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Combining Ability Analysis for Yield and Quality Traits in Rice (*Oryza Sativa* L.)

Ramesh Babu P* and Sreelakshmi Ch

Agricultural Research Station, Nellore-524003, ANGRAU, Andhra Pradesh, India
* Corresponding author (email: ramesh_2004@yahoo.com)

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Abstract

Seven parents were crossed in a diallel manner to study the combining ability for yield and quality attributes in rice at Agricultural Research Station, Nellore, ANGRAU, Andhra Pradesh. The preponderance of additive gene action was observed for plant height, ear bearing tillers per plant, number of secondary branches per panicle, number of filled grains per panicle, test weight and kernel L/B ratio. Non additive component was observed for grain yield and most of the quality traits. The parents Swarnamukhi, Bharani, NLR 33637, Samba Mahsuri and PR 164 were found to be the good general combiners and could be utilized to generate desirable segregants for future breeding programme. Whereas, Samba Mahsuri x NLR 33637, Swarnamukhi x Bharani and Erramallelu x Samba Mahsuri were found to be the best specific combiners for most of the traits studied.

Key words: Rice, gca, sca, yield, quality traits

Introduction

Rice is the staple food for more than half of the world's population and second most widely grown crop in the world. It is the most extensively and largest grown crop in India having an average of about 43.95 m ha and is grown in almost all parts of the country. In Andhra Pradesh rice is the major cereal crop grown in kharif, rabi and in some areas during summer season accounting in an area of about 3.80 m ha, with a production of 11.57 m.tonnes and a productivity of 2856 kg/ha during 2014-15.

With the enhanced income levels and changing food habits, breeding rice varieties with preferred grain quality features has become the second most important objective after yield. Although emphasis is having laid on improving rice grain quality, combining yield potential with good grain quality is challenging. Physical properties include yield of edible and marketable polished grain, uniform shape, whiteness and translucence. These traits are immediately obvious to consumers and so are major factors defining market value. The traits that exert major effects on the eating and cooking qualities are related to the physico-chemical properties of rice grains such as amylose content, gelatinization temperature, gel consistency, aroma and kernel length after cooking (Shobha Rani *et. al.,* 2008). Predictable expression of these traits across seasons and years gives reputation to a variety. Besides good milling quality and cooking quality traits, nutritional quality improvement in the cereals is the important factor to be considered in breeding. Recently, hidden hunger (micronutrient deficiency) has been recognized in developing countries, where rice is the staple food. Rice is consumed as a polished grain. Nutritional components such as minerals and vitamins are either absent or present at low levels in polished grains. So a modest increase in these levels in rice would provide a significant nutritional boost to the hundreds of millions of people who depend on it. Hence, there is an imperative need for a shift in emphasis towards development of nutritionally high quality rice.

Success of any breeding programme mainly depends on the choice of appropriate parents in the hybridization. The combining ability studies helps in selecting the parents for hybridization and provides information on additive and dominance variance (Thakare *et al* 2010) as well as breeding procedure to be followed to select desirable segregants (Salgotra *et al* 2009). Diallel analysis provides information about general combining ability (gca) and specific combining ability (sca) effects of parents and this method helps to compare the combining ability of parents where parents themselves are used as testers. The present investigation was undertaken to get an idea of the combining ability for yield and quality related traits in rice to identify good combiners for effective breeding programme.

