Combining ability analysis for yield in hybrid rice

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ABSTRACT

Sixty hybrids developed from crossing four CMS lines with 15 restorers were studied alongwith 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 L:B ratio of grain. The most promising specific combinations were IR 58025A x XBR-827-35-3-1, IR-58025A x RTN-3 and IR-68885AxRTN-711 for grain yield hill^{-1}.

Key words: *Combining ability, hybrid rice, yield, components*

The breeding methods to be adopted for improvement of a crop depend 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 efficient breeding programmes 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 restorers.

MATERIALS 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-l IR-46 IR-54 BR-827-35-3-1-1 RTN-3 KJT-14-7 KJT-2 Swarna, IR-5, Gurjari and GR-ll. All the 60 F_{1s}, 19 parents along with one inbred check Jaya (SC-l) and one hybrid check Pro agro-6201 (SC-II) 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 wet season 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 hill^{-1}, plant height, panicle length, number of grains panicle^{-1}, fertility, 100 grain weight, length of kernel, L:B ratio, grain yield hill^{-1}, straw yield hill^{-1}, harvest index and, protein content. Combining ability analysis was calculated following the method suggested by Kempthorne (1957). The pooled mean value 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 for combining ability for the data pooled across the environments revealed that both additive as well as non-additive variances were important in the inheritance of various traits as evident from significance of 1emales, males and females x males interaction for all the characters except panicle length, number of grains panicle^{-1}, fertility, 100-grain weight, kernel length, L:B ratio, straw yield hill^{-1}, harvest

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index and protein content for females, number of grains panicle^{-1} for males. The magnitude of specific combining ability (sca) variances were higher than the general combining ability (gca) variances for all the characters except days to 50 per cent flowering and. productive tillers hill^{-1} which indicated preponderance of non- additive gene action in the inheritance of these traits, while preponderance of additive type of gene action in days to 50 per cent flowering and productive tillers hill^{-1}. This was further supported by low magnitude of σ^2 gca : σ^2 sca ratios. Preponderance of non-additive variance in the expression of different traits in rice have 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), Singh *et al.* (1996) 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 panicle^{-1}, 100-grain weight, kernel length, L:B ratio and protein content as well as mean squares due to females x locations were non-significant for number of grains panicle^{-1}, 100-grain weight, L:B ratio, and harvest index, which indicated that gca variances of females and males were not influenced by the environments in 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 1). 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); IR-68885A was found good general combiner for plant height and L: B ratio while IR-68897 A was good combiner for protein content only.

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 hill^{-1} in BR 827-35-3-1, RTN-3, IR-64, IR-46 and KJT -2 was associated with grains panicle^{-1}, panicle length, productive tillers hill^{-1} and straw yield hill^{-1}. BR 827-35-3-1, RTN-3 and IR-64 possessed negative (desirable) gca effects for days to 50 per cent flowering. These findings are in agreement with those reported by Yadav *et al.* (1999), Shunmugavalli *et al.* (1999). In general, it was observed (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 good general combiner 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 hill^{-1}, 100-grain weight, grain yield hill^{-1}, straw yield hill^{-1} and harvest index. Out of 60 hybrids studied, as many as 20 cross combinations exhibited significant positive sca effects for grain yield hill^{-1} on pooled basis. These 20 crosses also manifested significant and desired sca effects for some of the yield attributing traits *viz.*, productive tillers hill^{-1} (2), number of grains panicle^{-1} (14), fertility (7), 100-grain weight (10) and harvest index (4). Hence, hybrids with high sca effects for seed yield hill^{-1} 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 hill^{-1} were IR-58025A x BR 827-35-3-1, IR-58025A x RTN-3 and IR- 68885A x RTN- 711. Of these, IR-58025A x BR 827-35-3-1 depicted significant positive sca effects for number of grains panicle^{-1}, 100-grain weight, straw yield hill^{-1}, harvest index and protein content, whereas IR- 58025A x RTN-3 exhibited significant positive sca effects for productive tillers hill^{-1}, panicle length, fertility, 100-grain weight and straw yield hill^{-1}.

A perusal of Table 2 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 1. Summary of general combining ability effects of the parents for different characters based on pooled data from three locations in Gujrat

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-58025B	G	G	P	G	G	A	G	G	P	G	G	G	A
IR-68885B	G	A	G	P	G	P	P	A	G	A	A	A	P
IR-68886B	G	P	A	A	P	G	G	P	P	P	P	P	P
IR-68897B	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-I	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-II	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

Table 2. Summary of three best performing 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 general combiner		Best performing hybrids	sca effect	Heterobeltiosis (%)	Standard heterosis over	
	Female	Male	Female	Male				SC-I	SC-II
Days to 50 % flowering	IR-68897B	R TN - 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	BR 827-35-3-1	IR-58025A	BR 827-35-3-1	IR-58025A x BR 827-35-3-1	0.80	16.47	57.93**	39.64**
	IR-58025B	RTN-3	IR-68897 A	R TN - 3	IR-68897A x BR 827-35-3-1	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	R TN - 7 I I	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-68897A x KJT 14-7	1.40**	8.29	27.90**	31.69**
	IR-58025B	PNL-l	IR-68886A	BR 827-35-3-1	IR-68897 A x IR-5	1.05	11.38*	22.52**	26.18**
	IR-68885B	IR-5		IR-5	IR-68886A x KJT 14-7	-0.47	3.53	22.28**	25.90**
No. of grains panicle-!	IR-58025B	GR-II	IR-68897 A	IR-64	IR-68897A x IR-64	19.11**	43.54**	65.46**	1.67
	IR-68885B	KJT 14-7	IR-58025A	KJT]4-7	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 BR 827-35-3-1	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-I		IR-54	IR-68897 A x RTN-711	1.77	1.51	-6.49**	2.84
100-grain weight	IR-68897B	RTN-3	IR-58025A	Gurjari	IR-58025A x BR 827-35-3-1	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-I		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**
LB ratio	IR-58025B	RTN-711	I R-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-68897 A x RTN-711	0.29**	-8.42*	35.89**	17.83**
	IR-68886B	Abhaya		RTN-7]]	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 827-3S-3-1	11 .85**	60.49**	72.89**	46.89**
	IR-68885B	KJT-3	IR-68885A	RTN - 3	IR-58025A x RTN-3	1 0.52**	49.32**	50.60**	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**
	I R-6888513	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-S8025B	Abhaya	IR-68885A	RTN-3	IR-68897 A 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-68897 A	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. I3**	-0.93	25.31**	20.71**

*,** Significant at 5 and p percent probability levels, respectively

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 hybrids 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 gca 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 2) 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 hill^{-1} *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. 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 hill^{-1}, 100-grain weight, straw yield hill^{-1} and harvest index, whereas IR-58025A x RTN-3 indicated superiority for number of tillers hill^{-1} and straw yield hill^{-1} (Table 3).

The data from Table l 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 Ramlingam *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 at.* (1980), 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-68897 A x IR-64, IR-68897 A 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 hill^{-1}, panicle length, number of grains panicle^{-1}, fertility, 100-grain weight, straw yield hill^{-1} 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 results 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 hill^{-1} 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.*, days to 50 per cent flowering and productive tillers hill^{-1} can be improved through selection (pure line/progeny) due to their additive gene action. The evaluation of hybrids have suggested that a substantial degree of heterosis over better parent and standard check Jaya and Pro-agro-6201 were available in several crosses.

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