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Combining ability and gene action analysis for morphological and quality traits in basmati rice

S.K. Pradhan* and S. Singh

Crop Improvement Division, Central Rice Research Institute, Cuttack-753006, Orissa, India

ABSTRACT

Thirty hybrids generated from crossing three lines with ten testers were studied along with parents for combining ability and gene action involved in expression of characters in basmati rice. The gca and sca effects were significant for all the characters, indicating the importance of both additive and non-additive genetic components. But it is found that there was predominance of non-additive genetic components for expression of different traits in the present set of materials. Amongst the parental lines, RP 3392-75-5-11-1 and RP3644-41-9-5-5 were best general combiners for grain yield along with other traits. The most specific combiners for grain yield and other traits were Pusa3A x RP 3392-75-11-1 IR 68281A x BTCE 10-98, IR58025A x HKR 97-401, Pusa x RP3644-36-15-8-4 and IR68281A x RP3644-41-9-5-5.

Key words: *Combining ability, gene action, basmati rice*

The concept of combining is an important tool for selecting potential parental lines for hybridization and narrowing down on specific crosses for further exploitation. From genetic viewpoint, gca measures additive gene effects and sca, non-additive gene effects including dominance and epistasis. Numerous reports are available in rice for combining ability and gene action on various characters including yield, but adequate information is not available on this aspect in basmati rice. Therefore, the present investigation was carried out to determine the combining ability and gene action involved in expression of different traits in basmati rice.

MATERIALS AND METHODS

The experimental materials comprised of thirty basmati rice hybrids derived from the crossing of three CMS lines with ten basmati type male parents in line x tester fashion. The parents used as lines were Pusa3A (L1),IR58025A (L2) and IR68281A(L3).HKR97-401 (T1), Pusa Basmati-1 (T2),Type III (T3), UPR2268-5-2 (T4), RP3644-36-15-8-4 (T5), RP3392-75-5-11-1 (T6), RP3644-41-9-5 (T7), BTCE10-98 (T8), Pusa2504-1-26 (T9) and Pusa1280-1-2-1 (T10) were used as testers. The hybridization work was carried out in wet season 2001. In 2002 wet season, the F1 hybrids along with parents and two popular check varieties were grown in randomized complete block design with three replications at Crop Research Centre, GBPUA&T, Pantnagar. Thirty days old single seedling hill^{-1} was planted at a spacing of 20 x 15cm with three meter length row having three rows in each entry. The experiment was conducted with normal package of practices with need based plant protection measures. Observations were recorded on five competitive plants of the middle row of each plot for twelve morphological and quality parameters. The combining ability analysis was performed following the method of Kempthorne (1957).

RESULTS AND DISCUSSION

Analysis of variance revealed significant differences among the lines, testers and line x testers (Table 1).This indicated that the treatments had wide genetic diversity among themselves. Significant variances due to line x tester interaction for all the characters suggested the presence of significant variation for sca among hybrids. These results emphasized the importance of combining ability studies and indicated good prospects for selection of suitable parents and the crosses for the development of appropriate varieties and hybrids. Estimates of highly

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

Sources of variation	PH	DF	SF	PN	PL	SN	SW	GY	GL	DM	GB	HI
Replication	9.5	1.65	5.3	13.1	0.8	23.4	5.8	61.5	0.2	91.2	0.04	7.2
Treatment	463.6**	137.1**	2425**	73.4**	10.6*	5824**	22.1**	602**	0.7**	385**	0.04**	512**
Parents	337.4**	185.3**	30.3**	7.6**	8.4**	4374**	10.4**	75.5**	0.8**	38.6**	0.03**	77.9**
Crosses	286.2**	107.0**	2025**	64.5**	9.5**	4162**	17.4**	719**	0.7**	328**	0.04**	527**
Parents vs.Crosses	4117**	4.7**	7876**	2052**	119**	110966**	5.5**	717**	6.8**	8925**	0.001**	2471**
Females	3571**	1954**	3153**	794**	70**	4202**	146**	2548**	3.9**	2315**	0.03**	2314**
Males	512.4**	61.8**	3408**	55.5**	5.7**	5218**	17.3**	674**	0.8**	412**	0.05**	762**
Females x Males	253.0**	67.7**	1229**	49.3**	7.2**	3253**	18.1**	513**	0.5**	237**	0.03**	413**
Error	56.6	0.4	13.4	4.4	0.5	290.4	8.5	9.2	0.3	18.3	0.02	7.6
σ^2_{gca}	50.15	34.13	53.02	11.4	1.78	46.96	2.7	39.4	0.04	33.88	0.4	37.2
σ^2_{sca}	95.46	37.81	689.43	31.96	3.93	1561.13	9.87	282.8	0.27	146.1	0.1	196
$\sigma^2_{gca}/\sigma^2_{sca}$	0.48	0.90	0.08	0.39	0.27	0.03	0.33	0.13	0.18	0.23	0.0	0.16

