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Combining ability analysis for yield and its components in hybrid rice

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Abstract : Sixty hybrids developed from crossing four CMS lines with 15 restorers were studied along with parents for 13 yield and yield attributing characters. Among the male parental lines, BR 827-35-3-1, RTN 3, IR 46 appeared the best general combiner for grain yield and most of the component characters. The female line IR 58025A was found to be good general combiner for all the traits except plant height and grain L: B ratio. The most promising specific cross combinations were IR 58025A X BR 827-35-3-1, IR 58025A X RTN 3 and IR 68885A X RTN 711 for grain yield/hill.

Keywords : Rice, combining ability, gene action, line x tester

Introduction

The breeding method to be adopted for improvement of a crop depends on the nature of gene action involved in the inheritance of economically important traits. Besides its use in selection of potential parents and superior crosses, combining ability studies also provide information on the nature and magnitude of gene effects involved in the expression of quantitative traits. Such information is of practical value in formulating as well as executing the efficient breeding programme for obtaining maximum gain with minimum resource and time. The present investigation was aimed to analyse the combining ability of four CMS lines with 15 varieties.

Material and Methods

Four male sterile lines were crossed with fifteen restorers in a line x tester fashion. The female parents were IR 58025A, IR 68885A, IR 68886A and IR 68897A.The male parents were RTN 711, KJT 3, Abhaya, IR 64, PNL 1, IR 46, IR 54, BR 827-35-3-1-1, RTN 3, KJT 14-7, KJT 2, Suwarna, IR 5, Gurjari and GR 11. All the 60 hybrids, 19 parents along with one inbred check Jaya (SCI) and one hybrid check Pro agro 6201 (SCII) were raised in randomized block design with three replications with a spacing of 20 cm. between rows and 15cm. between plants. Single seedling was transplanted at each hill of 4.5 m.length row during *Kharif-2003* at three locations *viz,* N.A.R.P.Navsari, Regional Rice Research Station, Vyara and Hill millet Research Station, Waghai in South Gujarat. Recommended agronomical practices were followed while raising the crop. Observations were recorded on the randomly selected hills from each treatment in each replication for days to 50 per cent flowering, productive tillers per hill, plant height, panicle length, number of grains per panicle, fertility, 100 grain weight, length of kernel, L:B ratio, grain yield per hill, straw yield per hill, harvest index and protein content. Combining ability analysis was calculated following the method suggested by Kempthorne (1957). The pooled mean value

Table 1. Analysis of variance (mean squares) of combining ability for various traits.

Source of variance	d.f	Days to 50% flow.	Tillers/ hill	Plant height	Panicle length	No. of grains/ panicle	Fertility	100 grain weight	Kernel length	L:B ratio	Grain yield	Straw yield	Harvest index	Protein content
Locations	2	474.48**	53.30**	641.87**	36.36**	18010.9**	82.09*	0.0052	0.875**	0.962**	2393.96**	1561.20**	167.62**	0.225**
Females	3	2318.69**	36.67*	1937.40**	32.96	3656.48	121.49	0.345	2.623	1.387	1183.87**	823.38	19.76	21.30
Males	14	559.34**	82.01**	1676.35**	73.76**	5745.41	151.29**	0.718**	6.097**	2.813*	1552.97**	1520.36**	27.94**	17.90**
Females x Males	42	188.66**	12.81**	334.97**	19.99**	3922.27**	59.68**	0.316**	1.556**	1.411**	394.97**	352.45**	12.67**	8.44**
Females x Locations	6	69.51*	25.05**	273.31**	32.46**	1998.24	50.89*	0.023	0.142*	0.064	483.51**	759.18**	13.07	0.066
Males x Locations	28	19.88	28.63**	87.21	23.94**	3224.67	77.10**	0.013	0.042	0.066	482.51**	502.63**	15.36**	0.080
Females x Males x Locations	84	25..99**	15.11**	80.47**	10.13*	2582.44**	84.91**	0.013**	0.064	0.065	342.46**	341.49**	14.95**	0.117**
Pooled error	354@	17.13	7.79	10.89	7.56	84.99	23.02	0.0052	0.071	0.061	31.57	64.95	7.93	0.031
σ^2 gca		28.81	0.81	32.10	0.36	17.54	2.28	0.00	0.06	0.02	19.48	3.65		
σ^2 sca		19.06	0.56	36.01	1.38	426.36	4.07	0.03	0.17	0.15	40.38	92.18		
σ^2 gca : σ^2 sca		1.51	1.45	0.891	0.261	0.041	0.560	0.00	0.353	0.133	0.482	0.039		

*, **, Significant at 5 and 1 per cent probability levels, respectively.

