11**	5.23**
IR-71218-93-1-4-3	0.93*	0.34	0.13	0.91**	-29.12**	-0.62	2.39**	-1.56
MGD-103	-0.15	-4.77**	-1.09*	-2.25**	1.02	-0.01	1.46**	-3.65*
MTU-1081	-0.40	-1.00	-0.57	-0.18	31.14**	1.78**	-3.91**	-4.39*
WGL-347	-0.07	4.66**	0.38	0.60*	39.02**		-3.05**	4.29*
SE (Testers)	0.63	1.45	0.58	0.36	6.40	0.91	0.2	2.51

* Significant at 5 per cent level ** Significant at 1 per cent level

Table 3. Estimation of specific combining ability effect of crosses for yield and its components in rice

Crosses	Days to 50% flowering	Plant height	No. of productive tillers per plant	Panicle length	No. of filled grains per panicle	Spikelet fertility (%)	1000 grain weight	Grain yield per plant
IR-58025 A x IR-79597-56-1-2-1	0.32	0.12	-1.08	-0.09	-21.81*	0.72	-0.07	-2.79
IR-58025 A x IR-71218-93-1-4-3	0.73	1.23	-1.35	-2.25**	-15.47	0.29	0.58	-6.49
IR-58025 A x MGD-103	-1.18	2.67	0.17	0.01	44.83**	0.60	-0.27	-0.05
IR-58025 A x MTU-1081	-0.60	2.18	1.27	1.51**	5.89	-0.05	0.09	6.21
IR-58025 A x WGL-347	0.73	-6.20**	0.98	0.83	-13.44	-1.55	-0.32	3.13
IR-79156 A x IR-79597-56-1-2-1	-0.35	-4.64**	-0.41	0.42	0.53	-2.43	-0.96**	-5.97
IR-79156 A x IR-71218-93-1-4-3	-0.60	6.47**	3.51**	0.86	-11.60	0.71	0.15	7.77*
IR-79156 A x MGD-103	-0.52	2.34	0.43	-0.31	-37.24**	-2.36	3.13**	0.32
IR-79156 A x MTU-1081	4.40**	3.35	-1.57	-1.58**	33.73**	1.65	-3.67**	-5.21
IR-79156 A x WGL-347	-2.93**	-7.52**	-1.96*	0.61	14.59	2.43	1.36**	3.09
IR-68897 A x IR-79597-56-1-2-1	0.12	7.98**	2.53**	-0.65	-16.01	-0.12	0.03	-0.51
IR-68897 A x IR-71218-93-1-4-3	0.87	-5.89**	-2.15*	0.22	35.48**	0.91	-2.94**	-2.55
IR-68897 A x MGD-103	-0.72	-2.77	-0.87	-0.79	-60.66**	-1.41	1.47**	-1.58
IR-68897 A x MTU-1081	-1.80	-8.51**	-0.95	1.49*	9.88	-1.23	3.21**	2.73
IR-68897 A x WGL-347	1.53	9.19**	1.44	-0.27	31.31**	1.85	-1.77**	1.91
APMS-6A x IR-79597-56-1-2-1	-0.08	-3.46	-1.04	0.32	37.29**	1.83	1.01**	9.27*
APMS-6A x IR-71218-93-1-4-3	-1.00	-1.80	-0.01	1.17*	-8.41	-1.91	2.21**	1.27
APMS-6A x MGD-103	2.42**	-2.25	0.26	1.09*	53.08**	3.17*	-4.33**	1.31
APMS-6A x MTU-1081	-2.00*	2.98	1.24	-1.42**	-49.51**	-0.37	0.377	-3.73
APMS-6A x WGL-347	0.67	4.53*	-0.45	-1.16*	-32.45**	-2.73*	0.74*	-8.13*
SE (Crosses)	1.26	2.89	1.16	0.72	12.81	1.82	0.41	5.02