PH-Plant height, DF-Days to 50% flowering, SF-Spikelet fertility%, PN-Panicle number plant^{-1}, PL-Panicle length, SN-Spikelets Panicle^{-1}, SW-1000-seed weight, GY-Grain yield plant^{-1}, GL-Grain length, GB-Grain breadth, DM-Dry matter plant^{-1}, HI-Harvest index

significant gca and sca variances for all the characters indicated the importance of both additive and non-additive gene effects for the expression of characters. The ratio of $\sigma^2_{gca}/\sigma^2_{sca}$ was less than unity for all the characters also indicated preponderance of non-additive genetic variance. It suggested greater importance of non additive gene action in their expression and indicated good prospects of the exploitation of non-additive genetic variation for grain and its components characters through hybrid breeding. Preponderance of non-additive gene effects have been reported by many workers for yield and some yield attributing traits (Ganesan, *et al*.,1997; Ramalingam *et al*.,1997; Ganesan and Rangaswamy, 1998; Bansal *et al*., 2000; Thirumeni, 2000 and Pradhan *et al*., 2006).

Estimates of gca effects showed that the male parents RP 3392-75-5-11-1 and RP3644-41-9-5-5 were found to be good general combiner for grain yield plant^{-1} (Table 2).High gca effect of RP 3392-75-5-11-1 for grain yield was associated with its high gca effect for panicle number plant^{-1}, panicle length, spikelet number, spikelet fertility, dry matter content, harvest index and gca effect for plant height and earliness. Better combining ability of RP 3644-41-9-5-5 for grain yield was due to high gca effects for spikelet number panicle^{-1}, harvest index, spikelet fertility and kernel length. Among the female parents, IR68281A was the best general combiner for grain yield plant^{-1} along with high gca effects for number of spikelets panicle^{-1}, number of panicles plant^{-1}, spikelet fertility, dry matter content plant^{-1} and harvest index.

Promising parental lines identified for short stature were RP3644-36-15-8-4 and IR 58025A. Earliness is a good trait for basmati rice and parents showing high gca for this trait were IR58025A and Pusa 2504-1-26.T3 and RP 3392-75-5-11-1 exhibited high gca effects for higher panicles plant^{-1} while good general combiners for long panicle were UPR 2268-5-2 and HKR 97-401. For higher spikelets panicle^{-1}, the good general combiners were BTCE 10-98 and Pusa1280-1-2-1. The good combiners for the important traits like high spikelet fertility were RP3644-41-9-5-5 and RP3392-75-5-11-1while RP3644-41-9-5-5 and Pusa2504-1-26 for high harvest index. Parents like RP3644-41-9-5-5 and Pusa 3A showed high gca effects for kernel length whileRP3644-36-15-8-4 and RP3392-75-5-11-1 for short kernel breadth.

