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Combining Ability Studies for Yield and its Component Characters in Rice (*Oryza sativa* L.)

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Abstract Combining ability analysis was carried out in rice (*Oryza sativa*) using line × tester design for 21 hybrids derived from crossing 3 superior CMS lines with 7 elite testers. This parental material is evaluated along with two standard checks for different yield and attributing traits during *kharif*, 2015 in a randomized block design with two replications to identify suitable general and specific combiners for breeding program and to determine the nature of gene action governing yield and its component traits. The component of variance due to SCA was higher than GCA for most of the characters except for test weight which indicate the prevalance of non additive gene action and the ratio of GCA to SCA was low for all the characters studied except for test weight. The line IR 58025A and testers NLR 33654, NLR 3083 were found to be promising general combiners for grain yield per plant and other contributing traits. The cross IR 58025A × NLR 33057 recorded significant SCA effects for majority of the characters which could be exploited in future rice breeding program by adopting heterosis breeding strategy.

Keywords Rice, Line × tester, Combining ability.

Introduction

Rice is an important staple food of almost half of the world population and referred to as Global Grain. Rice is Life was the theme of International year of rice 2004 denoting it's overwhelming importance as an item of food and commerce. With the increase of population at an alarming rate it is estimated that rice requirement by 2025 is about 130 million tones [1]. Plateauing trend in the yield of high yielding varieties (HYV's), declining and degrading natural resources like land and water and acute shortage of labor make the task of increasing rice production quite challenging.

Therefore, a breeding methodology to unfold the genetic information for various metric traits is prerequisite. Breeding strategies based on selection of hybrids require expected level of heterosis as well as the specific combining ability. Combining ability analysis is one of the useful tools available to estimate the combining ability effects and aids in selecting the desirable parents and crosses for the exploitation of heterosis [2]. Line × tester technique [3] is useful in deciding the relative ability of female and male lines to produce desirable hybrid combinations. It also provides information on genetic components

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Table 1. Analysis of variance for line × tester mating design for yield and yield components in rice (*Oryza sativa* L.). *Significant at 5% level, **Significant at 1%.

Source of variation	df	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of productive tillers per plant	Panicle length (cm)	Number of filled grains per panicle (g)	Test weight (g)	Grain yield per plant (g)
Replicates	1	0.09	0.14	5.77	0.06	0.02	20.90	0.006	0.56
Treatments	30	92.84**	50.86**	156.13**	7.20**	3.86**	1355.95**	12.71**	79.00**
Parents	9	84.13**	76.71**	316.09**	8.75**	9.44**	1943.85**	21.16**	139.21**
Lines	2	77.16**	70.16**	156.68**	4.58*	2.54**	157.12*	11.23**	0.06
Testers	6	33.11**	35.28**	320.34**	10.25**	13.31**	2738.68**	23.00**	31.35**
Lines vs Testers	1	404.15**	338.40**	609.46**	8.12*	0.03	748.26**	30.01**	1064.66**
Parents vs Crosses	1	320.88**	196.37**	1023.55**	0.66	2.72*	14.61	6.89**	34.61**
Crosses	20	85.36**	31.95**	40.78**	6.84**	1.40**	1158.46**	9.19**	54.13**
Error	30	0.99	1.21	6.22	0.76	0.39	19.22	0.24	1.21
σ^2 GCA		12.06	4.59	4.93	0.83	0.10	81.23	1.85	3.42
σ^2 SCA		36.89	10.78	7.53	2.85	0.33	543.09	1.55	28.26
σ^2 GCA/ SCA		0.32	0.42	0.65	0.29	0.30	0.14	1.19	0.12

and enables the breeders to choose appropriate breeding methods for hybrid variety or cultivar development programs [4]. Keeping this in view, the present investigation was carried out to study the combining ability in order to identify good combiners and superior hybrid combinations.

Materials and Methods

The experiment was carried out at Agricultural College Farm, Bapatla during *kharif* 2015. The experiment material consists of three stable CMS lines (IR 58025A, IR 68888A and IR 68897A) and seven testers viz., (NLR 40065, NLR 33654, NLR 33057, NLR 3083, NLR 3449, NLR 3042 and WGL 44) and their 21 hybrids along with two checks (DRRH 2 and MTU 1010) were grown in randomized block design with two replications. Standard agronomic practices were followed to raise good crop. Observations were recorded on ten randomly selected plants from each cross for eight metric traits viz., plant height (cm), number of productive tillers per plant, panicle length (cm), number of filled grains per panicle, test weight (g), grain yield per plant (g) in each replication. Days to 50% flowering and days to maturity were recorded on plot basis. Estimates of combining ability were computed as suggested earlier [3].

Results and Discussion

The analysis of variance for combining ability revealed highly significant differences among the crosses with respect to all the characters studied (Table 1). The significance of mean squares due to line × tester for all the characters indicate the presence of both additive and non additive variance for majority of the characters. The variance due to SCA was higher than the variance due to GCA for all the characters except for test weight which were reflected in $\sigma^2g : \sigma^2s$ ratio being less than unity. From this result, predominance of non-additive genetic components over the additive genetic components was revealed in the inheritance of most of the traits which is in agreement with earlier reports [5] and additive gene action for the trait test weight which is in corroboration with

Table 2. Contribution of lines, testers and line × tester for yield components in rice (*Oryza sativa* L.).

