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Combining Ability Analysis for Grain Yield and Some Quality Parameters in Rice Cultivars (*Oryza sativa* L.)

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Abstract A study was conducted for combining ability analysis involving 10 parents and their 45 F_1s (half diallel) for grain yield and quality parameters in ten rice genotypes. Hybridization was done for attempting the crosses in 2012-2013 and developed material was evaluated in 2013-2014. The results revealed that non-additive genetic variance play a predominant role in the inheritance of most of the traits. The best combinations mostly involved high × high and high × low general combiners for the characters under study. On the basis of GCA and SCA effects three parents (i.e. Vallabh Basmati 21, Pusa Basmati 1 and CSR 13), five cross combinations (three best crosses Vallabh Basmati 21 × Pusa 1121, Pusa 1121 × CSR 13 and Pusa Basmati 1 × CSR 13) were found good general and specific combiners and also for some other quality parameters respectively. Good × good GCA combinations could be due to additive type of gene actions which are fixable in nature and may be exploited further using pedigree method of breeding for the development of pure lines.

Keywords Combining ability, Diallel analysis, Rice, Quality parameters, Grain yield.

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Introduction

Rice is an important cereal crop and staple food for half of the world population. Diallel analysis provides information about general combining ability and specific combining ability effects of parents and helpful in estimating various types of gene action. Grain quality in rice is very difficult to define because preferences for quality vary from country to country and within country vary from region to region. Market value is determined largely by grain appearances and color, while percentage of hulling, milling and head rice recovery are the principal indices from trader's point of view. Whereas from consumer point of view kernel length, kernel length after cooking and elongation ratio are important quality parameters. Therefore grain shape and size, milling and cooking characters are important criteria of rice quality that breeder consider in developing new varieties of rice. In rice crop, grain quality was overshadowed by the need of higher yield but now a day rice grain quality is very important and become valuable tool for the acceptance of varieties. For the acceptance of rice variety both by farmers and traders, it should posses' not only high yield but also good acceptance quality. Designing of breeding strategy for crop improvement depends upon complexity and inheritance of the target trait under consideration. Therefore, the main objective of present investigation was to identify the best general and specific combiners in respect of grain yield and some quality parameters in rice.

Materials and Methods

The base material consists 10 diverse genotypes of

Table 1. Analysis of variance for combining ability of grain yield and some quality parameters in rice. *Significant at 5% probability level, **Significant at 1% probability level, GCA = General combining ability, SCA = Specific combining ability, $\delta^2 g$ / $\delta^2 s$ = Ratio of GCA variance to SCA variance, $(\delta^2 g / \delta^2 s)^{0.5}$ = Degree of dominance.

Source of variation	DF	Grain yield	Kernel length	Kernel breadth	L/B ratio	Kernel length after cooking	Elongation ratio	Amylose content	Hulling %
GCA	9	127.416**	1.340**	0.011**	0.717**	6.843**	0.045**	5.505**	9.059**
SCA	45	0.298**	0.019	0.012**	0.017**	0.091**	0.012**	0.128	0.098**
Error	108	0.083	0.012	0.009	0.014	0.007	0.007	0.120	0.020
$\delta^2 g$	–	10.611	0.112	0.016	0.060	0.570	0.004	0.449	0.753
$\delta^2 s$	–	0.215	0.021	0.012	0.029	0.084	0.002	0.008	0.077
$\delta^2 g$ / $\delta^2 s$	–	49.317	5.333	1.333	2.068	6.763	2.110	56.125	9.779
$(\delta^2 g / \delta^2 s)^{1/2}$	–	7.022	41.471	6.154	13.089	2.600	1.452	7.350	3.118

rice (Vallabh Basmati 21, Vallabh Basmati 22, MAUB 57, Pusa 1121, CSR 30, Pusa Basmati 1, Basmati 370, Pusa 1401, CSR 13, CSR 10) was planted at Crop Research Center, SVBPU and T, Meerut during *kharif* of 2011-2012 for attempting crossing in a 10 × 10 diallel fashion excluding reciprocals. In the next crop season (i.e. *kharif* of 2012-2013), experimental material consisted total 55 genotypes (10 parents and their 45 F_1s) was sown in a randomized block design with three replications. Seeds of each of the parental lines and also F_1s were dibbled in two row plot of 2 meter length maintaining spacing of 10 cm among plants within a row and 23 cm between rows. All the standard agronomical practices were followed to raise normal crop. Observations were recorded on grain yield per plant (g), kernel length (mm), kernel breadth (mm), L/B ratio, kernel length after cooking (mm), elongation ratio, amylose content (%) and hulling percent. Analysis of variance was carried out by method suggested by Panse and Sukhatme [1] for all the characters among the treatments. The mean values of parents and F_1s cross combinations were used for the estimation of heterosis over better parent. Analysis of combining ability was carried out according to Method II, Model I of Griffing [2]. Graph sheet was used to quantify the cooking characters.