Table 2. Estimates of general combining ability effects of parents

Name of genotypes	PH	DF	SF	PN	PL	SN	SW	GY	GL	DM	GB	HI	Combiner for yield
Female													
Pusa3A	5.3**	3.9**	-4.3**	-0.42	1.21**	5.7**	1.6**	-2.9**	0.3**	4.7**	0.03**	-5.7**	L
IR58025A	-7.5**	-6.1**	-3.9**	-2.9**	-0.98**	-8.9**	0.07	-4.4**	-0.2**	-5.8**	0	0.12	L
IR68281A	2.3**	2.2**	8.2**	3.3**	-0.04	3.4*	-1.6**	7.1**	-0.2**	1.3**	-0.09**	5.6**	G
SE(Sgi)Female	0.71	0.06	0.34	0.26	0.09	1.9	0.35	0.3	0.06	0.4	0	0.26	
SE(Sgi-Sgj)	1.08	0.12	0.51	0.36	0.14	2.35	0.38	0.4	0.08	0.5	0.04	0.4	
Male													
HKR97-401	15.8**	1.1**	-6.2**	3.6**	1.39**	-17.8**	0.17	-0.97	-0.2**	7.1**	-0.02	-0.9	A
Pusa Basmati-1	10.3**	7.1**	13.9**	3.04**	-0.58*	24.0**	-1.6**	-2.1*	0.2**	5.2**	-0.08**	-2.6**	L
T3	17.9**	3.4**	-24.4**	4.04**	-0.31	-10.63	-0.5	-1.7*	-0.2**	-0.22		-2.7**	L
UPR2268-5-2	4.0	4.8**	-25.9**	2.04**	1.47**	-5.63	1.5	-18.1**	0.2**	19.6**	0.01	-23.0**	L
RP3644-36-15-8-4	-8.8**	0.8**	-3.06**	-1.85**	-2.2**	-36.5**	-0.1	-2.3**	-0.3**	0.4	-0.17**	-2.2**	L
RP3392-75-5-11-1	-1.02	-1.1**	26.9**	3.82**	0.75**	17.5**	0.87	16.3**	-0.6	9.0**	-0.14**	6.6**	G
RP3644-41-9-5	2.2	2.5**	28.9**	0.37	0.43	17.0**	-0.9	13.7**	0.3**	-6.4**	-0.11**	14.6**	G
BTCE10-98	-6.8**	2.7**	-19.0**	-0.18	0.4	51.5**	-1.6**	-5.3**	-0.2**	5.1**	-0.05	-12.7**	L
Pusa2504-1-26	-4.7*	-1.6**	23.2**	-1.85*	-0.73**	-41.4**	0.2	-0.3	0.2**	-10.6**	-0.02	9.0**	A
Pusa1280-1-2-1	-5.1*	1.6**	-41.7**	-1.63*	-0.41	25.2**	-0.4	-14.2**	-0.3**	3.1*	0	-16.9**	L
SE(Sgi)Male	2.35	0.2	1.07	0.7	0.22	5.48	0.8	0.83	0.05	1.25	0.02	0.72	
SE(Sgi-Sgj)	3.32	0.24	1.51	0.99	0.31	7.55	1.1	1.18	0.07	1.76	0.02	1.02	

PH-Plant height, DF-Days to 50% flowering, SF-Spikelet fertility%, PN-Panicle number plant^{-1}, PL-Panicle length, SN-Spikelets Panicle^{-1}, SW-1000-seed weight, GY-Grain yield plant^{-1}, GL-Grain length, GB-Grain breadth, DM-Dry matter plant^{-1}, HI-Harvest index%, L-Poor combiner, A- Average combiner, G-good combiner

Table 3. Estimates of specific combining ability effects of crosses for various characters