@ for individual location, d.f. for error and replication were 118 and 2, respectively.

over three locations for each parent and hybrid was taken for computation of combining ability and standard heterosis over Jaya (SC I) and Pro agro-6201 (SC II).

Results and Discussion

Analysis of variance (Table 1) for combining ability for the data pooled over environments revealed that both additive as well as non-additive variances were important in the inheritance of various traits as evident from significance of females, males and females x males interaction for all the characters except panicle length, number of grains per panicle, fertility, l00 grain weight, kernel length, L;B ratio, straw yield per hill, harvest index and protein content for females, number of grains per panicle for males. The magnitude of *sca* variances were higher than the *gca* variances for all the characters except days to 50 per cent flowering and productive tillers per hill and this indicated preponderance of non-additive gene action on the inheritance of these traits, while preponderance of additive type of gene action was noticed for days to 50 per cent flowering and productive tillers per hill. This was further supported by low magnitude of $\sigma^2 gca$: $\sigma^2 sca$ ratios. Preponderance of non-additive variance in the expression of different traits in rice had also been reported by Ram *et al.* (1991) and Khirsagar (2002). Preponderance of additive variance in the expression of 50 per cent flowering and productive tillers was also reported by Rao *et al.* (1980) and Lavanya (2000).

Mean squares due to males x locations were found to be non-significant for days to 50 per cent flowering, plant height, number of grains per panicle, 100-grain weight, kernel length, L:B ratio and protein content. Mean squares due to females x locations were non-significant for number of grains per panicle, 100-grain weight, L.B ratio and harvest index, which indicated that gca variances of females and males were not influenced by the environments for the above said traits. The *sca* variances were more sensitive to environmental fluctuations as evident by the significance of mean squares due to females x males x locations interaction for all the characters.

Based on estimates of general combining ability effects on pooled basis for various characters, the parents were classified as good, average and poor combiners (Table 2). It was observed that among four females, IR 58025A was found to be good general combiner for all the traits except plant height, L:B ratio and average combiner for fertility and protein content. Similar results were also reported by Yadav *et al.* (1999) and Lavanya (2000) and. IR-68885A was found good general combiner for plant height and L: B ratio while IR 68897A was good combiner for protein content.

Among males, BR 827-35-3-1 was found to be good general combiner for most of the characters except plant height and protein content whereas average performance in days *to* 50 per cent flowering, kernel length and L:B ratio followed by IR-46, which showed poor performance in panicle length and 100-grain weight while it was average combiner for plant height, fertility and harvest index. Among males gca effects for grain yield per hill in BR 827-35-3-1, RTN 3, IR 64, IR 46 and KJT 2 was associated with grains per panicle, panicle length, productive tillers per hill and straw yield per hill. BR 827- 35-3-1, RTN 3 and IR 64 possesse negative (desirable) gca effect for days to 50 per cent flowering. These findings are in agreement with those reported by Yadav *et al.,* (1999)

Table 2. Summary of general combining ability effects of the parents for different characters based on pooled over environments in rice.

Characters / Parents	Days to 50% flowering	Productive tillers plant^{-1}	Plant height (cm)	Panicle length (cm)	No. of grains panicle^{-1}	Fertility (%)	100-grain weight(g)	Kernel length (mm)	L:B ratio	Grain yield hill^{-1} (g)	Straw yield hill^{-1} (g)	Harvest index (%)	Protein content (%)
Females													
IR-58025A	G	G	P	G	G	A	G	G	P	G	G	G	A
IR-68885A	G	A	G	P	G	P	P	A	G	A	A	A	P
IR-68886A	G	P	A	A	P	G	G	P	P	P	P	P	P
IR-68897A	P	A	P	A	G	A	P	P	G	P	A	A	G
Males													
RTN-711	G	P	G	A	G	G	P	G	G	P	P	A	G
KJT-3	G	A	G	P	P	A	G	P	P	P	P	A	G
Abhaya	G	A	G	A	P	P	P	P	A	P	P	A	P
IR-64	G	A	P	A	G	A	P	G	G	G	G	G	P
PNL-1	A	A	G	A	A	A	G	A	P	A	A	A	G
IR-46	G	G	A	P	G	A	P	G	G	G	G	A	G
IR-54	A	A	P	A	P	A	P	G	G	P	P	A	G
BR 827-35-3-1	A	G	P	G	G	G	G	A	A	G	G	G	P
RTN-3	A	G	P	P	G	A	G	P	P	G	G	G	A
KJT 14-7	P	A	G	G	G	A	P	G	A	G	G	A	P
KJT-2	P	P	P	P	P	A	P	G	G	P	P	P	P
Suwarna	P	A	P	A	P	A	P	G	G	A	A	A	G
IR-5	P	P	P	G	P	G	G	P	P	P	P	P	G
Gurjari	A	P	G	A	P	P	G	P	P	P	P	A	P
GR-11	P	P	G	P	G	P	P	G	A	P	P	A	G

