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Combining ability for yield and different quality traits in rice (*Oryza sativa* L.)

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Abstract: Gene action and combining ability for yields and quality traits were analyzed by line x tester analysis in 48 crosses along with 8 lines and 6 testers to find out their usefulness in improvement of quality traits. Analysis of variance revealed that ASD 16 line and Pusa Basmati 1 and Basmati 370 testers were the good combiners for both yield and quality traits. The crosses ADT 36 / GEB 24, ASD 16 / Pusa Basmati 1, ADT 43 / Jeeragasamba, MDU 2 / Pusa Basmati 1 and MDU 5 / Improved White Ponni were identified as the good specific combiners for grain yield and some other quality characters. Dominance gene action was found to be predominant for most of the quality characters along with yield giving way for exploitation of heterosis breeding for meeting out the increasing quality preference of the consumers.

Keywords: Gene action, *Gca* effect, *Per se, Sca* effect

INTRODUCTION

Though Rice is the staple food crop of India, self sufficiency and the changing food consumption pattern of people, has diverted the attention towards quality. Also rice export from India is mostly based on Basmati where two third of the production goes for export (Ramakrishna and Degaonkar, 2016). Keeping in view this market preference, breeding for quality places emphasis on long and short slender grains of dry flaking cooking quality. The market value of the milled rice largely depends on the length and breadth of the kernel and its market preference as reported by Adilakshmi and Upendra (2014). Combining ability analysis provides information on the nature and magnitude of gene action for the traits of economic importance which helps in the identification of potential parents and cross combinations for an efficient breeding programme in crop improvement.

MATERIALS AND METHODS

Seeds of Eight high yielding cosmopolitan varieties, viz., ADT 43, CO 43, MDU 2, MDU 4, ASD 16, ADT 36, IR 20 and MDU 5 and 6 fine grained rice varieties namely Improved White Ponni, GEB 24, Jeeragasamba, Basmati 370, Pusa Basmati 1 and ADT 41 were sown in nursery in a staggered manner to get synchrony with flowering. Thirty day old seedlings were transplanted in the main field with a spacing of 30 X 20 cm and crossing was carried out in L X T fashion. The F_1s obtained from those crosses and their parents were raised in a Randomized Block Design with two replications. Each plot consisted of a single row of 3m with a spacing of 20 cm between rows and 15 cm between plants. Recommended cultural and plant protection schedules were followed. Observations were recorded on five randomly chosen plants in each replication for panicles per plant, panicle length, grains per panicle, grain weight, milling per cent, head rice recovery, kernel length, length / breadth ratio, linear elongation ratio, volume expansion ratio, alkali spreading value, gel consistency, amylose content and single plant yield. The seeds were dehulled using Satake Grain Testing Mill and the qualitative characters were estimated using the standard procedures: Milling percentage and head rice recovery (Ghosh *et al.*, 1971), kernel length and kernel breadth before cooking and after cooking (Ramaiah classification, 1969), linear elongation ration (IARI, 1980), volume expansion ratio (Juliano *et al.*, 1965), Alkali spreading value (Little *et al.*, 1958), gel consistency (Cagampange *et al.*, 1973) and amylose content (Juliano, 1971). The combining ability analyses were subjected to analysis of variance appropriate for Line x Tester crossing design as suggested by Kempthorne (1957).

RESULTS AND DISCUSSION

The analysis of variance revealed highly significant differences among lines, testers and line x tester for all the character studies of rice indicating the presence of genetic variability in the experimental material (Table 1). Among the lines each line was found to be a good combiner for individual traits. However ASD 16 was found to be the best combiner since it exhibits good gca for 9 out of 13 characters. Pusa Basmati 1 and Basmati 370 were found to be best among testers for both

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Table 1. Analysis of variance for combining ability for yield, yield components and quality characters of rice.

