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COMBINING ABILITY ANALYSIS FOR YIELD AND YIELD CONTRIBUTING TRAITS USING CYTOPLASMIC MALE STERILE LINES IN AROMATIC HYBRIDS OF RICE

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ABSTRACT

Combining ability was studied for 60 F_1 aromatic rice hybrids involving three CMS lines and 20 aromatic testers using line × tester analysis along with 23 parents for yield and yield contributing traits. Variance of SCA was higher than that of GCA for all the characters suggesting the significant role of non-additive gene action on the inheritance of these characters. The relative contribution of lines, testers and combination of line × tester for all characters were calculated. It was found that lines were more important and their contribution was high for most of the traits indicated highly influence by maternal effects. Among the lines CRMS31A and tester *viz*. Indrabhesh Dubraj, Nagri Dubraj, Barhasal and Tarunbhog was identified as good general combiner. SCA effects of all the crosses revealed a very wide range of variation for all the characters. Cross combination CRMS31A × Tarunbhog, IR58025A × Indrabhes Dubraj and CRMS31A × Barhasal showed high magnitude of SCA effects for multiple traits. It was identified as the most promising hybrid.

Key words : Combining ability, L × T analysis, GCA, SCA, Hybrid rice.

Introduction

Rice is a staple food for a huge population and their food security. About half of the world's population depends on rice for their survival. It is very important to enhance rice production to satisfy the needs of this important crop. Exploitation of heterosis in rice has been recognized as practical tool improving yield and other important traits for developing promising varieties through hybridization. It is easy to obtain 15-20% higher yield just growing hybrid rice compared with the common varieties (Faiz *et al*., 2006). In breeding point of view, selection of right type of breeding material is crucial step for plant breeder in developing the high yielding variety or hybrid. Further the breeding methods to be adopted for improvement of any crop depends on the nature of gene action involved in the inheritance of economically important traits. The line × tester analysis is a powerful tool in selecting appropriate parental material and predicting type of gene action involved in the inheritance of various traits. It provides information about general combining ability and specific combining ability effects of parents and the best way to estimate different types of gene actions. General combining ability (GCA) is attributed to additive gene effects and additive × additive epistasis, and is theoretically fixable. On the other hand, specific combining ability attributable to non-additive gene action may be due to dominance or epistasis or both and is non-fixable. The presence of non-additive genetic variance is the primary justification for initiating the hybrid programme (Cockerham, 1961 and Pradhan *et al*., 2006). Therefore, the knowledge of combining ability provides information on the nature and magnitude of gene effects that regulate grain yield and yield characters hence enabling the breeder to design an effective breeding method for genetic enhancement of grain yield and yield components (Yuga *et al*., 2018). Thus, the main objective of the present study was to estimate combining ability for yield

and its contributing traits and to know the best hybrid combinations for breeding programs.

Materials and Methods

The present investigation was carried out during two season's *viz.*, *Kharif*-2019 and *Kharif*-2020 at the Director cum Instructional farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India. Twenty aromatic rice genotypes including traditional varieties/land races and three CMS lines were selected for crossing programme (Table 1).

Table 1 : Details of lines and testers used in the present study.

S.N.	Female Parent (Lines)	Cytoplasmic source	Source
1	IR 58025A	Wild Abortive (WA)	IRRI, Manila, Philippines
2	CRMS31A	Kalinga	NRRI, Cuttack, Orissa
3	CRMS32A	Kalinga	NRRI, Cuttack, Orissa
Male Parent (Testers)			
1	KALA JEERA	**11**	BASABHOG
2	TILKASTURI	**12**	SAMUNDCHINI
3	DHANIYA PHOOL	**13**	KALIMUCH
4	KASTURIBHOG	**14**	JAWA PHOOL
5	INDRABHES DUBRAJ	**15**	TARUNBHOG
6	CHI NNOR	**16**	NAGRI DUBRAJ
7	TULSI MOGRA	**17**	JAO PHOOL
8	KALIKAMOD	**18**	DAGRI KAJAR
9	RAMJEERA	**19**	TULSI BHOG
10	DHANIYA DHAN	**20**	BARHASAL
Checks			
1	C.G. DEVBHOG		
2	DUBRAJ SELECTION-1		
3	PUSA RH 10		

During *kharif* 2019, twenty genotypes were selected on the basis of their quality and aroma for generating F_1 crosses and all the genotypes were seeded in nursery at 3 dates, 10 days apart and transplanted in crossing blocks at 21 days after sowing. Crosses are made in Line × Tester fashion to developed 60 F_1 hybrids. In *kharif* 2020 these 60 F_1 hybrids, were raised at a standard spacing of 20 × 20 cm with twenty parents and standard checks were grown in a randomized block design with three replications.