Results and Discussion

The analysis of variance for combining ability (Table

Table 2. Estimates of GCA effects and mean performance of parents for grain yield and some quality parameters in rice. ***Significant level at 5% and 1% respectively, KB = Kernel breadth, KL=Kernel length, L/B ratio=Length / Breadth ratio, KLAC=Kernel length after cooking, ER=Elongation ratio, AC=Amylose content, H % = Hulling percent, GY= Grain yield.

Characters Parents	KB GCA	KL GCA	L/B ratio GCA	KLAC GCA	ER GCA	AC GCA	H % GCA	GY GCA
Vallabh Basmati 21	0.02**	0.28**	0.10**	0.91**	0.07**	0.40**	– 0.73**	3.56**
Vallabh Basmati 22	– 0.01**	0.17**	0.12**	0.45**	0.03**	0.23*	0.51**	– 2.00**
MAUB 57	0.00	0.08**	0.04**	0.22**	0.01**	0.12	0.04	– 3.41**
Pusa 1121	– 0.04**	0.37**	0.31**	0.52**	0.00	0.48**	– 1.25**	– 1.79**
CSR 30	0.03**	–0.01	–0.08**	– 0.28**	–0.04**	– 0.52**	0.11**	4.90**
Pusa Basmati 1	0.01**	–0.11**	–0.09**	0.67**	0.12**	1.07**	–0.76**	2.28**
Basmati 370	–0.03**	–0.13**	0.00	– 0.75**	–0.08**	– 0.10	0.80**	– 0.77**
Pusa 1401	– 0.05**	0.40**	0.35**	0.47**	–0.01**	0.32**	–0.91**	– 3.63**
CSR 13	0.01**	–0.45**	–0.29**	–1.23**	–0.08**	– 1.27**	1.05**	3.64**
CSR 10	0.05**	–0.61**	–0.45**	–0.98**	–0.01**	– 0.74**	1.14**	– 2.78**
Gi	0.00**	0.01**	0.01**	0.05**	0.01**	0.21**	0.09**	0.18**
Gi–Gj	0.00**	0.02**	0.01**	0.08**	0.01**	0.32**	0.13**	0.27**

Table 3. Estimates of SCA effects and *per se* performance in 45 cross combinations for grain yield and some quality parameters in rice.

Cross combinations	ER	AC	H%	KLAC	L/B ratio	KB	KL	GY
Vallabh Basmati 21 × Vallabh Basmati 22	0.07**	0.53	– 0.01	0.61**	–0.01	0.01	0.02	– 0.43
Vallabh Basmati 21×MAUB 57	– 0.03*	–0.03	–0.07	– 0.19*	– 0.01	0.01**	0.02	0.17
Vallabh Basmati 21×Pusa 1121	0.06**	0.61	–0.31*	0.54**	0.00	0.00	–0.01	1.52**
Vallabh Basmati 21×CSR 30	0.01	0.28	–0.07	0.12	0.04**	–0.02**	0.01	0.36
Vallabh Basmati 21×Pusa Basmati 1	0.03*	0.03	–0.10	0.25**	0.01	0.00	0.00	0.43
Vallabh Basmati 21×Basmati 370	–0.04**	0.20	0.13	–0.33**	0.02	0.00	0.01	0.07
Vallabh Basmati 21×Pusa 1401	0.09**	–0.55	–0.16	0.44**	–0.02	0.00	–0.03	– 0.08
Vallabh Basmati 21×CSR 13	0.01	–0.30	0.00	– 0.07	–0.03**	0.00	–0.04**	0.83**
Vallabh Basmati 21×CSR 10	–0.06**	–0.16	–0.05	–0.42**	–0.01	0.01	0.00	0.06
Vallabh Basmati 22×MAUB 57	0.02	0.14	–0.17	0.14	0.03**	–0.01**	0.00	0.49
Vallabh Basmati 22×Pusa 1121	– 0.02	0.11	0.08	–0.08	0.02*	–0.01	0.00	– 0.34
Vallabh Basmati 22×CSR 30	–0.04**	–0.22	–0.14	–0.29**	0.01	0.00	0.01	0.17
Vallabh Basmati 22×Pusa Basmati 1	– 0.03*	0.20	0.46**	–0.16*	0.01	0.00	0.01	– 1.40**
Vallabh Basmati 22×Basmati 370	0.02	0.03	0.00	0.05	0.00	0.00	–0.01	0.21
Vallabh Basmati 22×Pusa 1401	– 0.01	–0.05	– 0.08	– 0.04	0.01	0.00	0.03	0.17
Vallabh Basmati 22×CSR 13	–0.03*	–0.14	–0.09	– 0.27**	–0.03**	0.00	–0.03*	0.40
Vallabh Basmati 22×CSR 10	0.08**	0.00	–0.14	0.49**	–0.02*	0.01	–0.01	0.09
MAUB 57×Pusa 1121	0.01	–0.11	–0.33*	0.11	0.01	0.00	0.01	0.01
MAUB 57×CSR 30	– 0.01	–0.11	0.15	–0.06	–0.03**	0.01*	0.00	0.25
MAUB 57×Pusa Basmati 1	–0.01	0.31	– 0.10	– 0.09	0.01	0.00	0.01	– 0.14
MAUB 57×Basmati 370	0.08**	0.14	– 0.36**	0.49**	–0.01	0.00	–0.01	– 0.23
MAUB 57×Pusa 1401	0.01	0.39	0.12	0.15	0.01	0.00	0.00	– 0.13
MAUB 57×CSR 13	0.00	–0.03	0.19	– 0.04	–0.01	0.00	–0.04*	0.31
MAUB 57×CSR 10	– 0.06**	0.11	0.00	– 0.44**	–0.01	0.00	0.00	– 0.27
Pusa 1121× CSR 30	– 0.04**	0.20	– 0.34*	– 0.33**	–0.03**	0.01	–0.01	– 0.05
Pusa 1121×Pusa Basmati 1	–0.04**	–0.05	– 0.16	– 0.23**	0.00	0.00	0.00	– 0.18

