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Studies on Gene Action and Combining Ability Analysis in Hybrid Rice (*Oryza sativa* L.)

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ABSTRACT

Thirty two hybrids developed from crossing four CMS lines with 8 restorers were studied among with parents for 14 yield and yield attributing characters. Among the male parental lines, JGL 18047, IET 26264 and RNR 26060 appeared the best general combiners for yield and important yield component traits. The most promising specific cross combinations were JMS 13A x RNR 26060 and CMS 64A x WGL 14 for grain yield and most of the component characters.

Introduction

The success of hybrid rice programme depends on the availability of stable male sterile and restorer lines along with the exploitable level of heterosis and hybrid seed production. In recent years plant breeders have extensively explored and utilized heterosis in boosting up yield of many crops.

However, estimates of heterosis are meagre in rice. The success can further be hastened by choice of suitable parents with favourable alleles which on crossing could produce heterotic hybrids. Rice hybrids developed with the parental lines which are locally adaptable and possessing tolerance to biotic and abiotic stresses are expected to fare well especially in desired environmental conditions. The present investigation aims at assessing the relative importance of general and specific combining abilities effects in breeding programme for some important characters in a 4 x 8 L x T set of rice.

Materials and Methods

The experimental material consisted of four WA based cytoplasmic male sterile (CMS) lines and eight elite diverse proven restorer lines, which were crossed in according to the line × tester mating design. Twelve parents along with 32 F1 hybrids obtained as a result of crosses along with four checks (2 varietal checks MTU 1001 and JGL 11470 and 2 hybrid checks US 312 and HRI 174) grown in at Rice Research Centre, Agricultural Research Institute, PJTSAU, Hyderabad during *Kharif* 2017.

The experiment was laid out in a Randomized Block Design with two replications. Each treatment consists of two rows of one meter length at a distance of 20 x 15 cm spacing. All the necessary recommended package of practices followed to raise the superior hybrids. Five plants of each entry were tagged at random from each plot and data were recorded on the following quantitative characters viz., days to 50 % flowering, plant height, panicle length, number of productive tillers per plant, panicle weight, spikelet fertility (%), 1000 grain weight, hulling per cent, milling per cent, head rice recovery, kernel length, kernel breadth, kernel length-breadth ratio and grain yield per plant. General and specific combining ability effects were calculated following Kempthorne (1957).

Results and Discussion

The analysis of variance for combining ability (Table 1) revealed that no significant differences were recorded for replications for all the traits. Further, crosses partitioned into lines, testers and lines × testers. The lines were found significant for certain characters *viz.*, days to 50 per cent flowering, plant height, no. of productive tillers, panicle weight, 1000 grain weight, kernel breadth and length-breadth ratio whereas Ramesh *et al.*, (2017) reported significance of the characters *viz*., plant height, grain length and grain breadth. The testers were significant for 1000 grain weight while the interaction between lines and testers were significant for all the traits except kernel breadth indicating the genetic difference among them.

The estimates of variances due to SCA effects were higher than those due to GCA effects for all the characters except plant height and 1000 grain weight indicating the predominance of non-additive gene action.

The influence of non-additive gene action in the control of yield, yield component traits was also reported by Nadali Bagheri (2010) and Anusha *et al.,* (2017).

CMS 64B and three testers *viz.*, WGL 14, RNR 11450 and IET 26264 recorded high *gca* values and were found to be good general combiners for grain yield (Table 2). The line CMS 64B also showed high significant *gca* effects for number of productive tillers per plant, spikelet fertility (%) and 1000 grain weight. The line CMS 23B and three testers *viz.*, JGL 18047, JGL 11118 and RNR 1140 were good for early flowering and dwarf plant stature.

Among the restorer lines, JGL 18047, IET 26264 and RNR 26060 were identified as best general combiners for yield and important yield components *viz*., IET 26264 for grain yield per plant, panicle length, number of productive tillers per plant and 1000 grain weight.