The observation were recorded from each replication for both yield and quality traits *viz.*, days to 50% flowering, plant height (cm), panicle length (cm), no. of tillers per plant, productive tillers per plant, pollen fertility (%), fertile spikelets/panicle, sterile spikelets/panicle, total spikelets/ panicle, spikelet fertility (%), grain yield per plant (g), 1000 grain weight (g) and harvest index (%).

Results and Discussion

The present investigation was undertaken to assess the combining ability for yield and yield attributing traits in order to identify appropriate genotypes as parents in the hybridization programmes. Sixty F_1 hybrids from three CMS lines and 20 aromatic testers were evaluated to study the combining ability for various yields and yield contributing traits. Analysis of variance for all the genotypes GCA variance was found highest for number of fertile spikelets per panicle (100.73) followed by total spikelets per panicle (29.92), number of sterile spikelets per panicle (23.33), pollen fertility (11.91), spikelet fertility percent (11.71), biological yield per plant (5.8), grain yield (3.99), harvest index (3.04), plant height (1.90), thousand grain weight (0.12), number of tillers per plant (0.05), spikelet fertility (0.03), productive tillers per plant (0.028), days to 50% flowering (0.025) and panicle length (0.02).

The SCA variance was found highest for total number of spikelets per panicle (1158.84), followed by number of sterile spikelets per panicle (1157.16), number of fertile spikelets per panicle (1131.55), pollen fertility percent (338.78), spikelet fertility percent (299.89), harvest index (54.6), grain yield (35.49), plant height (26.10), days to 50% flowering (10.05), biological yield per plant (9.81), productive tillers per plant (1.41), number of tillers per plant (1.28), panicle length (0.75) and thousand grain weight (0.64). The comparative variances due to general combining ability and specific combining ability for different characters under study and their ratio presented in Table 2.

The higher magnitude of SCA than GCA variance and low predictability ratio was observed in all the characters. This suggested significant role of non-additive gene action which resulted from dominance, epistatic and various other interaction effects. Predominance of non-additive genetic variance indicated the presence of heterozygosity in the population. As such this type of genetic variance is non-fixable and thus development of hybrids is an appropriate crop improvement tool. Breeding methods such as biparental matting followed by recurrent selection may increase the frequency of genetic combinations and break undesirable linkages. Similar findings have been reported by Ramesh *et al.* (2018)

Table 2 : Analysis of Variance for combining ability.

Source of variation	df	Characters													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Replication	1	1.99	4.80**	1.06**	0.47**	5.80**	4.92	2.97	0.24	0.29	0.66**	11.57**	0.02	0.03	0.47**
Crosses	59	23.04**	184.89**	6.77**	4.88**	1500.77**	9221.75**	4757.59**	4391.72**	1408.47**	3.06**	421.69**	346.83**	9.75**	319.5**
Lines (C)	2	30.58**	88.82**	29.77**	13.78**	1044.30**	3356.09**	1389.68**	3263.45**	790.63**	8.61**	7.67**	11.77**	0.75**	16.19**
Testers (C)	19	25.71**	458.52**	12.24**	7.8**	3193.79**	23750.49**	8333.99**	8643.47**	3090.18**	5.45**	1266.39**	933.60**	27.59**	771.5**
Line × Testers (C)	38	21.3**	53.14**	2.82**	2.95**	678.29**	2266.09**	3146.65**	2325.23**	600.13**	1.57**	21.13**	71.07**	1.29**	109.5**
Error	59	1.18	0.92	0.25	0.097	0.72	2.98	4.01	7.16	0.36	0.08	1.5	0.084	0.023	0.12
Variance of GCA		0.025	1.90	0.05	0.028	11.91	100.73	23.33	29.92	11.71	0.02	5.8	3.99	0.12	3.04
Variance of SCA		10.05	26.10	1.28	1.43	338.78	1131.55	1571.16	1158.84	299.89	0.75	9.81	35.49	0.64	54.7

*- significant at 5% level of significance, **- significant at 1% level of significance
1. Days to 50% flowering 2. Plant height (cm) 3. No. of tillers/plant 4. Productive tillers/plant 5. Pollen fertility (%)
6. Fertile spikelets/Panicle 7. Sterile spikelets/panicle 8. Total Spikelets/Panicle 9. Spikelet Fertility (%) 10. Panicle Length(cm)
11. Biological yield (g) 12. Grain yield (g)/plant 13. Thousand seed weight (g) 14. Harvest index (%)

and Gramaje *et al*. (2020).