Table 3. Continued.

Cross combinations	ER	AC	H%	KLAC	L/B ratio	KB	KL	GY
Pusa 1121× Basmati 370	0.01	−0.22	−0.26	0.04	−0.02	0.01**	0.01	−0.09
Pusa 1121× Pusa 1401	0.01	0.03	−0.27*	−0.16	−0.01	0.01	−0.01	−0.34
Pusa 1121× CSR 13	0.05**	−0.05	−0.37**	0.38**	0.01	0.00	0.03	0.85**
Pusa 1121× CSR 10	0.03*	0.42	1.54**	0.22**	−0.04**	0.01	−0.02	−0.12
CSR 30×Pusa Basmati 1	−0.01	−0.05	−0.02	−0.10	−0.02	0.01**	−0.01	0.08
CSR 30×Basmati 370	−0.02	−0.22	−0.12	−0.13	−0.03**	0.01**	−0.01	0.16
CSR 30×Pusa 1401	−0.04**	0.36	−0.02	−0.23**	−0.03**	0.01*	0.00	−0.46
CSR 30×CSR 13	0.06**	0.28	−0.06	0.43**	0.01	0.00	0.02	−0.40
CSR 30×CSR 10	0.01	0.42	−0.20	0.09	0.02*	−0.01*	0.00	−0.16
Pusa Basmati 1× Basmati 370	−0.01	0.20	0.10	−0.11	0.00	0.00	0.00	−0.40
Pusa Basmati 1× Pusa 1401	−0.05**	0.11	0.02	−0.26**	0.01	0.00	0.00	0.73**
Pusa Basmati 1× CSR 13	0.03*	0.36	−0.08	0.20*	0.03*	0.00	0.03*	0.87**
Pusa Basmati 1× CSR 10	0.06**	0.17	−0.17	0.29**	0.02	0.00	0.00	0.10
Basmati 370× Pusa 1401	0.01	−0.05	0.09	0.14	0.03	−0.01	0.01	0.20
Basmati 370× CSR 13	−0.05**	0.20	0.00	−0.30**	0.00	0.00	−0.01	−0.39
Basmati 370× CSR 10	−0.06**	0.34	−0.13	−0.34**	0.00	−0.01	0.00	0.31
Pusa 1401× CSR 13	−0.06**	0.11	0.03	−0.39**	0.00	0.00	0.02	−0.59*
Pusa 1401× CSR 10	0.04**	0.59	−0.10	0.33**	−0.02*	0.00	−0.01	0.28
CSR 13×CSR 10	0.01	0.17	−0.11	0.19*	0.04**	0.00	0.05*	−0.52

1) showed that GCA variances were highly significant for all the eight traits whereas SCA variances was significant for five traits namely kernel breadth, L/B ratio, kernel length after cooking, elongation ratio and hulling %. The result revealed that both additive and non additive gene action play important role in the inheritance of these traits. The value of δ^2g was higher than δ^2s for eight traits namely grain yield, kernel length, kernel breadth, L/B ratio, kernel length after cooking, elongation ratio, amylose content and hulling % indicated additive gene action same as the ratio of (δ^2g / δ^2s) were found more than unity for all the traits. Similar results were earlier reported by Sreeniwas et al. [3] for kernel length, kernel breadth, L/B ratio, kernel length after cooking. The average degree of dominance $(\delta^2 g / \delta^2 s)^{1/2}$ showed over dominance for all the eight characters. Non additive type of gene action was reported by Singh et al. [4] for grain yield. The existence of predominantly large amount of non-additive gene action would be required for maintenance of heterozygosity in the population. Since, this type of gene action is non fixable, breeding method such as biparental mating followed by recurrent selection may accelerate the rate of genetic improvement for these types of characters. To exploit the additive genetic variance, pedigree method of breeding suggested for the genetic improvement of these traits.