Materials and Methods

The experimental material comprised of twenty one hybrids derived from seven parents in a diallel method II, model I of Griffing (1956). The parents used for hybridization are Erramallelu, IR 72, Samba Mahsuri, PR 164, Swarnamukhi, Bharani and NLR 33637. All the parents and hybrids were grown in a randomized block design (RBD) with three replications at Agricultural Research Station, Nellore, ANGRAU, Andhra Pradesh. The standard agronomic practices were followed to raise a good crop. The seedlings were planted with a spacing of 15 x 10 cm and a plot size of 3 rows of 3 m length with single plant per hill. The observations were recorded on ten randomly selected plants per replication per treatment by avoiding border rows and the mean values were expressed on per plant basis per plant basis for quantitative traits and days to flowering on per plot basis. The traits studied in the present experiment were, days to 50% flowering, plant height (cm), number of ear bearing tillers, panicle length (cm), primaries per panicle, secondaries per panicle, filled grains per panicle, unfilled grains per panicle, test weight (g), grain yield per plant (g), kernel length (mm), kernel breadth (mm), kernel L/B ratio, hulling percentage, milling percentage, head rice recovery, chalkiness percentage, gelatinization temperature score (GT score), water uptake, volume expansion, kernel length after cooking (KLAC), kernal breadth after cooking (KBAC), amylose and protein content. The mean values were taken from the replicated data and utilized for analysis by following the method given by Griffing (1956).

Results and Discussion:

The analysis of variance (Table 1) revealed significant genotypic effects for all the traits under study indicating the wider variability for the respective characters among the seven parents. The mean sum of squares due to sca was also significant for all the characters except number of secondaries, number of filled grains per panicle and unfilled grains per panicle suggesting that there was considerable variation among the crosses for the characters under study indicating the possibility for improvement of yield through yield contributing characters. The *perse* performance was closely associated with the gca of the parents and sca of the crosses in majority of the traits studied. Similar findings were also reported by Singh *et al* (1996).

The general combining ability (gca) identifies superior parental genotypes while specific combining ability (sca) helps in identification of good hybrid combinations. The parents with significant negative general combining ability estimates for days to 50% flowering and plant height and with significant positive gca effects for the remaining characters are considered as good general combiners. The parents with significant positive gca effects for days to 50% flowering and plant height are considered as poor general combiners. The parents with non significant gca estimates for all the characters were considered as average general combiners.

The estimates of gca effects of parents (Table 2) revealed that the parent, Swarnamukhi was found to be the best general combiner among all the seven parents studied and it recorded high mean values coupled with high gca for ten characters *viz*., effective bearing tillers per plant, primary branches per panicle, secondary branches per panicle, grain yield, kernel length, kernel breadth, kernel L/B ratio, gelatinization temperature score, amylose content and kernel breadth after cooking. The next best parent was Bharani which exhibited high mean and gca for nine traits *viz*., plant height, days to 50% flowering, less ill filled grains per panicle, test weight, hulling percentage, head rice recovery, gelatinization temperature score, and kernel length after cooking. NLR 33637 was good for seven characters *viz*., panicle length, number of primaries per panicle and number of secondary branches per panicle, number of filled grains per panicle, milling percentage, water uptake, kernel length after cooking followed by Sambamahsuri which was found good for secondary branches per panicle, less ill filled grains per panicle, lower test weight, less kernel breadth, gelatinization temperature score, volume expansion and kernel length after cooking. However, good general combiners may not necessarily produce good specific combinations for different traits. Similar results were reported by Ramalingam *et al* (1997) and Aditya and Anuradha (2015). It could be mentioned that the parents with significant and positive GCA values might be contributed positive alleles in their hybrids due to its additive nature of gene action for the respective traits. The crosses involving these parents might produce good progenies for the respective traits.

Specific combining ability (sca) of a cross is the estimation and the understanding of the effect of non additive gene action for the trait which is an indicator for the selection of a hybrid combination (Akter *et al* 2010). Therefore the highly significant sca effect is desirable for a successful hybrid breeding programme. Specific combining ability effects were estimated for all the twenty one hybrids and for all the twenty four traits (Table 3). The estimates of sca

effects revealed that none of the hybrids were consistently superior for all the traits. In the present study, positive significant sca effects for grain yield was exhibited by the cross PR 164 x NLR 33637. The high sca effects may be associated with high hybrid vigour (Saidaiah *et al* (2010).