The estimates of GCA, SCA effects and magnitude of additive and dominance variance were worked out for all the traits presented in Tables 3 and 4.

A good restorer of pollen fertility must have the spikelet and pollen fertility more than 70 per cent for producing a well fertile F_1 hybrid. Among the lines, only IR58025A observed significant positive general combining ability (GCA) effect. CRMS31A and CRMS32A were observed to have negative general combining ability (GCA) effect. Thus, only IR58025A can be used as pollen fertility restorer. Among the testers, six (06) out of 20 namely, Indrabhes Dubraj (59.34), Nagri Dubraj (50.76), Barhasal (19.56), Kalimuch (17.97), Tarunbhog (17.26) and Jaophool (1.29) had significant positive GCA value. These are. Thirteen (13) testers had negative GCA value for pollen fertility. Among the 60 hybrids, 55 hybrids had significant SCA effects; among these 28 hybrids have shown the positive significant SCA effects and 27 hybrids have shown the negative significant effect for percent of pollen fertility. The highest positive significant SCA effect has shown by cross IR58025A × Kalajeera (30.68) followed by CRMS31A × Tarunbhog (30.27) and CRMS31A × Barhasal (29.67).

For fertile spikelets per panicle, only IR58025A (9.63) observed significant positive general combining ability (GCA) effect among lines. CRMS31A (-1.03) and CRMS32A (-8.60) were observed to have negative general combining ability (GCA) effect. Among the testers, Indrabhes Dubraj (181.33), Nagri Dubraj (152.48), Tarunbhog (56.61), Barhasal (28.18) and Kalimuch (16.40) had significant positive GCA value for fertile spikelets per panicle. Rest all the testers have negative GCA for this trait. Among the 60 hybrids, 55 hybrids have shown significant SCA effects; among these 25 hybrids have shown the positive significant SCA effect and 30 hybrids have shown the negative significant effect for fertile spikelets per panicle. The highest positive significant SCA effect has shown by cross CRMS 31A x Tarunbhog (72.99), CRMS31A × Barhasal (71.73) and CRMS31A × Kalimuch (44.21).

Sterility of spikelets per panicle, IR58025A (-4.77) and CRMS32A (-1.82) showed highly negative significant GCA effects whereas, CRMS31A (6.59) had significant positive GCA effects among the lines. Testers namely, Indrabhes Dubraj (-88.32), Nagri Dubraj (-73.51), Kalimuch (-39.94), Barhasal (-31.52), Jaophool (-9.51), Dhaniyaphool (-9.31), Tarunbhog (-7.07), Tilkasturi (-6.72), Kalajeera (-6.32) and Samindchini (-1.94) had significant negative GCA values and hence were identified

Table 3 : General Combining Ability (GCA) effect of different parents.