Seven crosses *viz*., JMS 13A x IET 26274, CMS 59A x WGL 14, JMS 13A x RNR 26060, CMS 23A x IET 26264, CMS 64A x WGL 14, CMS 59A x JGL 11118 and CMS 23A x JGL 18047 exhibited ppositive significant *sca* effects for grain yield (Table 3). Among these promising hybrids, CMS 64A x WGL 14 had both the parents with significant positive *gca* effects possessing additive x additive type of gene action. The crosses, CMS 59A x WGL 14 and CMS 23A x IET 26264 possessed only one parent with significant positive *gca* effects indicating the involvement of additive and dominance genetic interaction.

Table.1 Analysis of variance of combining ability for different characters in rice

Source of Variation	Degrees of freedom	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	No. of Productive tillers per	Panicle weight (g)	Spikelet fertility (%)	1000 grain weight
Replicates	1	2.91	2.32	0.45	0.27	0.01	2.42	0.03
Treatments	43	93.00**	344.27**	10.80**	7.02**	0.29**	76.76**	18.17**
Parents	11	59.01	259.38	6.75	7.31	0.15	46.41	22
Lines	7	90.29	368.02	8.98	6.79	0.09	52.42	25.76
Testers	3	3.46	66.83	3.03	8.95	0.23	31.75	19.97
L x T	1	6.75	76.51	2.25	6.02	0.37	48.3	1.75
Crosses	31	72.72**	382.38**	11.11**	7.06**	0.29**	79.68**	17.37**
Lines	7	156.14*	998.52**	15.35	14.61**	0.73**	92.82	37.35**
Testers	3	79.64	310.48	1.52	2.68	0.04	32.15	34.83*
L x T	21	43.93**	187.28**	11.07**	5.17**	0.18**	82.09**	8.21**
Parents vs Crosses	1	1095.38	96.78	45.62	2.82	1.81	320.11	0.91
Error	43	1.05	7.68	1.04	1.76	0.03	1.09	0.87
Total	87	46.52	173.98	5.85	4.34	0.16	38.51	9.41
Source of Variation	**Degrees of freedom**	**Hulling Per cent**	**Milling Per cent**	**Head Rice Recovery (%)**	**Kernel length (mm)**	**Kernel breadth (mm)**	**Kernel length-breadth ratio**	**Grain yield per plant (g)**
Replicates	1	2.53	0.33	2.54	0	0	0.01	4.18
Treatments	43	10.77**	12.30**	15.68**	0.53**	0.03**	0.19**	169.33**
Parents	11	3.87	11.73	7.49	0.59	0.04	0.28	44.42
Lines	7	1.6	2.1	2.19	0.66	0.05	0.33	53.24
Testers	3	10.14	32.64	5.61	0.61	0.01	0.11	21.22
L x T	1	0.9	16.4	50.25	0.04	0.15	0.41	52.25
Crosses	31	13.48**	12.85**	16.98**	0.48**	0.03**	0.13**	178.03**
Lines	7	22.89	22.14	15.3	0.6	0.08**	0.24*	279.89
Testers	3	6.26	6.67	2.89	0.73	0.02	0.07	95.83
L x T	21	11.38**	10.63**	19.56**	0.41**	0.01	0.10*	155.82**
Parents vs Crosses	1	2.77	1.79	65.46	1.41	0.12	1.13	1273.67
Error	43	1.87	4.33	4.88	0.07	0.01	0.04	10.94
Total	87	6.28	8.23	10.19	0.3	0.02	0.11	89.15

**Significant at 1% level of significance; * Significant at 5 % level of significance

Table.2 Estimates of general combining ability effects in lines and testers for yield and yield contributing characters in rice