When the sca effects were considered based on the performance among the 21 cross combinations, Samba Mahsuri x NLR 33637 was the best specific combiner for most of the characters *viz*., days to 50 % flowering, primary branches per panicle, filled grains per panicle, low chalkiness percentage, head rice recovery, intermediate gelatinization temperature score and protein content. The next best cross was, Swarnamukhi x Bharani for ear bearing tillers per plant, kernel breadth (high), hulling percentage, kernel breadth after cooking (low), amylose content and protein content. For plant height, less number of ill filled grains per panicle, milling percentage, head rice recovery, KLAC, GT score and protein content, Erramallelu x Samba Mahsuri was the best specific combiner. Swarnamukhi x NLR 33637 was the best cross for less number of ill filled grains, milling percentage, head rice recovery, KBAC (high) and amylose content. Erramallelu x Swarnamukhi was the best combiner for KBAC, amylose content and protein content. For the traits, head rice recovery, volume expansion, and water uptake Samba Mahsuri x Swarnamukhi was the best specific combiner. IR 72/ NLR 33637 was the only good cross combination for grain yield but, this was not found good any other character except for low kernal breadth. The cross combination IR 72 x PR 164 was not found good for any one of the characters studied.

Table 1: Analysis of variance for various yield and quality characters in rice

S.No	Character	Mean sum of squares			σ^2gca	σ^2sca	σ^2gca / σ^2sca+ σ^2gca
		gca	sca	error			
1	Plant height	104.469**	22.655**	3.035	11.270	20.620	0.520
2	Days to 50% flowering	122.896**	27.541**	0.708	13.576	26.830	0.503
3	Ear bearing tillers per plant	5.562**	1.165**	0.646	0.546	0.519	0.678
4	Panicle length	4.037**	0.815**	0.360	0.408	0.455	0.642
5	Primary branches per panicle	3.357**	0.255**	0.055	0.367	0.200	0.786
6	Secondary branches per panicle	48.402**	5.241**	2.367	5.115	2.874	0.781
7	Filled grains per panicle	1093.454**	95.049**	33.254	117.800	61.795	0.790
8	Ill filled grains per panicle	48.199**	32.458**	5.555	4.738	26.903	0.260
9	Test weight	19.836**	0.891**	0.139	2.188	0.752	0.850
10	Grain yield per plant	7.633**	3.063	2.614	0.557	0.449	0.356
11	Kernal length	0.462**	0.129**	0.004	0.051	0.125	0.449
12	Kernel breadth	0.034**	0.026**	0.001	0.004	0.025	0.242
13	Kernal L/B ratio	0.113**	0.007**	0.003	0.012	0.004	0.873
14	Chalkiness percentage	7.025**	31.123**	1.899	0.569	29.224	0.037
15	Hulling percentage	3.489**	0.716**	0.037	0.383	0.679	0.530
16	Milling percentage	6.890**	3.377**	0.455	0.715	2.922	0.598
17	Head rice recovery	49.304**	68.910**	1.438	5.318	67.417	0.136
18	GT score	3.693**	0.397**	0.068	0.403	0.329	0.710
19	Amylose content	14.181**	8.008**	0.823	1.484	7.185	0.292
20	Water uptake	1226.665**	996.655**	195.830	114.537	800.825	0.222
21	Volume expansion	0.067	0.149	0.130	-0.006	0.029	-0.693
22	KLAC	0.056**	0.025**	0.001	0.006	0.024	0.339
23	KLBC	0.016**	0.032**	0.004	0.001	0.028	0.088
24	Protein content	0.964**	1.938**	0.011	0.106	1.927	0.099

**: Significant at 1% level

Table 2: General combining ability effects for various yield and quality characters in rice