LINES	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
IR 58025A	0.54**	1.29**	0.57**	0.40**	5.74**	9.63**	-4.77**	4.86**	4.92**	0.52**	-0.2	-0.18**	-0.15**	0.41**
CRMS 31A	-1.01**	0.34*	0.42**	0.28**	-1.67**	-1.03**	6.59**	5.56**	-1.21**	-0.16**	0.50*	0.61**	0.04	0.33**
CRMS 32A	0.47**	-1.63**	-0.99**	-0.67**	-4.07**	-8.60**	-1.82**	-10.42**	-3.72**	-0.36**	-0.31	-0.43**	0.11**	-0.73**
TESTERS														
KALA JEERA	2.49**	4.39**	0.33	0.89**	-16.56**	-39.66**	-6.32**	-45.98**	-15.29**	0.26*	-15.04**	-8.33**	-1.42**	-8.23**
TILKASTURI	-1.01**	-0.79*	-1.77**	-1.23**	-18.77**	-44.02**	-6.72**	-50.74**	-16.65**	-0.45**	-19.43**	-9.03**	-0.62**	-9.07**
DHANIYA PHOOL	-0.58	5.34**	-1.66**	-0.98**	-1.89**	-23.85**	-9.31**	-33.16**	-3.49**	-0.05	-7.44**	-4.79**	-0.14*	-3.77**
KASTURIBHOG	-0.64	6.91**	-0.65**	-1.05**	-7.67**	-21.59**	34.76**	13.17**	-10.33**	-0.77**	-3.08**	-4.71**	-0.17**	-4.29**
INDRABHES DUBRAJ	4.43**	-31.48**	1.27**	2.44**	59.34**	181.33**	-88.32**	93.01**	57.60**	-2.00**	35.16**	38.81**	4.75**	31.51**
CHINNOR	1.15*	-0.54	-1.72**	-0.93**	-28.96**	-55.51**	47.83**	-7.68**	-26.83**	-1.60**	-2.05**	-9.35**	-0.84**	-10.65**
TULSI MOGRA	1.82**	2.72**	0.31	0.32*	-024	-13.45**	19.99**	6.54**	-4.09**	0.46**	-0.49	-2.9**	-2.67**	-2.30**
KALIKAMOD	-1.42**	2.91**	0.32	-0.26*	-11.97**	-34.79**	18.61**	-16.18**	-13.24**	0.66**	-9.68**	-4.92**	-0.24**	-3.72**
RAMJEERA	1.35**	7.97**	-1.40**	-0.75**	-16.51**	-34.99**	25.53**	-9.46**	-16.87**	1.25**	-7.16**	-7.64**	-1.47**	-7.96**
DHANIYA DHAN	-1.11*	5.06**	-0.62**	-0.85**	-5.02**	-12.99**	28.16**	15.17**	-4.77**	1.76**	6.58**	-3.76**	-0.03	-4.06**
BASABHOG	0.82	2.54**	0.82**	-0.11	-2.62**	-12.92**	2.59**	-10.33**	-3.84**	0.93**	-6.30**	-2.08**	-1.19**	-0.07
SAMUNDCHINI	-1.66**	5.51**-	1.13**	-0.50**	-5.57**	-19.44**	-1.94*	-21.38**	-5.90**	0.43**	-12.20**	-4.53	-1.80**	-2.63**
KALIMUCH	-5.63**	3.01**	0.50*	0.97**	17.97**	16.40**	-39.94**	-23.54**	18.43**	-1.07**	-0.08	2.56**	0.24**	4.84**
JAWAPHOOL	-0.34	-0.81*	-1.68**	-1.23**	-7.25**	-20.79**	28.14**	7.36**	-6.59**	-0.43**	-9.00**	-5.04**	-1.12**	-4.20**
TARUNBHOG	0.99*	5.96**	0.32	0.59**	17.26**	56.61**	-7.07**	49.54**	20.09**	-0.15**	-1.91**	5.55**	-0.87**	8.93**
NAGRI DUBRAJ	0.17	-4.44**	0.57**	1.49**	50.76**	152.48**	-73.51**	78.97**	51.44**	-0.65**	19.73**	28.18**	1.53**	27.83**
JAO PHOOL	0.67	0.08	-2.17**	-1.70**	1.29**	-19.87**	-9.51**	-29.38**	-0.05	0.15	-8.33**	-3.31**	-1.35**	-1.47**
DAGRI KAJAR	-1.93**	-12.21**	0.85**	0.32*	-24.76**	-41.34**	61.18**	19.84**	-22.64**	-0.04	16.09**	-6.40**	2.95**	-8.31**
TULSI BHOG	-1.13*	1.09**	2.05**	0.74**	-18.39**	-37.81**	7.36**	-30.45**	-16.09**	0.04	-5.29**	-7.11**	-1.14**	-7.45**
BARHASAL	1.54**	2.79**	3.20**	1.82**	19.56**	26.18**	-31.52**	-5.34**	19.11**	1.28**	29.9**	8.81**	5.61**	5.09**
SE	0.44	0.39	0.20	0.12	0.34	0.70	0.81	1.09	0.24	0.11	0.50	0.11	0.06	0.14

*- significant at 5% level of significance, **- significant at 1% level of significance.