Where,

G = Good parent having significant *gca* effect in desired direction

A = Average parent having either positive or negative but non-significant *gca* effects.

P = Poor parent having significant *gca* effects in undesired direction.

and Shunmugavalli *et al.* (1999). In general, it was seen from the Table 2 that among females IR 58025A and IR 68885A and among males BR 827-35-3-1, RTN 3, IR 64, IR 46 and KJT 2 were observed good general combiners for yield and most of the yield contributing characters. Therefore, these parents may be extensively used in future hybrid rice breeding programme.

The estimates of *sca* effects revealed that none of the hybrids was consistently superior for all the traits. The hybrid IR 58025A x BR 827-35-3-1 was superior or ranking first in productive tillers per hill, 100-grain weight, grain yield per hill, straw yield per hill and harvest index. Out of 60 hybrids studied, as many as 20 cross combinations exhibited significant positive *sca* effects for grain yield per hill on pooled basis. These 20 crosses also manifested significant and desired *sca* effects for some of the yield attributing traits *viz.*, productive tillers per hill (2), number of grains per panicle (14), fertility (7), 100-grain weight (10) and harvest index (4). Hence, hybrids with high *sca* effects for seed yield per hill were also associated with high and desired *sca* effects for yield contributing characters. The best three hybrids on the basis of significant positive *sca* effects for grain yield per hill were IR 58025A x BR 827- 35-3-1, IR 58025A x RTN 3 and IR 68885A x RTN 711. Of these three hybrids, IR 58025A x BR 827-35-3-1 depicted significant positive *sca* effects for number of grains per panicle, 100-grain weight, straw yield per hill, harvest index and protein content, whereas IR 58025A x RTN 3 exhibited significant positive *sca* effects for productive tillers per hill, panicle length, fertility, 100-grain weight and strawyield per hill.

A perusal of Table 3 showed a good agreement between best general combining parents and best performing parents for most of the traits. This suggested that while selecting the parents for hybridization programme, *per se* performance of parents should be given due weightage. It is also evident from Table 3 that the three best performing hybrids for various characters also had high heterotic response over better parent and standard checks and desired *sca* effects except one hybrid for the characters *viz.*, plant height, panicle length, kernel length and protein content. Therefore, it can be concluded that *per se* performance of parents and hybrids agrees well with general combining ability effects of parents and heterotic response of hybrids, respectively. Thus, the potentiality of a genotype to be used as a parent in hybridization, or a cross to be used as a commercial hybrid may be judged by comparing *per se* performance of parents and hybrids, alongwith combining ability effects of parents and heterotic response of hybrids. The crosses exhibiting higher *per se* performance, high heterosis and significant desirable *sca* effects (Table 3) for various traits involved either good x good, good x average, good x poor, average x good and poor x good combining parents. Thus, crosses exhibiting high *sca* effects did not always involve parents with high *gca* effects. It may be suggested that interallelic interactions were also important for these characters.

The best three hybrids for grain yield per hill *viz.*, IR 58025A x BR 827-35-3-1 (good x good), IR 58025A x RTN-3 (good x good) and IR 58025A x IR 46 (good x good) had significant desired *sca* effects and significant desired heterotic response over better parent as well as both standard checks.

Table 3. Summary of three best performance parents, best general combining parents and best performing hybrids alongwith their *sca* effect and per cent heterosis for various traits.