S.No	Character	Erramallelu	IR 72	PR 164	Sambamahsuri	Swarnamukhi	Bharani	NLR 33637	SE(gi)
1	Plant height	-3.858**	-2.384**	1.921**	-0.492	0.749*	-2.895**	6.958**	0.388
2	Days to 50% flowering	-5.947**	-0.947*	-0.910*	4.312**	3.942**	-0.984*	0.534	0.350
3	Ear bearing tillers per plant	1.060*	-0.483	-0.413	0.079	0.886*	-0.227	-0.902*	0.430
4	Panicle length	-0.471**	-0.261	0.379*	-0.790**	0.014	-0.408*	1.537**	0.165
5	Primary branches per panicle	-0.830**	-0.458**	-0.750**	0.689**	0.702**	0.067	0.581**	0.114
6	Secondary branches per panicle	-1.467**	-2.003**	-2.037**	2.598**	2.115**	-2.404**	3.198**	0.579
7	Filled grains per panicle	-0.889	-11.092**	-13.856**	16.410**	-0.181	-10.359**	19.-968**	2.680
8	Ill filled grains per panicle	-2.795	1.160	-3.978*	0.211	6.054**	-1.357	0.704	1.622
9	Test weight	-1.057**	1.076**	1.675**	-3.338**	0.372**	1.011*	0.261**	0.113
10	Grain yield per plant	0.803	-1.844	-1.509	-0.335	2.395*	-1.468	1.956	1.041
11	Kernal length	0.004	0.163*	0.347**	-0.423**	0.030*	-0.043*	-0.077**	0.0346
12	Kernel breadth	-0.004	-0.023	0.013	-0.008	-0.047*	0.019	0.050*	0.013
13	Kernal L/B ratio	-0.011	0.184**	0.217**	-0.294**	0.150**	-0.066	-0.179**	0.047
14	Chalkiness percentage	-0.254	3.001**	-2.802**	-3.959**	2.043**	2.673**	-0.702*	0.393
15	Hulling percentage	-0.903**	1.638**	-0.197	-0.333**	-1.623**	0.548**	0.870**	0.116
16	Milling percentage	1.368**	-0.238**	-0.570**	0.181*	-1.340**	0.109	0.491**	0.076
17	Head rice recovery	-3.049**	-0.397**	2.370**	-0.243	-5.769**	3.957**	3.133**	0.084
18	GT score	1.974**	-0.026	0.048	-0.804**	-0.804**	-0.249*	0.139	0.098
19	Amylose content	0.106	0.682**	-2.490**	-0.243	-0.620**	1.708**	0.857**	0.195
20	Water uptake	-3.968	-11.228*	13.624**	14.921**	-12.746**	2.894	2.291	2.563
21	Volume expansion	-0.058	-0.203**	-0.073	0.139*	0.113	0.098	-0.016	0.060
22	KLAC	-0.023**	-0.075**	0.027**	0.093**	-0.072**	0.021*	0.030**	0.009
23	KLBC	-0.177**	-0.022	0.074**	0.019	0.053**	-0.004	0.057**	0.012
24	Protein content	-0.385**	-0.503**	0.286**	0.028	-0.391**	0.433**	0532**	0.053

***:** Significant at 5% level, ** :Significant at 1% level of significance

The results indicated that the gca variances were higher than the sca variances for the traits *viz*., plant height, ear bearing tillers per plant, number of secondary branches per panicle, number of filled grains per panicle, test weight, kernel L/B ratio suggesting that these traits were under the control of additive gene action and these traits can be improved through simple selection methods in segregating generations. Similar results were already reported by Aditya and Anuradha (2015) for plant height and ear bearing tillers per plant, Ramalingam and Jebaraj (2013) for filled grains per panicle, Tushara *et al* (2013) for test weight, Gnanamalar and Vivekanandan (2013) for kernel L/B ratio. Preponderance of non additive gene action was observed in the rest of the traits indicating that these characters can be improved by repeated back crossing besides biparental mating in the early generations followed by selection. These results were in close agreement with the earlier findings of Satheesh kumar and Saravanan (2013) for days to 50% flowering, Satya and Jebaraj (2015) for panicle length, Ramalingam and Jebaraj (2013) for ill filled grains per panicle, Mallikarjuna *et al* (2014) for grain yield per plant, Upadhyaya and Jaiswal (2015) for kernal length and kernel breadth, Showkat *et al* (2015) for hulling%, Milling %, head rice recovery, Malini *et al* (2014) for amylose content and Audilakshmi and Upendra *et al* (2014) for water uptake and volume expansion ratio.