1. Days to 50% flowering
2. Plant height (cm)
3. No. of Tillers
4. Productive tillers
5. Pollen fertility (%)
6. Fertile spikelets/Panicle
7. Sterile spikelets/panicle
8. Total spikelets/Panicle
9. Spikelet Fertility (%)
10. Panicle length(cm)
11. Biological yield (g)
12. Grain yield (g)
13. Thousand seed weight
14. Harvest index (%)

Table 4 : Specific Combining Ability (SCA) effect of different hybrids.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
IR58025A														
KALA JEERA	0.85	-1.76*	0.27	-0.01	20.68**	9.31**	-27.11**	12.20**	27.50**	0.58**	-1.20	7.05**	-0.08	11.27**
TILKASTURI	3.40**	0.42	-1.69**	-0.65**	2.20**	4.47**	26.89**	31.36**	0.43	0.69**	-3.00**	1.95**	0.47**	3.22**
DHANIYA PHOOL	2.80**	-5.26**	-0.84*	-0.15	-15.98**	-15.60**	40.02**	24.42**	-14.04**	0.19	2.50**	-1.86**	0.74**	-3.72**
KASTURIBHOG	3.53**	4.37**	-1.50**	-0.73**	-6.90**	0.69	6.15**	6.84**	-1.11*	0.31	-0.61	0.18	0.42**	-0.36
INDRABHES DUBRAJ	0.50	-8.29**	1.63**	1.09**	29.27**	35.52**	-51.44**	26.96**	28.37**	-0.06	2.70**	7.92**	0.40**	11.56
CHINNOR	-0.57	7.27**	0.46	-0.30	-11.22**	-17.39**	-24.26**	-41.66**	-9.25**	1.04**	5.21**	-2.23**	-0.46**	-3.88**
TULSI MOGRA	-5.19**	4.11**	1.86**	1.40**	-1.78**	-8.40**	-17.28**	-25.68**	-1.36**	0.27	2.75**	0.73**	0.32**	-0.10
KALIKAMOD	-4.75**	0.82	1.43**	1.63**	14.20**	12.79**	-34.00**	-21.21**	11.85**	0.98**	2.80**	2.25**	-0.16	2.28**
RAMJEERA	-3.57**	6.76**	-0.05	-0.23	12.33**	23.89**	0.09	23.97**	11.18**	0.44*	-1.53	3.49**	-0.43**	4.64**
DHANIYA DHAN	1.99*	6.02**	-1.19**	-0.78**	2.05**	13.09**	11.35**	24.44**	0.38	-0.42*	-8.72**	0.68**	0.45**	1.18**
BASABHOG	-1.34	-1.56*	0.93*	0.64**	13.20**	34.07**	-15.13**	18.94**	15.98**	-0.09	1.96*	4.55**	0.54**	5.39**
SAMUNDCHINI	-0.45	7.17**	0.16	0.22	12.05**	35.39**	7.10**	42.49**	12.39**	0.72**	1.41	4.2**	0.11	5.63**
KALIMUCH	5.27**	0.54	0.25	-0.15	-14.94**	-32.95**	14.60**	-18.34**	-14.77**	-0.14	-0.75	-3.71**	0.33**	-5.33**