Source	df	Mean squares												
		PP	PL	GP	GW	MP	HRR	KL	L/B ratio	LER	VER	ASV	GC	AC	SPY
Hybrids	47	19.70**	14.65**	1155.36**	0.08**	64.01**	124.05**	0.35**	0.92**	0.03**	0.60**	6.19**	767.23**	9.17**	19.21**
Lines	7	26.04**	16.37**	1238.18**	0.26**	36.21**	143.76**	0.88**	2.01**	0.05**	0.70**	2.07**	1970.22*	7.34**	23.56**
Testers	5	13.37**	20.41**	574.95**	0.05**	11.54**	198.36**	0.60**	1.30**	0.01*	2.33**	37.79*	747.97**	9.53**	43.09**
Line / tester interaction	35	19.34**	13.48**	1221.71**	0.04**	77.07**	109.50**	0.21**	0.64**	0.02**	0.33**	2.49**	529.39**	9.48**	14.92**
Error	47	0.81	1.34	6.62	0.01	2.18	2.84	0.01	0.01	0.00	0.10	0.11	1.69	0.13	1.57

* and ** significant at P = 0.05 and 0.01 respectively; PP Panicles per plant; GW: Grain weight; KL: Kernel length; VER: Volume expansion ratio; AC: Amylose content; PL: Panicle length; MP: Milling per cent ; L/B : Length / breadth ratio; ASV: Alkali spreading value: SPY: Single plant yield; GP: Grains per panicle; HRR: Head rice recovery; LER: Linear elongation ratio; GC: Gel consistency

Table 2. General combining ability effect of parents of rice for quality and yield traits of rice.

Genotypes	PP	PL	GP	GW	MP	HRR	KL	L/B RATIO	LER	VER	ASV	GC	AC	SPY
Lines														
L_1	0.25	1.29**	16.12**	-0.30**	0.14	0.28	-0.45**	-0.26**	0.06**	0.43**	0.22*	-12.80**	-0.26*	-0.70
L_2	-0.51	0.63	-10.97**	0.12**	1.27**	-5.75**	0.02	-0.14**	0.02	-0.02	-0.04	-8.83	0.54**	-1.15**
L_3	-1.15**	-1.69**	-1.89*	-0.05	-2.26**	-3.05**	-0.12**	0.03	0.11**	-0.18*	-0.18*	4.80**	0.47**	-1.94**
L_4	2.34**	1.36**	-1.86*	-0.08*	-0.99*	-2.45**	0.14**	0.32**	0.00	0.03	-0.08	4.97**	-0.18	2.00**
L_5	1.86**	-0.58	-6.45**	0.11**	1.90**	1.11*	0.13**	-0.16**	-0.06**	-0.17	-0.11	24.42**	0.97**	1.97**
L_6	0.21	0.31	-11.75**	0.13**	1.99**	4.36**	0.38**	0.85**	0.01	0.20	0.41**	-2.70**	0.54**	-0.11
L_7	-1.62**	-1.51**	11.08**	-0.04	-2.39**	2.78**	-0.29**	-0.44**	-0.05**	-0.34**	-0.79	5.27**	-1.43**	-0.40
L_8	1.39**	0.19	5.72**	0.10**	0.33	2.72**	0.20**	-0.19**	-0.08**	0.04	0.56**	-15.12**	-0.63**	0.34
SEd(5%)	0.26	0.33	0.74	0.03	0.43	0.49	0.03	0.03	0.02	0.09	0.09	0.37	0.10	0.36
Testers														
T_1	0.35	0.64**	-1.43*	0.03	0.37	1.71**	-0.08**	-0.32**	0.02	-0.39**	-1.48**	-5.75**	0.55**	0.02
T_2	-1.36**	-1.00**	8.87**	-0.05*	0.28	2.30**	-0.25**	-0.30**	0.03*	-0.43**	-1.39**	-9.57**	-0.70**	-1.08**
T_3	0.54*	-0.24	-5.18**	-0.08**	-1.71**	0.27	-0.15**	-0.15**	-0.03*	-0.20*	-1.34**	1.02**	-1.17**	-1.50**
T_4	0.66**	-0.17	-7.21**	0.04	0.61	-7.06**	0.23**	0.23**	-0.04**	0.33**	1.32**	2.55**	0.83**	0.64*
T_5	0.76**	1.90**	4.46**	0.07**	0.26	1.45**	0.21**	0.22**	0.03*	0.30**	1.56**	1.85**	0.30**	2.93**
T_6	-0.95**	-1.13**	0.48	0.00	0.20	1.33**	0.04*	0.31**	-0.01	0.39**	1.31**	9.91**	0.19*	-1.02**
SEd(5%)	0.23	0.29	0.64	0.02	0.37	0.42	0.02	0.02	0.01	0.08	0.08	0.32	0.09	0.31