Table 3: Specific combining ability effects for various yield and quality characters in rice

S. No	Cross	Plant height	Days to 50% flowering	Ear bearing tillers per plant	Panicle length	Primary branches per panicle	Secondary branches per panicle	Filled grains per panicle	Ill filled grains per panicle	Test weight	Grain yield per plant	Kernel length	Kernal breadth
1	1x2	1.595	-3.130**	1.215	0.309	0.139	-1.584	-8.646	-6.054	1.770**	2.361	0.157	0.040
2	1x3	-1.400	-1.833**	-1.112	-1.081**	0.147	-0.310	-0.809	-1.739	0.347	-0.321	-0.107	0.024
3	1x4	1.906**	-3.722**	1.336	0.408	-0.108	-2.041	9.199	-6.655	-0.319	3.355	0.220*	0.019
4	1x5	1.669	-2.019*	0.862	1.197**	-0.208	1.322	11.286	2.858	0.250	3.763	-0.253**	-0.139**
5	1x6	1.327	1.574	-2.121*	0.036	-0.123	1.166	-5.842	9.623*	1.315**	-2.999	0.266**	-0.048
6	1x7	0.297	4.056**	0.503	0.141	-0.070	3.308*	18.384**	2.872	-0.102	3.894	0.320**	0.008
7	2x3	3.550**	0.167	-0.912	0.163	0.219	-0.631	-3.162	-1.114	0.135	-0.834	0.375**	-0.010
8	2x4	0.329	-7.056**	0.117	-0.245	0.014	1.297	-2.241	-1.887	-1.612**	0.845	0.568**	-0.048
9	2x5	-2.968**	1.315	-2.884**	1.674**	-0.116	0.797	-6.324	0.636	1.461**	-3.864	0.055	-0.270**
10	2x6	-0.941	6.241**	-5.021**	0.442	-0.888**	1.009	7.661	-2.209	-0.650*	-7.528**	0.141	-0.079*
11	2x7	5.779**	1.389	4.787**	-0.012	-0.115	1.583	-1.149	3.254	0.052	7.891**	0.185*	0.000
12	3x4	0.158	-5.426**	0.283	0.252	-0.294	0.062	-0.918	6.848	-0.158	0.567	0.878*	0.142**
13	3x5	-4.747**	-0.389	-2.761**	-0.739	-0.611*	0.298	-8.260	-1.215	-0.585*	-6.129*	0.038	-0.006
14	3x6	5.915**	4.870**	1.352	0.666	0.330	1.106	0.088	-2.291	1.477**	3.637	0.411**	-0.205**
15	3x7	-1.165	3.685**	0.416	0.465	0.153	-0.382	-6.842	2.922	0.800**	0.396	-0.039	-0.219**
16	4x5	1.486	3.389*	-1.446	0.357	0.127	-0.770	-1.573	2.986	-0.135	-3.746	-0.325**	0.049
17	4x6	4.124**	-1.019	-0.626	1.609**	0.635*	-1.685	-3.284	1730	0.270	-1.200	-0.669**	-0.114**
18	4x7	1.064	-4.204**	-1.425	0.544	1.512**	1.836	19.065**	2.926	0.976**	-0.201	-0.225**	-0.041
19	5x6	2.893**	-1.981*	2.620*	0.757	0.552	3.688*	7.893	15.967**	-0.730**	-5.524*	0.348**	0.088**
20	5x7	-1.244	-2.500**	1.551	-0.277	-0.532	-0.014	7.633	-0.984	0.169	5.543*	0.222**	0.024
21	6x7	-4.539**	-1.574	-0.456	0.058	2.193**	-0.002	-5.819	-0.423	0.197	1.422	0.221**	0.132**
		0.960	0.865	1.064	0.408	0.283	1.685	6.633	0.280	0.280	2.577	0.101	0.033

1:Erramallelu, 2: IR 72, 3: PR 164, 4: Sambamahsuri, 5: Swarnamukhi, 6: Bharani, 7:NLR 33637