JAWAPHOOL	1.18	-4.26**	-0.10	0.25	23.27**	37.94**	-43.93**	-15.99**	21.47**	-0.70**	2.59**	7.3**	0.19	9.84**
TARUNBHOG	-0.40	-6.28**	-1.97**	-2.71**	-25.14**	-51.56**	59.54**	7.97**	-24.98**	-1.56**	-2.03*	-9.68**	-0.03	-12.98**
NAGRI DUBRAJ	0.57	-4.38**	-0.12	0.19	-2.98**	-9.23**	9.57**	0.34	-6.50**	1.75**	1.60	-1.93**	-0.24*	-3.25**
JAO PHOOL	-2.59**	-7.99**	0.01	0.77**	15.73**	4.92**	-41.83**	-36.91**	13.93**	-1.36**	-3.16**	0.18	0.02	0.26
DAGRI KAJAR	-2.19**	5.54**	1.30**	2.00**	-15.27**	-31.96**	-30.31**	-62.28**	-13.86**	-0.62**	-0.13	-5.14**	-3.35**	-6.23**
TULSI BHOG	1.86*	-1.01	0.80*	-0.21	14.86**	26.01**	-2.80	23.21**	14.09**	-0.89**	1.15	4.23**	0.44**	5.18**
BARHASAL	-0.90	-6.26**	-0.65	-1.85**	-42.08**	-70.98**	69.89**	-1.09	-39.94**	-1.14**	-2.54**	-13.5**	0.34**	-13.04**
CRMS31A														
KALA JEERA	-0.46	1.40*	-0.09	0.11	-17.27**	-23.74**	32.63**	8.89**	-15.67**	-0.94**	0.15	-4.08**	0.33**	-6.22**
TILKASTURI	-4.36**	2.63**	0.56	-0.38	9.20**	6.33**	-30.82**	-24.50**	9.91**	-0.77**	2.20*	0.36	0.18	1.02**
DHANIYA PHOOL	-3.09**	-0.65	-0.70	-0.83**	6.97**	12.86**	-19.44**	-6.58**	8.91**	0.13	-0.95	-0.15	-0.11	0.37
KASTURIBHOG	0.17	-6.17**	2.19**	-0.06	3.00**	-7.61**	-19.51**	-27.11**	0.75	0.15	3.04**	-1.91**	0.17	-2.58**
INDRABHES DUBRAJ	0.80	-3.11**	1.83*	1.81**	20.43	32.92**	-17.07**	30.00**	22.58**	-0.02	1.75**	6.48**	0.34**	10.59*
CHINNOR	2.08**	-5.42**	-0.34	0.22	-4.57**	-6.59**	47.58**	40.98**	-4.09**	-1.02**	-1.89*	-3.04**	-0.06	-3.81**
TULSI MOGRA	-0.69	-9.04**	-1.72	-1.33**	11.22**	15.26**	-28.39**	-13.13**	9.60**	-0.94**	-3.70**	-0.99**	-0.37**	-0.32
KALIKAMOD	2.19**	1.63*	-0.72*	-0.84**	-8.30**	-7.46**	28.29**	20.84**	-6.88**	-0.04	-5.30**	-2.13**	0.20	-1.91**
RAMJEERA	1.13	-0.99	0.09	-0.16	0.08	-5.96**	14.33**	8.37**	-2.15**	0.18	-0.37	0.24	0.12	0.82**
DHANIYA DHAN	-4.81**	-2.37**	1.01**	1.19**	-28.94**	-50.41**	48.99**	-1.41	-26.63**	0.06	7.23**	-8.58**	-1.06**	-10.42**
BASABHOG	-0.54	-2.35**	0.03	-0.19	-1.75**	-6.72**	18.31**	11.59**	-3.86**	-0.30	-3.14**	0.41*	-0.36**	1.77**