Parents	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	No. of Productive tillers per plant	Panicle weight (g)	Spikelet fertility (%)	1000 grain weight (g)
LINES							
RNR 26060	0.172	8.295 **	1.825 **	-1.756 **	-0.271 **	7.151 **	1.927 **
WGL 14	5.422 **	-8.442**	-1.238 **	1.494 **	0.124	2.266 **	-0.165
JGL 18047	-6.328**	-12.45**	-0.363	-1.069 *	-0.249 **	-2.138**	1.570 **
JGL 11118	-5.203**	-3.442 **	0.763 *	-0.881	-0.258 **	-1.579 **	-2.443 **
RDR 1140	-2.578**	-4.392 **	-1.488 **	-0.319	0.623 **	-3.121 **	0.677 *
RNR 11450	3.547 **	13.308 **	0.6	2.056 **	0.112	-2.845 **	-2.192 **
IET 26264	4.547 **	16.695 **	1.575 **	0.981 *	0.044	0.061	3.056 **
IET 26274	0.422	-9.567 **	-1.675 **	-0.506	-0.126	0.204	-2.430 **
S.E	0.36	0.97	0.36	0.46	0.06	0.36	0.33
TESTERS							
CMS 23B	-3.328**	-3.136 **	0.181	0.131	-0.037	-1.816 **	0.458
CMS 59B	0.859 **	5.308 **	0.256	-0.569	-0.039	0.455	0.989 **
CMS 64B	1.047 **	1.902 **	-0.006	0.4	0.015	1.574 **	0.742 **
JMS 13B	1.422 **	-4.073 **	-0.431	0.037	0.061	-0.214	-2.189 **
S.E	0.25	0.69	0.25	0.33	0.04	0.26	0.23
Parents	**Hulling Per cent**	**Milling Per cent**	**Head Rice Recovery (%)**	**Kernel length (mm)**	**Kernel breadth (mm)**	**Kernel length-breadth ratio**	**Grain yield per plant (g)**
LINES							
RNR 26060	-0.736	-0.734	0.779	0.479 **	0.066	0.124	-10.111
WGL 14	-3.619**	-2.804**	-1.646 *	0.314 **	-0.001	0.155 *	4.239 **
JGL 18047	-0.428	-1.029	-2.008 *	0.006	-0.001	0.003	-0.648
JGL 11118	1.665 **	1.239	0.747	-0.149	-0.013	-0.057	0.107
RDR 1140	0.252	-0.599	-0.977	-0.216 *	-0.056	-0.017	-2.106
RNR 11450	1.504 **	2.609 **	1.11	-0.338 **	-0.115 **	0.015	4.902 **
IET 26264	0.38	0.252	0.192	-0.118	0.210 **	-0.381**	8.489 **
IET 26274	0.981	1.067	1.804 *	0.022	-0.090 *	0.157 *	-4.873 **
S.E	0.48	0.73	0.78	0.09	0.03	0.06	1.16
TESTERS							
CMS 23B	-0.368	-0.674	-0.473	0.1	0.036	-0.005	-1.23
CMS 59B	0.491	0.157	0.49	0.182 **	0.026	0.044	1.492
CMS 64B	-0.69	-0.306	0.188	0.022	-0.023	0.052	2.533 **
JMS 13B	0.568	0.823	-0.205	-0.304 **	-0.039	-0.091	-2.795 **
S.E	0.34	0.52	0.55	0.06	0.02	0.04	0.82

** Significant at 1% level of significance; * Significant at 5 % level of significance

Table.3 Estimates of specific combining ability effects in hybrids for yield and Yield related traits in rice