* Significant at 5 per cent level ** Significant at 1 per cent level

Table 4. Estimation of standard heterosis for yield and its components in rice

Crosses	Days to 50% flowering	Plant height	No. of productive tillers per plant	Panicle length	No. of filled grains per panicle	Spikelet fertility (%)	1000 seed weight	Seed yield per plant
IR-58025 A x IR-79597-56-1-2-1	4.71**	-22.17**	-18.92	9.36**	25.24	0.67	8.72**	23.83
IR-58025 A x IR-71218-93-1-4-3	6.40**	-21.50**	-30.66**	0.28	44.06**	1.49	8.44**	-14.09
IR-58025 A x MGD-103	3.37*	-25.18**	-27.93**	-.3.49	132.4**	2.63	0.98	1.63
IR-58025 A x MTU-1081	3.70**	-21.89**	-13.39	11.45**	123.80**	2.54	-20.13**	21.88
IR-58025 A x WGL-347	5.39**	-24.62**	-7.42	11.87**	112.60**	2.19	-18.24**	41.88*
IR-79156 A x IR-79597-56-1-2-1	5.05**	-23.51**	15.11	16.06**	39.76**	-4.23	4.42*	35.71
IR-79156 A x IR-71218-93-1-4-3	6.06**	-12.78**	41.14**	17.88**	40.54**	0.96	6.10**	60.78**
IR-79156 A x MGD-103	5.05**	-22.07**	2.4	-0.28	44.94**	-2.03	14.69**	26.32
IR-79156 A x MTU-1081	9.76**	-17.26**	-10.87	3.07	143.70**	3.58	-36.49**	3.91
IR-79156 A x WGL-347	2.69**	-22.50**	-5.89	15.50**	132.69**	6.01*	-11.73**	65.06**
IR-68897 A x IR-79597-56-1-2-1	1.68	-10.86**	42.94**	9.78**	37.89**	-1.3	5.02**	63.41**
IR-68897 A x IR-71218-93-1-4-3	3.70**	-25.26**	-8.41	13.41**	100.81**	1.3	-10.50**	31.44
IR-68897 A x MGD-103	1.01	-27.25**	-7.9	-4.05	36.34**	0.78	4.15*	27.38
IR-68897 A x MTU-1081	-0.34	-29.23**	3.9	14.13**	134.68**	0.15	-11.13**	40.57**
IR-68897 A x WGL-347	3.37*	-5.76	26.13*	10.06**	163.30**	5.40*	-28.44**	68.78**
APMS-6A x IR-79597-56-1-2-1	6.73**	-20.60**	3.12	9.22**	62.94**	-4.11	-2.93	56.96**
APMS-6A x IR-71218-93-1-4-3	7.07**	-19.38**	3.09	12.71**	30.93*	-7.33**	-0.88	3.45
APMS-6A x MGD-103	9.43**	-24.96**	-5.41	-0.84	120.45**	-0.36	-32.28**	-3.95
APMS-6A x MTU-1081	4.71**	-15.92**	8.11	-2.70	49.66**	-3.98	-35.09**	-24.62
APMS-6A x WGL-347	7.74**	-8.67**	1.41	1.68	74.01**	-5.39*	-29.96**	-9.34

* Significant at 5 per cent level ** Significant at 1 per cent level

The study revealed the preponderance of non-additive gene action controlling the majority of traits and it shows the presence of heterozygosity in the population. The estimates of general combining ability effects of lines and testers showed that the line IR-68897A and testers IR-79597-56-1-2-1 and WGL-347 were superior general combiners for seed yield and its contributing traits. A critical evaluation of the results with respect to specific combining ability effects showed that none of the hybrid exhibited desirable significant *sca* effects for all the characters. Similar results were reported by Sanghera and Hussain (2012) and Dilruba and Singh (2019). The crosses APMS-6A x IR-79597-56-1-2-1 and IR-79156A x IR-71218-93-1-4-3 were found to be the best specific combiner for grain yield per plant. The cross IR-68897A x WGL-347 showed higher magnitude of standard heterosis for grain yield per plant and its components such as number of productive tillers per plant, panicle length, number of filled grains per panicle and spikelet fertility. Based on the study, the crosses IR-79156A x IR-71218-93-1-4-3 and APMS-6A x IR-79597-56-1-2-1 found to be superior for *sca* effects and heterosis for grain yield and its components. These cross combinations could be used for exploitation of heterosis in rice.

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