Table 4 continued...

Table 4 continued...

SAMUNDCHINI	1.84*	-1.57*	-1.29**	-0.81**	0.65	-17.86**	-26.96**	-44.81**	-2.48**	-0.06	-3.09**	-1.51**	-0.30**	-1.30**
KALIMUCH	-0.89	-0.30	0.24	0.37	15.99**	44.21**	-21.96**	22.25**	18.18**	0.55**	0.55	5.37**	-0.22*	7.29**
JAWAPHOOL	1.67*	1.65*	0.17	0.87**	-26.65**	-41.50**	78.21**	36.71**	-24.49**	0.40*	-3.06**	-7.38**	-0.42**	-10.26**
TARUNBHOG	3.64**	7.53**	2.23**	3.11**	30.27**	72.99**	-70.02**	2.97	29.95**	0.98**	3.35**	14.6**	0.17	18.78**
NAGRI DUBRAJ	3.86**	3.48**	-0.87*	-0.64**	1.77**	-4.37**	-12.39**	-16.76**	2.86**	-0.87**	1.38	0.68**	0.28*	0.14
JAO PHOOL	-0.59	4.86**	-1.09**	-1.46**	-11.87**	-1.27	42.71**	41.44**	-9.78**	0.68**	1.36	0.09	0.33**	0.32
DAGRI KAJAR	1.06	-1.60*	-0.46	-1.63**	5.28**	-1.26	-32.92**	-34.18**	3.71**	-0.49*	1.09	0.82**	2.09**	1.11**
TULSI BHOG	-2.74**	2.55**	-0.31	0.01	-15.18**	-25.70**	2.99*	-22.71**	-14.76**	1.46**	0.50	-5.21**	-0.50**	-6.91**
BARHASAL	-0.26	3.65**	0.24	1.62**	29.67**	71.73**	-44.57**	27.15**	27.85**	0.85**	2.37**	13.8**	-0.14	12.70**
CRMS32A														
KALA JEERA	-0.39	0.36	-0.18	-0.09	-13.42**	-15.57**	-5.52**	-21.09**	-11.82**	0.36	1.05	-2.97**	-0.25*	-5.05**
TILKASTURI	0.96	-3.05**	1.13**	1.02**	-11.40**	-10.80**	3.93**	-6.86**	-10.35**	0.08	0.81	-2.32**	-0.65**	-4.25**
DHANIYA PHOOL	0.29	5.91**	1.54**	0.97**	9.02**	2.74*	-20.58**	-17.84**	5.13**	-0.32	-1.55	2.01**	-0.63**	3.35**
KASTURIBHOG	-3.70	1.80**	-0.69	0.79**	3.90**	6.92**	13.35**	20.27**	1.86**	-0.46*	-2.43**	1.74**	-0.59**	2.94**
INDRABHES DUBRAJ	-1.30	3.18**	1.46**	1.49**	13.83**	17.40**	-5.64**	23.04**	18.78**	0.08	1.55	6.17	0.56**	6.60**
CHINNOR	-1.51	-1.85**	-0.12	0.07	15.79**	23.99**	-23.32**	0.67	13.34**	-0.02	-3.32**	5.27**	0.52**	7.69**
TULSI MOGRA	5.88**	4.93**	-0.15	-0.08	-9.43**	-6.86**	45.67**	38.81**	-8.24**	0.66**	0.94	0.27	0.05	0.41
KALIKAMOD	2.56**	-2.45**	-0.71*	-0.79**	-5.90**	-5.33**	5.70**	0.37	-4.97**	-0.94**	2.51**	-0.12	-0.04	-0.37
RAMJEERA	2.44**	-5.77**	-0.04	0.39	-12.42**	-17.93**	-14.41**	-32.34**	-9.02**	-0.62**	1.90*	-3.72**	0.31**	-5.46**
DHANIYA DHAN	2.82**	-3.65**	0.18	-0.41	26.90**	37.32**	-60.35**	-23.03**	26.25**	0.36	1.49	7.9**	0.61**	9.24**
BASABHOG	1.88*	3.91**	-0.96**	-0.44*	-11.45**	-27.35**	-3.18*	-30.53**	-12.12**	0.39*	1.18	-4.95**	-0.18	-7.16**
SAMUNDCHINI	-1.39	-5.60**	1.13**	0.59**	-12.70**	-17.53**	19.85**	2.32	-9.91**	-0.66**	1.68	-2.69**	0.18	-4.33**
KALIMUCH	-4.38**	-0.24	-0.49	-0.23	1.04	-11.26**	7.35**	-3.91*	-3.41**	-0.41*	0.21	-1.65**	-0.11	-1.96**
JAWAPHOOL	-2.85**	2.61**	-0.07	-1.13**	3.38**	3.57**	-24.28**	-20.71**	3.02**	0.30	0.47	0.07	0.23*	0.42
TARUNBHOG	-3.24**	-1.25	-0.26	-0.39	-5.13**	-21.43**	10.48**	-10.94**	-4.96**	0.58**	-1.32	-5.01**	-0.14	-5.8**
NAGRI DUBRAJ	-4.43**	0.90	0.99**	0.46*	1.22*	13.60**	2.82	16.42**	3.64**	-0.88**	-2.98**	1.25**	-0.04	3.1**
JAO PHOOL	3.18**	3.13**	1.08**	0.69**	-3.87**	-3.65**	-0.88	-4.53*	-4.15**	0.68**	1.80*	-0.27	-0.34**	-0.58*
DAGRI KAJAR	1.13	-3.94**	-0.84*	-0.38	9.98**	33.22**	63.24**	96.46**	10.16**	1.11**	-0.97	4.32**	1.26**	5.12**
TULSI BHOG	0.88	-1.54*	-0.49	0.21	0.32	-0.31	-0.20	-0.51	0.68	-0.57**	-1.65	0.98**	0.06	1.72**
BARHASAL	1.16	2.61**	0.41	0.22	12.42**	-0.75	-25.31**	-26.06**	12.09**	0.29	0.17	-0.25	-0.20	0.34
SE	0.77	0.67	0.35	0.22	0.59	1.22	1.41	1.89	0.42	0.19	0.86	0.20	0.10	0.24

*- significant at 5% level of significance, **- significant at 1% level of significance.