* and ** significant at P = 0.05 and 0.01 respectively; L_1 ADT 43; L_2 Co 43 ; L_3 MDU 2 ; L_4 MDU 4; L_5 ASD 16 ; L_6 ADT 36 ; L_7 IR 20; L_8 MDU 5; T_1 Improved White Ponni; T_2 GEB 24; T_3 Jeeragasamba; T_4 Bamati 370; T_5 Pusa Basmati 1; T_6 ADT 41

Table 3. Specific combining ability effect of best perfoming hybrids of rice for quality and yield traits of rice.

Gentypes	PP	PL	GP	GW	MP	HRR	KL	L/B RATIO	LER	VER	ASV	GC	AC	SPY
$L_5 \times T_5$	3.87**	-0.29	-18.18**	0.13	-1.38	4.87**	0.02	0.23**	-0.07	0.56*	0.47*	14.17**	4.03**	5.56**
$L_6 xT_2$	4.42**	3.43**	-6.93**	-0.18*	2.45*	5.88**	-0.23**	-0.35**	0.11**	0.47*	2.30**	36.00**	-0.94**	4.04**
$L_1 xT_2$	-2.58**	1.63	58.93**	-0.05	4.64**	8.38**	0.25**	0.42**	-0.22**	0.36	-0.01	2.20*	-0.54*	2.26*
$L_1 xT_3$	2.37**	0.59	-26.01**	0.12	4.38**	7.25**	0.21**	0.30**	-0.08*	-0.24	1.74**	29.31**	0.34	1.58
$L_3 xT_5$	-0.53	5.58**	30.56**	-0.14*	3.95**	10.14**	0.11	-0.32**	-0.01	0.10	0.44	18.39**	5.53**	2.91**
$L_4 xT_1$	-4.84**	2.26**	16.27**	0.01	5.92**	14.32**	-0.16**	-0.27**	0.06	-0.16	1.78**	-2.38*	0.53*	-2.96**

yield and quality traits.

Partitioning of the combining ability variances into fixable additive genetic variance and non-fixable dominance variance indicated that both additive and dominant gene action play a significant role in controlling the expression of all the traits. Dominance gene action was predominant for all the five quantitative characters viz., panicles per plant, panicle length, grains per panicle, grain weight and single plant yield. Predominance of non additive gene action for yield and yield related traits was also reported by Hasan *et al*. (2015), Waza *et al*. (2015), Ghosh *et al.* (2013), Srivastava *et al.* (2012), Saidaiah (2010) and Jayasudha and Sharma (2009). Also in case of panicle length and grain weight the additive gene action was found to be lower than dominant gene action as reported by Hasan *et al*. (2015). Dominant gene action seems to be more important for the expression of physico-chemical traits like head rice recovery, kernel length, length / breadth ratio, linear elongation ratio, volume expansion ratio, alkali spreading value, gel consistency and amylose content which was in agreement with the findings of Adilakshmi and Upendra (2014) and Thakare *et al.* (2013). Milling percent also had higher SCA variance as reported by Waza *et al*. (2015) whereas Alkali spreading value was the single character which exhibited additive genetic variance in contrast to their reports.

General combining ability effects of parents: The potential of a variety is judged by comparing the mean performance and combining ability effects of the parents (Singh *et al*., 1985). Combining ability analysis seems to be the most reliable and quickest method of understanding the genetic nature of quantitatively inherited characteristics (Sharma *et al.,* 2012). Gilbert (1958) suggested that the parents with high mean performance would be much useful in producing better offspring in any breeding programme. According to Sprague and Tatum (1942) the parents having high *gca* effects could be useful, since the *gca* effect is due to additive gene action which is fixable.