Character	Best performing parents		Best generated combiner		Best performing hybrids	*sca* effect	Hetero-beltiosis (%)	Standard heterosis over	
	Female	Male	Female	Male				SC-I	SC-II
Days to 50% flowering	IR-68897B	RTN-711	IR-68886A	Abhaya	IR-68886A x Abhaya	-0.73	-7.23**	-13.78**	-6.66**
	IR-68885B	Gurjari	IR-58025A	RTN-711	IR-58025A X Gurjari	-8.72**	-10.05**	-13.32**	-6.16*
		KJT-3	IR-68885A	KJT-3	IR-68885A x Abhaya	-1.36	-5.06*	-12.30**	-5.05*
Productive tillers hill^{-1}	IR-68885B	BR827-35-3-1	IR-58025A	BR827-35-3-1	IR-58025A x BR827-35-3-1	0.80	16.47	57.93**	39.64**
	IR-58025B	RTN-3	IR-68897A	RTN-3	IR-68897A x BR827-35-3-1	0.27	9.28	48.17**	31.01**
	IR-68886B	KJT 14-7		IR-46	IR-58025A x RTN-3	1.68*	13.94	45.16**	28.34**
Plant height	IR-68885B	Suwarna	IR-68885A	RTN-711	IR-68897A x RTN-711	-5.42**	0.99	-13.72**	-18.07**
	IR-68897B	RTN-711	IR-68886A	KJT-3	IR-68885A x RTN-711	0.13	1.28	-13.55**	-17.91**
	IR-68886B	KJT-3		Abhaya	IR-68886A x RTN-711	-4.06**	-1.53	-13.52**	-17.69**
Panicle length	IR-68886B	KJT 14-7	IR-58025A	KJT 14-7	IR-688897A x KJT 14-7	1.40**	8.29	27.90**	31.69**
	IR-58025B	PNL-1	IR-68886A	BR827-35-3-1	IR-68897A x IR-5	1.05	11.38*	22.52**	26.18**
	IR-68885B	IR-5		IR-5	IR-68886A x KJT14-7	-0.47	3.53	22.28**	25.90**
No. of grains panicle^{-1}	IR-58025B	GR-11	IR-68897A	IR-64	IR-68897A x IR-64	19.11**	43.54**	65.46**	1.67
	IR-68885B	KJT 14-7	IR-58025A	KJT 14-7	IR-68886A x RTN-3	37.42**	31.78**	63.78**	0.64
	IR-68886B	Suwarna	IR-68885A	BR 827-35-3-1	IR-68885A x GR-11	26.79**	9.77	63.09**	0.22
Fertility	IR-68885B	IR-46	IR-68886A	IR-46	IR-68885A x BR827-35-3-1	5.79**	1.81	-3.46	6.16*
	IR-68897B	Abhaya	IR-58025A	RTN-711	IR-68885A x RTN-711	2.96**	2.87	-5.23*	4.22
	IR-68886B	PNL-1		IR-54	IR-68897A x RTN-711	1.77	1.51	-6.49**	2.84

Table 3 Contd...

Character	Best performing parents		Best generated combiner		Best performing hybrids	sca effect	Hetero-beltiosis (%)	Standard heterosis over	
	Female	Male	Female	Male				SC-I	SC-II
100-grain weight	IR-68897B	RTN-3	IR-58025A	Gurjari	IR-58025A x BR827-35-3-1	0.22**	-0.12	-3.52	27.36**
	IR-68885B	Gurjari	IR-68886A	BR 827-35-3-1	IR-58025A x Gurjari	0.12**	-4.63**	-6.43**	23.51**
	IR-68886B	PNL-1		KJT-3	IR-68886A x RTN-3	0.21**	-7.44**	-7.75**	21.77**
Kernel length	IR-58025B	IR-54	IR-58025A	IR-64	IR-58025A x IR-64	-0.06	-0.46	6.87**	12.78**
	IR-68886B	IR-64		KJT-2	IR-58025A x GR-11	0.08	-0.15	6.38**	12.26**
	IR-68885B	RTN-711		Suwarna	IR-68885A x KJT-2	0.14**	4.68*	6.22**	12.09**
L:B ratio	IR-58025B	RTN-711	IR-68885A	KJT-2	IR-68897A x KJT-3	0.97**	38.55**	39.11**	20.63**
	IR-68885B	KJT 14-7	IR-68897A	Suwarna	IR-68897A x RTN-711	0.29**	-8.42*	35.89**	17.83**
	IR-68886B	Abhaya		RTN-711	IR-68885A x BR 827-35-3-1	0.58**	30.62**	35.89**	17.83**
Grain yield hill^{-1}	IR-58025B	BR 827-35-3-1	IR-58025A	BR 827-35-3-1	IR-58025A x BR 827-35-3-1	11.85**	60.49**	72.89**	46.89**
	IR-68885B	KJT-3	IR-68885A	RTN-3	IR-58025A x RTN-3	10.52**	49.32**	50.6**	27.96*
	IR-68886B	IR-5		IR-64	IR-58025A x IR-46	9.44**	40.29**	41.30**	20.04*
Straw yield hill^{-1}	IR-58025B	BR 827-35-3-1		BR 827-35-3-1	IR-58025A x BR 827-35-3-1	5.97**	27.36**	48.21**	29.99**
	IR-68886B	IR-5	IR-58025A	IR-46	IR-58025A x RTN-3	11.52**	32.66**	42.31**	24.81**
	IR-68885B	KJT-3		RTN-3	IR-58025A x IR-46	7.58**	33.16**	35.68**	19.01**
Harvest index	IR-68885B	IR-46	IR-58025A	BR 827-35-3-1	IR-58025A x BR 827-35-3-1	2.45**	12.01*	8.39**	7.23*
	IR-58025B	Abhaya	IR-68885A	RTN-3	IR-68897A x IR-64	2.34**	8.41**	5.48	4.37
	IR-68886B	KJT-3		IR-64	IR-68885A x BR 827-35-3-1	0.45	2.10	3.63	2.53
Protein content	IR-68897B	IR-5	IR-68897A	IR-5	IR-68886A x IR-5	0.99**	0.93	27.66**	22.87**
	IR-68886B	GR-11	IR-58025A	GR-11	IR-68897A x RTN-3	1.29**	10.41**	27.23**	22.56**
	IR-68885B	Gurjari		IR-46	IR-68897A x IR-5	-0.13**	-0.93	25.31**	20.71**