Hybrid	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	No. of Productive tillers per plant	Panicle weight (g)	Spikelet fertility (%)	1000 grain weight (g)
CMS 23A x RNR 26060	0.703	-0.539	-3.244 **	0.119	-0.572 **	-0.492	-1.308
CMS 59A x RNR 26060	-0.484	-0.233	0.081	-0.431	0.096	-4.022 **	-0.304
CMS 64A x RNR 26060	-1.172	8.673 **	2.044 **	-1.9	0.046	-1.202	0.803
JMS 13A x RNR 26060	0.953	-7.902 **	1.119	2.213 *	0.430 **	5.716 **	0.809
CMS 23A x WGL 14	7.453 **	-1.552	-0.931	-1.381	-0.182	2.418 **	-0.536
CMS 59A x WGL 14	1.766 *	8.505 **	-0.506	0.319	-0.064	6.293 **	1.503 *
CMS 64A x WGL 14	4.078 **	-0.589	0.256	2.350 *	0.346 *	-1.142	1.646 *
JMS 13A x WGL 14	-13.297 **	-6.364 **	1.181	-1.288	-0.1	-7.569 **	-2.613 **
CMS 23A x JGL 18047	0.703	1.961	0.444	0.431	0.187	-3.038 **	-1.181
CMS 59A x JGL 18047	-0.484	-1.983	-0.381	0.381	0.109	7.536 **	-0.127
CMS 64A x JGL 18047	-0.672	-4.327 *	-2.119 **	-1.588	-0.11	-2.628 **	1.521 *
JMS 13A x JGL 18047	0.453	4.348 *	2.056 **	0.775	-0.186	-1.870 *	-0.213
CMS 23A x JGL 11118	-2.922 **	-15.052 **	-2.931 **	-1.506	-0.249	2.093 **	2.247 **
CMS 59A x JGL 11118	1.391	8.255 **	2.744 **	0.194	-0.047	-6.418 **	-0.959
CMS 64A x JGL 11118	-3.297 **	3.661	1.256	0.725	0.324 *	6.633 **	-0.677
JMS 13A x JGL 11118	4.828 **	3.136	-1.069	0.588	-0.028	-2.309 **	-0.611
CMS 23A x RNR 1140	1.953 *	9.348 **	2.819 **	0.431	-0.156	-0.204	3.247 **
CMS 59A x RNR 1140	1.266	-11.795 **	-1.256	-0.119	0.302 *	0.12	0.631
CMS 64A x RNR 1140	-2.922 **	-11.139 **	-1.494 *	-0.338	-0.433 **	-6.494 **	-3.677 **
JMS 13A x RNR 1140	-0.297	13.586 **	-0.069	0.025	0.286 *	6.579 **	-0.201
CMS 23A x RNR 11450	-5.172 **	9.448 **	2.131 **	1.306	0.501 **	7.234 **	-1.535 *
CMS 59A x RNR 11450	2.141 **	-10.745 **	-2.244 **	2.256 *	-0.232	-1.461	0.62
CMS 64A x RNR 11450	-0.047	1.161	-2.281 **	-0.463	-0.116	8.099 **	1.952 **
JMS 13A x RNR 11450	3.078 **	0.136	2.394 **	-3.100 **	-0.152	-13.873 **	-1.037
CMS 23A x IET 26264	0.328	7.811 **	1.206	0.981	0.073	-3.417 **	-2.182 **
CMS 59A x IET 26264	1.141	2.367	1.881 *	-0.669	0.066	-1.808 *	-1.213
CMS 64A x IET 26264	-1.047	5.773 **	2.144 **	-1.138	0.011	-2.927 **	-0.965
JMS 13A x IET 26264	-0.422	-15.952 **	-5.231 **	0.825	-0.15	8.151 **	4.360 **
CMS 23A x IET 26274	-3.047 **	-11.427 **	0.506	-0.381	0.398 **	-4.594 **	1.249
CMS 59A x IET 26274	-6.734 **	5.630 **	-0.319	-1.931 *	-0.229	-0.24	-0.152
CMS 64A x IET 26274	5.078 **	-3.214	0.194	2.350 *	-0.069	-0.339	-0.604
JMS 13A x IET 26274	4.703 **	9.011 **	-0.381	-0.037	-0.1	5.174 **	-0.493
S.E	0.72	1.95	0.72	0.93	0.12	0.73	0.66