Among the testers Pusa Basmati 1 was identified as the best parent based on both *per se* and *gca* for eight traits namely panicle length, grain weight, kernel length, length / breadth ratio, volume expansion ratio, alkali spreading value, gel consistency and amylose content. It was followed by ADT 41 for kernel length, length / breadth ratio, volume expansion ratio, alkali spreading value and gel consistency (Table 2). This was observed by Faiz *et al*. (2006). However MDU 5 showed desirable performance for three characters namely grain weight, kernel length and alkali spreading value followed by ADT 36 for head rice recovery and amylose content; ASD 16 for grain weight and milling per cent and MDU 2 for linear elongation ratio and gel consistency. Among the lines there was no parallelism between *per se* performance and *gca* effects as ob-

Table 4. Hybrids for recombination breeding for quality and yield traits in rice.

Characters	Good combining line	Good combining tester	Promising crosses for recombination breeding
Panicles per plant	MDU 4	Jeeragasamba	-
	ASD 16		
		Pusa Basmati 1	
Panicle length	ADT 43	Improved White Ponni	ADT 43 / Improved White Ponni
	MDU 4	Pusa Basmati 1	-
Grains per panicle	ADT 43	GEB 24	
	IR 20	Pusa Basmati 1	
	MDU 5		
Grain weight	CO 43	Pusa Basmati 1	ASD 16 / Pusa Basmati 1
	ASD 16		ADT 36 / Pusa Basmati 1
	ADT 36		MDU 5 / Pusa Basmati 1
	MDU 5		
Head rice recovery	ASD 16	Improved White Ponni	IR 20 / ADT 41
	ADT 36	GEB 24	
	IR 20	Pusa Basmati 1	
	MDU 5	ADT 41	
Kernel length	MDU 4	Basmati 370	ASD 16 / Pusa Basmati 1
	ASD 16	Pusa Basmati 1	ASD 16 / ADT 41
	ADT 36	ADT 41	ADT 36 / Basmati 370
			MDU 5 / Pusa Basmati 1
Length / breadth ratio	MDU 4	Basmati 370	
	ADT 36	Pusa Basmati 1	
		ADT 41	
Linear elongation ratio	ADT 43	GEB 24	
	MDU 2	Pusa Basmati 1	-
Volume expansion ratio	ADT 43	Basmati 370	ADT 43 / Basmati 370
		Pusa Basmati 1	ADT 43 /ADT 41
		ADT 41	
Alkali spreading value	ADT 43	Basmati 370	ADT 43 / Pusa Basmati 1
	ADT 36	Pusa Basmati 1	ADT 43 /ADT 41
	MDU 5	ADT 41	ADT 36 / Basmati 370
			ADT 36 / Pusa Basmati 1
			ADT 3 6 / ADT 41
			MDU 5 / Basmati 370
			MDU 5 / ADT 41
Gel consistency	MDU 2	Jeeragasamba	ASD 16 / ADT 41
	MDU 4	Basmati 370	
	ASD 16	Pusa Basmati 1	
	IR 20	ADT 41	
Amylose content	CO 43	Improved White Ponni	MDU 2 / Basmati 370
	MDU 2	Basmati 370	
	ASD 16	Pusa Basmati 1	
	ADT 36	ADT 41	
Grain yield	MDU 4	Basmati 370	
	ASD 16	Pusa Basmati 1	

served by Adilakshmi and Upendra (2014). In contrary Sharma *et al.* (2012) reported that the *per se* performance of the parent and their gca effects for all the characters were almost in close correspondence, which indicated that the *per se* performance of the parent for these traits could possibly be taken as a criterion for selection of parent. Hence in this study superior lines were be selected based on *per se* since the *per se* performance is the realized value while *gca* effects are merely estimates. The parents can be considered for further exploitation if they possess higher order of *per se* performance. Based on this criterion the lines MDU 5, ASD 16, ADT 36 and MDU 2 were selected as the best lines for yield and quality traits.

Specific combining ability of the hybrids: According to Sprague and Tatum (1942) the *sca* effects are due to

Table 5. Hybrids for heterosis breeding for quality and yield traits in rice.