Name of genotypes	PH	DF	SF	PN	PL	SN	SW	GY	GL	DM	GB	HI	GCA for yield
Pusa3AxHKR97-401	-3.2	7.9**	-30.6**	7.96**	-0.96*	-43.9**	2.2	-19.4**	0.76**	16.4**	0.14**	-23.8**	L/A
Pusa3AxPusa Basmati-1	19.9**	4.6**	26.9**	3.18*	2.38**	4.14	-2.41	2.69	-0.46**	1.31	-0.07*	3.61**	L/L
Pusa3AxT$_3$	-27.6**	-11.4**	-15.7**	3.84**	-1.09**	6.14	-0.16	-16.3**	0.20*	-12.9**	0.08**	-12.6**	L/L
Pusa3AxUPR2268-5-2	-5.7	-4.9**	-11.3**	4.84**	0.4	34.5**	-0.45	2.02		17.9**	-0.13**	1.84	L/L
Pusa3AxPR3644-36-15-8-4	6.0	-0.21	44.1**	0.73	2.24**	44.4**	0.14	21.6**	0.32**	6.4**	-0.05	15.9**	L/L
Pusa3AxRP3392-75-5-11-1	3.9	0.68*	9.4**	-0.93	-1.08**	41.7**	0.34	33.7**	0.16	10.5**	0.15**	15.2**	L/G
Pusa3AxRP3644-41-9-5	-1.9	-2.6**	15.0**	6.84**	1.66**	31.8**	0.88	-2.8	0.02	-1.69	-0.01	0.28	L/G
Pusa3AxBTCE10-98	-6.6	-3.1**	-21.1**	4.07**	0.13	54.7**	-0.26	-15.8**	-0.41**	2.76	0.09	-11.5**	L/L
Pusa3AxPusa2504-1-26	-3.7	1.6**	8.7**	-2.27	-2.27**	-16.8	-1.65	3.9**	0.08	-2.91	-0.10**	5.0**	L/A
Pusa3AxPusa1280-1-2-1	-4.3	0.34	1.6	-1.82	-0.26	33.7**	-1.16	-7.2**	0.02	-0.91	-0.12**	-6.9**	L/L
IR58025AxHKR97-401	-2.9	-7.2**	28.1**	-3.25**	-0.41	-5.1	-1.53	23.7**	-0.72**	-2.85	-0.07*	21.5**	L/A
IR58025AxPusa Basmati-1	-12.8**	2.5**	-22.8**	-6.37**	-1.91**	-29.7**	-0.51	-5.9**	0.06	-10.3**	0.08**	-2.13	L/L
IR58025AxT$_3$	25.6**	11.2**	39.9**	-2.7*	1.73**	17.02	1.27	9.8**	-0.27**	10.2**	-0.10**	5.82**	L/L
IR58025AxUPR2268-5-2	6.2	6.0**	10.4**	0.97	0.45	6.35	-0.59	-0.54	-0.13	-8.6**	0.16**	-4.54**	L/L
IR58025AxPR3644-36-15-8-4	-13.0**	0.7*	-36.0**	3.19*	-2.51**	-39.1**	-1.13	-13.3**	-0.02	2.48	0.24**	-18.3**	L/L
IR58025AxRP3392-75-5-11-1	2.2	-2.1**	-6.4**	5.19**	0.44	-36.8**	-1.53	-17.2**	-0.05	-4.7*	-0.06*	-8.5**	L/G
IR58025AxRP3644-41-9-5	0.6	0.38	-6.1**	-7.03**	-2.92**	-15.31	-2.09	-15.3**	-0.08	-10.6**	0.01	-0.66	L/G
IR58025AxBTCE10-98	-0.68	3.8**	-15.8**	-2.48*	-2.69**	-106**	-0.6	-12.7**	0.12	-5.5*	-0.12**	-11.1**	L/L
IR58025AxPusa2504-1-26	6.2	-0.8**	5.0**	-2.81*	2.25**	8.13	3.45*	4.7**	0.67**	-2.19	0.06*	6.5**	L/A
IR58025AxPusa1280-1-2-1	-0.01	-6.1**	1.2	-0.03	0.26	-10.8	0.1	-4.1**	-0.22*	7.8**	0	-9.9**	L/L
IR68281AxHKR97-401	6.1	-0.7	2.5	-4.70**	1.37**	49.1**	-0.67	-4.3**	-0.04	-13.6**	-0.06*	2.35	G/A
IR68281AxPusa Basmati-1	-7.2	-7.0**	-4.1*	3.19*	-0.47	25.5**	2.92*	3.2*	0.4**	8.99**	-0.01	-1.49	G/L
IR68281AxT$_3$	2.0	0.28	-24.3**	-1.15	-0.63	-23.2*	-1.11	6.5**	0.07	2.77	0.02	6.23**	G/L
IR68281AxUPR2268-5-2	-0.5	-1.2**	0.8	-5.81**	-0.85*	-40.8**	1.04	-1.48	0.02	-9.4**	-0.03	2.70*	G/L
IR68281AxPR3644-36-15-8-4	7.0	-0.5	-8.0**	3.92**	0.27	-5.27	0.99	-8.3**	-0.31**	-8.9**	-0.18**	2.44	G/L
IR68281AxRP3392-75-5-11-1	-6.2	1.4**	-3.0	-4.26**	0.64	-4.94	1.19	-16.5**	-0.11	-5.8**	-0.08**	-6.72**	G/G
IR68281AxRP3644-41-9-5	1.3	2.2**	-9.0**	0.19	1.25**	-16.5	1.21	18.1**	0.06	12.3**	-0.01	0.38	G/G
IR68281AxBTCE10-98	7.3	-0.7*	36.9**	-1.59	2.55**	51.7**	0.86	28.4**	0.29**	2.77	0.03	22.6**	G/L
IR68281AxPusa2504-1-26	-2.5	-0.7*	-13.6**	5.08**	0.02	8.62	-1.79	-8.6**	-0.75**	5.1*-	0.04	-11.5**	G/A
IR68281AxPusa1280-1-2-1	4.3	5.7**	-2.8	1.85	0	-22.9*	1.06	11.3**	0.19*	-6.9**	0.12**	16.7**	G/L
SE(Sij)	4.52	0.3	1.85	1.21	0.39	9.49	1.35	1.44	0.08	2.16	0.03	1.24	
SE(Sij-Skl)	5.83	0.46	2.65	1.72	0.55	13.43	1.91	2.04	0.12	3.05	0.04	1.76	