*, ** Significant at 5 and 1 per cent probability levels, respectively.

High yielding hybrids had high *sca* effects, high heterosis as well as high *per se* performance for most of the yield contributing characters. This appeared appropriate as yield being a complex character depends on a number of its component traits. Considering the *per se* performance, heterotic response and *sca* effects in desirable direction, hybrid IR 58025A x BR 827-35-3-1 showed its superiority for productive tillers per hill, 100-grain weight, straw yield per hill and harvest index, whereas IR 58025A x RTN 3 indicated superiority for number of tillers per hill and straw yield per hill (Table 3).

The data from Table 3 revealed that parents with good *per se* performance were in general, good combiners for most of the traits. Further, good general combiners may not necessarily produce good specific combinations for different traits. Similar results were reported by Ramalingam *et al.,* (1997). In many cases, it was observed that at least one good general combining parent was involved in heterotic hybrid having desirable *sca* effects. This was true for most of the traits studied. Parents with highest *gca* effect will not necessarily generate top specific cross combinations as also reported by Rao *et al.,* (1980) and Peng and Virmani (1990). This suggested that information of *gca* effects of parents should be considered alongwith *sca* effects and *per se* performance of hybrid for predicting the value of any hybrid. It is desirable to search out parental lines with high *gca* effects and low sensitivity to environmental variation in a crop improvement programme.

The hybrids IR 68886A x RTN 3, IR 68897A x IR 64, IR 68897A x BR 827-35-3-1 and IR 68885A x RTN 711 resulted from one good and one poor general combiners. This might be due to dominant x recessive type of interaction with non-additive, non-fixable genetic component for grain yield. Random mating and selection among the segregants could lead to transgressive desirable early segregants in later generations. With respect to combining ability effects, following broad inferences could be drawn from the present study.

i) In general, the crosses showing desirable *sca* effects for grain yield also had high *sca* effects for yield contributing characters *viz.* productive tillers per hill, panicle length, number of grains per panicle, fertility, 100-grain weight and straw yield per hill and harvest index.

ii) The crosses having best heterotic effects of various traits always involved one good general combining parent for that character.

iii) Best performing parents were mostly good general combiners for majority of the traits.

iv) The crosses exhibiting high heterosis with desirable *sca* effects did not always involve parents with high *gca* effects, thereby suggesting the importance of interallelic interaction. However, it was also observed that at least one good general combiner was involved in best performing cross combinations.

From the above discussion, it is clear that hybrids IR 58025A x BR 827-35-3-1, IR 58025A x RTN 3 and IR 58025A x IR 46 having high mean, high heterosis over better parents and standard checks, desirable *sca* effects for grain yield per hill and its related traits can be exploited in practical breeding.

It is also clear that the high degree of non-additive gene action for grain yield and its component traits observed in the present study favours hybrid breeding programme. The two characters *viz.*, 50 per cent flowering and productive tillers per hill can be improved through selection (pure line/progeny) due to their additive gene action. The evaluation of hybrids has suggested that a substantial degree of heterosis over better parent and standard checks Jaya and Pro-agro 6201 were available in several crosses.

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