Characters	Hybrids
Panicles per plant	MDU4 / Jeeragasamba, MDU4 / Pusa Basmati 1, ASD 16 / Improved White Ponni, ASD 16 / Pusa Basmati 1
Panicle length	-
Grains per panicle	CO 43 / Pusa Basmati 1, MDU 2 / Pusa Basmati 1, MDU 4 / Improved White Ponni, ASD 16 / Jeeragasamba, ADT 36 / GEB 24, IR 20 / Jeeragasamba, MDU 5 / GEB 24
Grain weight	CO 43 / Pusa Basmati 1
Milling per cent	CO 43 / Jeeragasamba, MDU 2 / Improved White Ponni, ADT 36 / Basmati 370, IR 20 / Basmati 370, IR 20 / Pusa Basmati 1, MDU 5 / ADT 41
Head rice recovery	ADT 43 / Improved White Ponni, ADT 43 / GEB 24, ADT 43 / Jeeragasamba, MDU 2 / GEB 24, MDU 2 / Pusa Basmati 1, MDU 4 / Improved White Ponni, ASD 16 / Pusa Basmati 1, ASD 16 / ADT 41, ADT 36 / GEB 24, ADT 36 / Basmati 370, IR 20 / Basmati 370, IR 20 / Pusa Basmati 1, MDU 5 / Improved White Ponni, MDU 5 / Jeeragasamba.
Kernel length	-
Length / breadth ratio	MDU 2 / ADT 41, MDU 4 / Basmati 370, ADT 36 / Pusa Basmati 1, ADT 36 / ADT 41
Linear elongation ratio	ADT 43 / Pusa Basmati 1, ADT 43 / ADT 41, CO 43 / Jeeragasamba, MDU 2 / Improved White Ponni, ADT 36 / GEB 24
Volume expansion ratio	-
Alkali spreading value	-
Gel consistency	ADT 43 / Jeeragasamba, MDU 2 / Improved White Ponni, MDU 2 / Basmati 370, MDU 2 / Pusa Basmati 1, MDU 2 / ADT 41, MDU 4 / Jeeragasamba, MDU 4 / ADT 41, ASD 16 / Improved White Ponni, ASD 16 / GEB 24, ASD 16 / Jeeragasamba, ASD 16 / Basmati 370, ASD 16 / Pusa Basmati 1, ADT 36 / GEB 24, IR 20 / Jeeragasamba, IR 20 / Basmati 370, IR 20 / ADT 41
Amylose content	MDU 2 / Pusa Basmati 1, ASD 16 / Pusa Basmati 1
Single plant yield	MDU 2 / Pusa Basmati 1, MDU 4 / Basmati 370, MDU 4 / Pusa Basmati 1, ASD 16 / Basmati 370, ASD 16 / Pusa Basmati 1, MDU 4 / Improved White Ponni,

non-additive gene action. In the present study significant *sca* effect was exhibited for nine characters namely panicles per plant, panicle length, milling per cent, head rice recovery, linear elongation ratio, volume expansion ratio, alkali spreading value, gel consistency and single plant yield by the hybrid ADT 36 / GEB 24. This was followed by the hybrid ASD 16/ Pusa Basmati 1 which had significant *sca* for eight characters namely panicles per plant, head rice recovery, length / breadth ratio, volume expansion ratio, alkali spreading value, gel consistency, amylose content and single plant yield. The hybrid ADT 43 / GEB 24 was found to be best for grains per panicle, milling per cent, head rice recovery, kernel length, length / breadth ratio, gel consistency and single plant yield while ADT 43 / Jeeragasamba recorded significant *sca* for panicles per plant, milling per cent, head rice recovery, kernel length, length / breadth ratio, alkali spreading value and gel consistency. The other two hybrids which had recorded positive *sca* for seven characters are MDU 2 / Pusa Basmati 1 and MDU 5 / Improved White Ponni. MDU 2 / Pusa Basmati 1 was found to be best for panicles per plant, grains per panicle, milling per cent, head rice recovery, gel consistency, amylose content and single plant yield. MDU 5 / Improved White Ponni showed significant positive *sca* for panicles per plant, grains per panicle, head rice recovery, alkali spreading value, gel consistency and single plant yield (Table 3). Most of the crosses having significant *sca* effects recorded higher *per se* performance. Thus all these crosses were found to be outstanding with respect to grain yield and quality traits.