Contd.,

Hybrid	Hulling Per cent	Milling Per cent	Head Rice Recovery (%)	Kernel length (mm)	Kernel breadth (mm)	Kernel length-breadth ratio	Grain yield per plant (g)
CMS 23A x RNR 26060	-0.079	-0.732	-1.514	0.186	-0.088	0.236	-7.558 **
CMS 59A x RNR 26060	-0.073	0.512	2.972	-0.3	-0.014	-0.117	-1.779
CMS 64A x RNR 26060	0.538	0.874	0.274	0.15	0.041	-0.001	-0.771
JMS 13A x RNR 26060	-0.385	-0.654	-1.732	-0.035	0.061	-0.117	10.108 **
CMS 23A x WGL 14	3.703 **	3.098 *	5.461 **	-0.039	0.064	-0.135	-0.307
CMS 59A x WGL 14	3.324 **	2.732	2.797	-0.035	0.009	-0.039	14.971 **
CMS 64A x WGL 14	-6.660 **	-4.506 **	-7.801 **	-0.335	-0.022	-0.137	4.929 *
JMS 13A x WGL 14	-0.368	-1.324	-0.457	0.410 *	-0.051	0.311 *	-19.593 **
CMS 23A x JGL 18047	2.427 *	1.203	0.873	0.078	-0.041	0.107	7.280 **
CMS 59A x JGL 18047	-0.132	-0.093	-0.54	-0.343	-0.066	-0.061	-0.642
CMS 64A x JGL 18047	-0.936	0.419	2.012	-0.158	0.018	-0.105	-3.883
JMS 13A x JGL 18047	-1.359	-1.529	-2.345	0.423 *	0.089	0.059	-2.755
CMS 23A x JGL 11118	-1.926	-1.356	-0.622	0.238	0.016	0.087	-3.405
CMS 59A x JGL 11118	-0.744	-1.397	-3.385 *	-0.523 **	0.05	-0.341 *	6.353 *
CMS 64A x JGL 11118	0.721	0.231	3.507 *	0.282	-0.091	0.305 *	-1.838
JMS 13A x JGL 11118	1.949	2.522	0.5	0.003	0.025	-0.051	-1.11
CMS 23A x RNR 1140	-1.138	-2.212	-4.008 *	-0.104	-0.041	0.007	-2.338
CMS 59A x RNR 1140	-1.162	-0.123	-0.522	0.21	-0.026	0.154	-5.214 *
CMS 64A x RNR 1140	2.439 *	1.474	0.505	-0.715 **	0.023	-0.400 **	4.624
JMS 13A x RNR 1140	-0.139	0.861	4.024 *	0.610 **	0.044	0.239	2.928
CMS 23A x RNR 11450	0.896	3.399 *	1.425	-0.303	-0.032	-0.1	1.53
CMS 59A x RNR 11450	-1.133	-2.032	-1.979	0.516 **	0.073	0.141	3.158
CMS 64A x RNR 11450	0.617	-0.319	1.843	0.506 **	0.042	0.203	1.267
JMS 13A x RNR 11450	-0.38	-1.048	-1.288	-0.719 **	-0.082	-0.244	-5.955 *
CMS 23A x IET 26264	-0.301	1.257	1.173	-0.498 *	0.048	-0.284 *	10.393 **
CMS 59A x IET 26264	-0.089	-0.724	-0.84	0.221	-0.042	0.158	-4.929 *
CMS 64A x IET 26264	1.091	-0.262	-0.538	0.381 *	0.007	0.149	-5.971 *
JMS 13A x IET 26264	-0.701	-0.271	0.205	-0.104	-0.013	-0.022	0.508
CMS 23A x IET 26274	-3.582 **	-4.658 **	-2.789	0.442 *	0.073	0.083	-5.595 *
CMS 59A x IET 26274	0.009	1.126	1.497	0.256	0.017	0.105	-11.917 **
CMS 64A x IET 26274	2.190 *	2.088	0.199	-0.109	-0.018	-0.014	1.642
JMS 13A x IET 26274	-0.079	-0.732	-1.514	-0.589 **	-0.073	-0.175	15.870 **
S.E	0.96	1.47	1.56	0.18	0.07	0.13	2.33

Whereas JMS 13A x IET 26274, JMS 13A x RNR 26060, CMS 59A x JGL 11118 and CMS 23A x JGL 18047 crosses had both parents with low *gca* effects for grain yield per plant indicating over dominance and epistatic interactions. Similar to the present findings, the role of non-additive gene action was documented by other researchers in rice for different traits such as panicle length (Thorat and Kunkerkar, 2017), panicle weight (Ramesh *et al.*, 2017 and Thorat B.S and Kunkerkar, 2017), spikelet fertility percentage (Thorat and Kunkerkar, 2017), grain yield per plant (Dorosti and Monajjem, 2014 and Thorat and Kunkerkar, 2017).

The CMS line CMS 64B and three testers *viz.*, WGL 14, RNR 11450 and IET 26264 are good general combiners for grain yield. The Hybrids JMS 13A x RNR 26060 and CMS 64A x WGL 14 were best specific combiners for grain yield and yield attributing traits with long slender grain type. The hybrids developed may be further tested extensively in different Agro-climatic zones over seasons for their superiority and stability before commercial release.

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