Contribution	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of productive tillers per plant	Panicle length (cm)	Number of filled grains per panicle	Test weight (g)	Grain yield per plant (g)
Lines %	18.99	15.64	6.53	18.15	2.34	0.15	22.21	1.63
Testers %	28.44	41.58	62.15	25.15	52.48	42.58	55.89	34.37
Line × Tester %	52.55	42.76	31.31	56.69	45.17	57.25	21.88	63.99

findings [6, 7]. It could be concluded that the improvement of the characters with greater non additive genetic component could be contemplated for the exploitation of heterosis.

The proportional contribution of lines, testers and their interaction for yield and yield contributing characters are presented in (Table 2). It is evident from the table that testers and line×tester component were responsible for a great proportion of variation of all the traits. Testers played an important role towards plant height (62.15%), panicle length (52.48%) and test weight (55.89%). Line × tester played an important role towards traits like Days to 50% flowering (52.55%), Days to maturity (42.76%), Number of productive tillers per plant (56.69%), Number of filled grains per panicle (57.25%) and Grain yield per plant (63.99%). This indicates higher estimates of GCA vari-

Table 3. Estimates of general combining ability (GCA) effects of lines and testers for different characters in rice (*Oryza sativa* L.). *Significant at 5% level, **Significant at 1% level.

Parents	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of productive tillers per plant	Panicle length (cm)	Number of filled grains per panicle (g)	Test weight (g)	Grain yield per plant (g)
Lines								
IR 58025A	2.67**	1.43**	– 0.06	– 1.02**	– 0.08	1.07	– 1.01**	0.82*
IR 68888A	1.17**	0.71*	– 1.35	0.18	0.18	0.14	– 0.32*	– 0.76*
IR 68897A	– 3.83**	– 2.14**	1.41*	0.84**	– 0.10	– 1.21	1.34**	– 0.06
Testers								
NLR 40065	2.00**	0.52	– 0.34	0.09	0.43	0.23	– 0.01	– 0.31
NLR 33654	0.67	1.02*	4.89**	0.77*	0.81**	21.40**	0.27	5.12**
NLR 33057	– 3.67**	– 0.98*	0.73	– 1.00*	0.58*	0.73	1.82**	0.62
NLR 3083	7.00**	5.19**	3.11**	0.84*	– 0.33	– 1.87	1.31**	2.99**
NLR 3449	– 1.50**	– 0.31	–5.07**	– 0.36	– 0.57*	16.53**	– 3.10**	– 1.80**
NLR 3042	– 3.17**	– 2.98**	–4.74**	– 1.45**	– 0.92**	– 29.10**	– 1.24**	– 2.50**
WGL 44	– 1.33**	– 2.48**	1.43	1.10**	0.02	– 7.90**	0.95**	– 4.11**
CD 95% GCA (Line)	0.85	0.94	2.12	0.74	0.53	3.73	0.42	0.94
CD 95% GCA (Tester)	0.56	0.61	1.39	0.49	0.35	2.44	0.28	0.61

Table 4. Estimates of specific combining ability (SCA) effects of hybrids for different characters in rice (*Oryza sativa* L.). *Significant at 5% level, **Significant at 1% level.

Crosses	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of productive tillers per plant	Panicle length (cm)	Number of filled grains per panicle (g)	Test weight (g)	Grain yield per plant (g)
IR 58025A× NLR 40065	–7.50**	–3.10**	– 1.46	–1.03	– 0.19	2.93	0.79*	3.29**
IR 68888A× NLR 40065	10.50**	5.12**	1.33	–0.03	– 0.50	22.36*	– 0.91*	0.28
IR 68897A× NLR 40065	–3.00**	– 2.02*	0.13	1.06	0.69	– 25.29**	0.12	– 3.57**
IR 58025A× NLR 33654	– 0.67	2.40**	0.56	–0.76	– 0.07	– 30.74**	0.47	– 9.24**
IR 68888A× NLR 33654	–5.67**	– 4.88**	– 0.65	–0.96	0.07	1.19	– 0.72	3.34**
IR 68897A× NLR 33654	6.33**	2.48**	0.09	1.73*	0.00	29.55**	0.25	5.90**
IR 58025A× NLR 33057	–2.33**	– 3.10**	– 6.08**	2.50**	– 0.42	37.93**	– 0.65	7.51**
IR 68888A× NLR 33057	–5.33**	– 1.38	3.07	–0.95	0.39	– 21.14**	0.90*	– 6.91**
IR 68897A× NLR 33057	7.67**	4.48**	3.01	–1.55*	0.03	– 16.79**	– 0.25	– 0.60
IR 58025A× NLR 3083	4.50**	– 0.26	0.64	1.02	0.50	– 2.47	– 0.02	– 2.46*
IR 68888A× NLR 3083	2.50**	2.95**	2.43	0.17	0.66	3.66	1.20**	– 0.27
IR 68897A× NLR 3083	–7.00**	– 2.69**	–3.07	–1.19	– 1.16*	– 1.19	– 1.19**	2.73
IR 58025A× NLR 3449	1.00	0.24	5.27**	–1.58*	0.11	– 4.87	– 0.28	– 1.12
IR 68888A× NLR 3449	1.50*	0.45	–3.43	0.12	– 0.50	– 3.94	1.88**	1.12
IR 68897A× NLR 3449	–2.50**	– 0.69	–1.84	1.46*	0.39	8.81*	– 1.59**	0.00
IR 58025A× NLR 3042	1.67*	2.40**	0.94	0.70	– 0.54	1.66	0.46	4.68**
IR 68888A× NLR 3042	– 0.83	– 0.88	– 0.77	2.10**	– 0.45	– 20.71**	– 1.38**	1.36
IR 68897A× NLR 3042	– 0.83	– 1.52	– 0.17	–2.80**	0.99*	19.05**	0.91*	– 6.04**
IR 58025A× WGL 44	3.33**	1.40	0.12	–0.85	0.62	– 4.44	– 0.78*	– 2.66**
IR 68888A× WGL 44	–2.67**	– 1.38	–1.98	–0.45	0.31	18.59**	– 0.97*	1.08
IR 68897A× WGL 44	– 0.67	– 0.02	1.86	1.30*	– 0.93*	– 14.15**	1.75**	1.58
CD 95% SCA	1.47	1.62	3.68	1.29	0.93	6.47	0.73	1.63