Hybrids for recombination breeding: In case of hybrids with significant *sca* effects, selection in early segregating generations is likely to fail as the *sca* effects mask the true performance of the selected parents. As suggested by Nadarajan and Sree Rangaswamy (1990) and Srivastava *et al*. (2012) it will be useful to select only those hybrids having parents with high *gca* effects with non significant *sca* effects for recombination breeding, since it is likely to throw segregants with favourable genes derived from both the parents. In this study, evaluation of hybrids based on the above criterion revealed that the combinations ASD 16 / Pusa Basmati 1 and MDU 5 / Pusa Basmati 1 were best for grain weight and kernel length; ADT 36 / Basmati 370 for kernel length and alkali spreding value; ADT 43 / Improved White Ponni for panicle length; ASD 16 / ADT 41 for gel consistency and kernel length; IR 20 / ADT 41 for head rice recovery; ADT 43 / Basmati 370 and ADT 43 / ADT 41 for volume expansion ratio; MDU 2 / Basmati 370 and ASD 16 / Basmati 370 for amylose content would result in superior segregants through recombination breeding. Hence these hybrids may serve as better sources for deriving superior segregants by recombination breeding for the improvement of the respective traits (Table 4).

Hybrids for heterosis breeding: The presence of non-additive genetic variance offers scope for exploitation of heterosis. The hybrid combinations with a higher expression of the genetic parameters namely mean and *sca* effects were selected for heterosis breeding. MDU

2 / Pusa Basmati 1 was found to be best for five traits namely head rice recovery, grains per panicle, gel consistency, amylose content and single plant yield. ASD 16 / Pusa Basmati 1 was also found to be best for five traits namely panicles per plant, head rice recovery, gel consistency, amylose content and single plant yield followed by ADT 36 / GEB 24 with four traits namely grains per panicle, head rice recovery, linear elongation ratio and gel consistency. MDU 2 / Improved White Ponni was found to be best for milling per cent, head rice recovery and gel consistency. The higher sca value in these crosses indicated the presence of non-additive genetic variance offering the scope for exploitation of heterosis. In an overall manner three hybrids namely ASD 16 / Pusa Basmati 1, MDU 2 / Pusa Basmati 1 and ADT 36 / GEB 24 were selected for heterosis breeding. But the mean performance being the actual realized value and *sca* being estimated the former should be given due importance as reported by Pethani and Kapoor (1984) and Saleem *et al*. (2010). Based on the above critera, the hybrids ASD 16 / Pusa Basmati 1, ADT 36 / GEB 24, MDU 4 / Basmati 370 and MDU 4 / ADT 41 were found to be best for most of the yield and quality traits (Table 5).

Though different lines were found to be best for different characters based on their gca and mean the line ASD 16 was found to be the best combiner followed by ADT 36 and MDU 5 whereas in case of tester Pusa Basmati 1 and Basmati 370 were found to be good. It was noticed that crosses with good sca was found to be obtained from parents that are found to be best combiners and also from parents that have poor gca as observed by Adilakshmi and Upendra (2014) and Roy and Senapati (2012). Since most of the characters exhibited non additive gene action, heterosis breeding was found to be effective to further exploit their genetic potential.

Conclusion

From this study it was noted that both additive and non-additive gene actions were important in controlling various characters though non additive gene action was found to be predominant. The best combiners Pusa Basmati 1, Basmati 370, ADT 41, MDU 5 and ADT 36 could be utilized in future breeding programme. The crosses ASD 16 / Pusa Basmati 1, ADT 36 / GEB 24, ADT 43 / GEB 24, ADT 43 / Jeeragasamba, MDU 2 / Pusa Basmati 1 and MDU 5 / Improved White Ponni could be used for exploitation of heterosis for yield, its components and quality traits.

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