PH-Plant height, DF-Days to 50% flowering, SF-Spikelet fertility%, PN-Panicle number plant^{-1}, PL-Panicle length, SN-Spikelets Panicle^{-1}, SW-1000-seed weight, GY-Grain yield plant^{-1}, GL-Grain length, GB-Grain breadth, DM-Dry matter plant^{-1}, HI-Harvest index%, L-Poor combiner, A- Average combiner, G-good combiner

The estimates of specific combining ability effects of 30 crosses for 12 characters are presented in Table 3.It is observed that a total of 11 crosses exhibited positive and significant sca effects for grain yield plant^{-1}. The promising specific combinations for grain yield along with other traits were Pusa 3A x Rp3392-75-11-1,IR68281A x BTCE 10-98,IR58025A x HKR 97-401, Pusa 3A x RP 3644-36-15-8-4 and IR68281A x RP3644-41-9-5-5. It is observed that majority of the crosses with high sca effects for grain yield were involved with high/low combinations indicating additive x dominance type of gene interactions for expression of traits. But very few crosses showing low/low general combiners showed high sca effects, suggesting the epistatic gene action may be due to genetic diversity in the form of heterozygous loci. Also, very few crosses having high/high general combiners showed high sca effects, which could be ascribed due to predominance of additive x additive type of gene action. Thus, in majority of the crosses, high sca effects for grain yield were attributed to dominance and epistasis gene action and and only few cases attributed to additive interactions. Similar results have also been reported by Shrivastava and Seshu (1983), Young (1987), Dwivedi *et al.* (1999), Pradhan *et al.* (2006) and others.

The cross combinations showing desirable sca effects for days to panicle emergence (earliness) were Pusa3A x T3,IR58025A x HKR97-401 and IR68281A x Pusa Basmati-1. For plant height, negative estimates of sca are desirable and the promising specific combiners were Pusa3A x T3, and IR58025A x Pusa basmati-1.The cross combinations like IR68281A x BTCE10-98 and Pusa 3A x Pusa Basmati-1 were good specific combiners for panicle length. The promising specific combiners for number of grains panicle^{-1} were Pusa3A x BTCE10-98,IR68281A x HKR97-401 and Pusa3a x RP3644-36-15-8-4.The cross combinations Pusa3A x RP3644-36-15-8-4, IR58025A x T3, IR68281A x BTCE10-98 and IR58025A x HKR97-401 showed higher sca effects for spikelet fertility. For number of panicles plant^{-1}, the cross of Pusa3A x HKR97-401, Pusa3A x RP3644-41-9-5-5, IR58025A x RP3392-75-11-1 and IR68281A x Pusa2504-1-26 exhibited high specific combining ability effects for the trait.IR68281A x BTCE10-98,IR68281A x Pusa1280-1-2-1 and Pusa3A x RP3644-36-15-8-4 showed high sca effects for harvest index. Good specific combiners for kernel length were Pusa3A x HKR97-401,IR58025A x Pusa2504-1-26 and IR68281A x Pusa Basmati-1 while IR68281A x RP3644-36-15-8-4, Pusa3A x Pusa1280-1-2-1 and IR58025A xBTCE10-98 for low kernel breadth.

From the study it is revealed that the importance of good x good general combiners exhibiting high sca effects can be utilized for improvement through single plant selection in segregating generations. But in crosses having high sca effects due to good x poor general combiners have to be improved through population improvement. The crosses showing high sca effects involving poor x poor general combiners may be exploited for heterosis breeding programme.

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