S. No	Cross	Kernal L/B ratio	Chalkiness percentage	Hulling percentage	Milling percentage	Head rice recovery	GT score	Amylose content	Water uptake	Volume expansion	KLAC	KLBC	Protein content
1	1x2	-0.035	-5.488**	2.701**	-0.840**	-7.394**	0.065	-2.692**	18.648**	0.246	-0.136**	-0.113**	-0.948**
2	1x3	-0.171	2.235**	-4.274**	-1.683**	-0.551**	-0.009	0.007	-13.204**	1.315**	0.275**	-0.121**	0.150
3	1x4	0.126	1.109*	0.011	2.763**	11.582**	0.843**	-3.5373**	-22.167**	-0.713**	0.183**	-0.067**	1.744**
4	1x5	0.231*	15.107**	-1.592**	0.591**	-2.982**	1.176**	6.857**	19.167**	-1.231**	-0.229**	-0.121**	2.386**
5	1x6	0.288*	10.253	-1.670**	0.956**	5.896**	0.620*	2.113**	-46.352**	-0.952**	-0.135**	0.009	0.559**
6	1x7	0.174	-4.396**	-2.528**	-4.593**	-4.068**	0.509*	3.916**	-14.204*	-0.639**	0.072**	-0.325**	1.240**
7	2x3	-0.297*	-2.133*	-0.102	-4.652**	-7.053**	-1.349**	-2.462**	-45.275**	-0.379*	-0.102**	-0.017	0.990**
8	2x4	0.534**	12.557**	-0.016	0.914**	1.877**	-1.157**	-2.008**	15.093*	-0.928**	-0.081**	0.035	-0.305*
9	2x5	0.976**	8.549**	0.040	0.736**	6.089**	0.509*	1.857**	-35.907**	-0.575**	-0.126**	-0.290**	0.224
10	2x6	0.266*	13.335**	0.862**	3.216**	1.360**	0.954**	-3.723**	7.907	-0.897**	-0.226**	-0.203**	1.290**
11	2x7	0.069	5.017**	-0.326	0.404*	1.520**	-0.491*	0.577	-26.944**	1.004**	-0.082**	0.457**	0.858**
12	3x4	0.178	3.657**	2.365**	2.551**	4.076**	1.102**	-1.817**	14.907*	0.815**	-0.130**	0.506**	0.070
13	3x5	-0.017	-0.141	-3.189**	-1.260**	0.326	0.102	-3.017**	48.574**	-1.226**	0.048*	-0.068*	-1.845**
14	3x6	0.953**	8.215**	0.571*	1.537**	0.293	1.546**	-1.211*	-8.611	-1.207**	-0.261**	-0.054	-1.832**
15	3x7	0.613**	-3.207**	0.840**	0.922**	2.490**	-1.231**	-2.258**	-14.130*	-0.913**	-0.277**	-0.302**	1.623**
16	4x5	-0.359**	-6.588**	-0.516*	-1.841**	6.082**	-0.713**	-2.097**	35.278**	1.502**	-0.094**	-0.150**	-0.360**
17	4x6	-0.196	-5.622**	-1.770**	-2.454**	-1.297**	-1.269**	-0.913	34.426**	-0.983**	-0.034	0.070*	1.976**
18	4x7	-0.046	-2.707**	0.725*	0.671**	4.540**	-1.380**	-2.523**	-57.426**	-1.072**	-0.246**	-0.117**	2.660**
19	5x6	-0.057	0.246	1.176**	-0.302	-1.148**		-5.114**	-71.907**	0.130	-0.052*	0.121**	2.012**
20	5x7	0.039	4.694**	2.291**	2.716**	11.182**	-1.046**	-6.531**	12.907*	-0.050	-0.055*	0.512**	2.466**
21	6x7	-0.194	17.627**	-0.753**	0.263	-3.704**	-0.935**	-3.485**	42.056**	0.692**	-0.021	0.148**	-2.714**
	SE(sij)	0.117	0.686	0.287	0.187	0.209	0.242	0.483	6.344	0.021	0.021	0.029	0.130

1:Erramallelu, 2: IR 72, 3: PR 164, 4: Samba Mahsuri, 5: Swarnamukhi, 6: Bharani, 7:NLR 33637

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