ances for interaction.

Studies on general combining effect revealed that none of the lines or testers found to be good general combiner for all the characters studied (Table

3). Negative GCA effects were desirable for days to 50% flowering and plant height while in other traits positive GCA effects were desirable. Among the parents line IR 68897A, testers NLR 33057, NLR 3042 and WGL 44 showed significant negative GCA effects for days to 50% flowering and days to maturity indicating as a good general combiners for earliness. The line IR 58025A and testers NLR 33654 and NLR 3083 showed significant positive effects and were found to be promising general combiners for grain yield per plant and other traits. The tester NLR 33654 recorded significant GCA effects in desirable direction for majority of the characters viz., number of productive tillers per plant, panicle length, filled grains per panicle and grain yield per plant. Hence, these good general combiners of males and females may be extensively used in future for hybrid rice breeding program.

Based on the estimates of SCA effects none of the cross combinations exhibited significant and desirable SCA effect for all the parameters simultaneously (Table 4) indicating that no specific combination was desirable for all traits. These results are in complete agreement with earlier findings [8, 9]. The results showed that out of 21 crosses, five crosses possessed significant and negative SCA which were desirable for early maturity hybrid. Only one cross combination IR 58025A × NLR 33057 showed significant positive SCA effect for short plant height. Similarly a single cross combination IR 68897A× NLR 3042 showed significant positive SCA effect for panicle length. Significant and positive SCA effects were observed in five hybrid combinations for test weight in which IR 68888A× NLR 3449 showed the highest value.

Yield is ultimate goal of a rice breeding and hybrid development program. Character wise estimation of results indicated that out of 21 cross combinations five crosses expressed significant positive SCA effects and six crosses showed significant negative SCA effect for grain yield per plant. Out of these five crosses best performing cross was IR 58025A × NLR 33057 for grain yield per plant along with other yield contributing characters like number of productive tillers per plant and number of filled grains per panicle. This crossed showed high × low general combiners for grain yield per plant the rest of the crosses showed high × high, low × high combinations which is in conformity with the earlier reports [10].

The GCA effects of parents and SCA effects of their hybrids indicated that the crosses with high SCA effects were resulted due to high × high, low × high, high × low and low × low GCA combinations indicating additive, non additive and over dominant epistatic gene interactions. It is obvious that best cross combinations are not always found between high× high general combiners but may also occur in other types of parental combinations. Parents with highest GCA effects will not necessarily generate top specific cross combination which is in conformity with earlier findings [9]. The good specific combinations for different traits involving good general combiners are expected to throw some useful trangressive segregants particularly for developing high yielding pure lines due to additive type of gene action. There are instances where low× low combiners produced the best combinations which is in corroboration with earlier results [9]. Such behavior has been attributed due to over dominance and epitasis.

The present study on combining ability analysis revealed that there is preponderance of non additive gene action for majority of the traits except for test weight and additive gene action for this trait. It could be concluded that the improvement of the characters which possess greater non additive genetic components could be contemplated for the exploitation of heterosis and with bi-parental mating. Parents IR 58025A, IR 68897A and NLR 33654 were excellent general combiners for improving yield contributing traits. Out of 21 crosses the cross IR 58025A × NLR 33057 recorded significant SCA effects for majority of the characters viz., days to 50% flowering, days to maturity, plant height, number of productive tillers per plant, number of filled grains per panicle and grain yield per plant. Other crosses like IR 68897A × NLR 33654, IR 68888A × NLR 33654 and IR 58025A × NLR 3042 were identified as most promising for yield based on SCA effects.

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