In the present investigations, it was observed that none of the parents was found as good general combiner for all the eight characters under study. Based on significant GCA effects in desirable direction we selected a good general combiner based on multiple traits. Therefore the parent CSR 10 was found to be good general combiner for kernel breadth and hulling percent, CSR 30 for grain yield, kernel breadth and hulling percent ; Vallabh Basmati 21 for kernel length, kernel breadth, L/B ratio, kernel length after cooking, elongation ratio, amylose content and hulling percent, Pusa Basmati 1 for kernel breadth, kernel length after cooking, elongation ratio, amylose content, Vallabh Basmati 22 for kernel length, L/B ratio, kernel length after cooking, elongation ratio, amylose content and hulling percent, MAUB 57 for kernel length, L/B ratio, kernel length after cooking, elongation ratio ; Pusa 1121 for kernel length, L/B ratio, kernel length after cooking and amylose content ; Basmati 370 for hulling percent and Pusa 1401 for kernel length, L/B ratio kernel length after cooking and amylose content. The parents CSR 13, CSR 30, Vallabh Basmati 21 and Pusa Basmati 1 were found good general combiners for grain yield. Similar results were also reported by earlier reporters [3—8] for different yield contributing traits and quality attributes in rice. The present findings indicated that Pusa Basmati 1 and Vallabh Basmati 21 were found best general combiners for grain yield, kernel length, kernel length after cooking, elongation length, amylose content and hulling % which may be exploited for grain yield and quality attributes (Table 2). It is clear from above study that some parents are good general combiners for more than one trait therefore these parents can be used for crossing program to have the superior recombinants for multiple traits and / or respective traits.

Normally specific combining ability effects do not play an important role in the improvement of self pollinated crops except those crops, where commercial exploitation of heterosis is possible. The significant positive and negative SCA effects were found in F_1s generations for yield and quality parameters. In the present study, out of 45 cross combinations, none of the crosses showed good specific combiners for all eight traits. Out of 45 crosses, seven crosses for grain yield, five for kernel length, nine for kernel breadth, fifteen for L/B ratio, twenty seven for kernel elongation after cooking, twenty six for kernel elongation ratio, none for amylose content and eight for hulling percent exhibited significant SCA effects in desirable direction. Specific combining ability effects are associated with interaction effects which may be due to dominance and epistatic components of variation which are non fixable in nature, it would be worthfull for commercial exploitation of heterosis. Among 45 crosses, five crosses namely Vallabh Basmati 21 × CSR 13, Vallabh Basmati 21 × Pusa 1121, Vallabh Basmati 21× CSR 13, Pusa Basmati 1× Pusa 1401 and Pusa Basmati 1 × CSR 13 exhibited significant specific combining ability effects in desirable direction for grain yield and also showed significant SCA effects for some quality attributes (Table 3). The best specific cross combination namely Vallabh Basmati 21× Pusa 1121, Pusa Basmati 1 × CSR 13, Pusa 1121 × CSR 13 showed desirable SCA effects with high *per se* performance for kernel length after cooking, elongation ratio, hulling percentage and grain yield. It is interested to note that the best crosses in SCA effects were also having high *per se* performance. Out of three crosses, one cross Pusa Basmati 1× CSR 13 in which both parents having good × good GCA effects, could be due to additive type of gene actions which are fixable in nature. Good × good type of general combiners may be exploited further using pedigree method of breeding for the development of pure lines. Similar types of results were also reported by earlier reporters [3, 6, 8, 9]. The other two crosses namely Vallabh Basmati 21× Pusa 1121 and Pusa 1121× CSR 13 involved good × poor or poor × good combining parents for grain yield. This might be due to additive × dominance type of gene interaction with epistasis gene action and non fixable genetic components for grain yield. The crosses involved at least one parent with good general combining ability which indicated that presence of additive × additive or additive × dominance interaction, while remaining crosses involved poor combiners suggesting the epistatic gene action which could be mainly due to genetic diversity in the form of heterozygous loci [10]. On the basis of combining ability the most promising parents for yield and quality attributes were Vallabh 21, Pusa Basmati 1 and CSR 13 and most promising crosses were Vallabh Basmati 21 × Pusa 1121, Pusa 1121 × CSR 13 and Pusa Basmati 1 × CSR 13 may be exploited for the development of single cross hybrids and also through the population improvement program for the development of high yielding varieties.

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