1. Days to 50% flowering
2. Plant height (cm)
3. No. of tillers/plant
4. Productive tillers/plant
5. Pollen fertility (%)
6. Fertile spikelets/Panicle
7. Sterile spikelets/panicle
8. Total Spikelets/Panicle
9. Spikelet Fertility (%)
10. Panicle Length(cm)
11. Biological yield (g)
12. Grain yield (g)/plant
13. Thousand seed weight (g)
14. Harvest index (%)

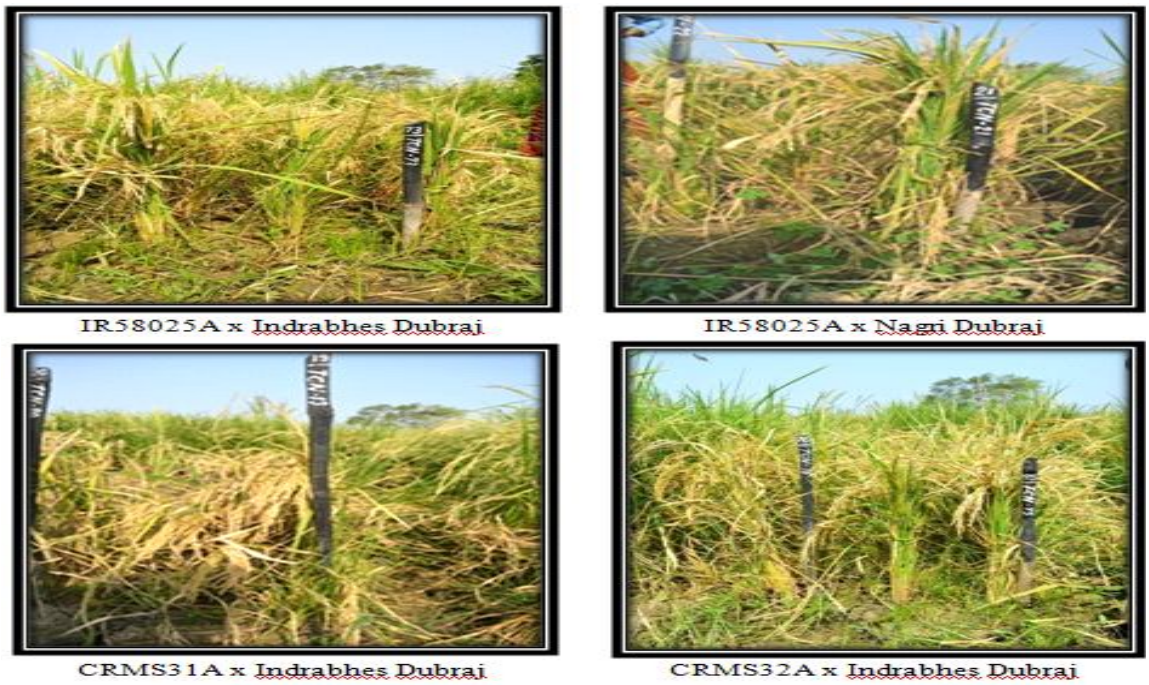

Fig. 1 : Specific combiners for grain yield.

as good general combiners for less number of sterile spikelets per panicle. These good combiners may be useful for developing new hybrids for less number of sterile spikelets per panicle. Among the 60 hybrids, 54 hybrids have shown significant SCA effects; among these 27 hybrids have shown the positive significant SCA effects and 27 hybrids have shown the negative significant effect for sterile spikelets per panicles. The highest negative significant SCA effect has shown by cross CRMS31A × Tarunbhog (-70.02) followed by cross CRMS32A × Dhaniya dhan (-60.35) and IR58025A × Jawaphool (-53.93), respectively.

Similar findings have been reported by Wang *et al.* (2009), Sharma *et al.* (2012), Malik and Singh (2013), Widyastuti *et al.* (2017), Hadi *et al.* (2018), Sudeepthi *et al.* (2018) and Kargbo *et al.* (2019).

High biomass is the ultimate goal of plant breeders for improving the grain yield of rice. In our study, among the lines, CRMS31A (0.50) showed highly significant positive GCA effects, whereas, CRMS32A (-0.31) and IR58025A (-0.2) showed negative non significant GCA effects or this trait. Five (05) out of 20 testers namely, Indrabhes Dubraj (35.16), Barhasal (29.9), Nagri Dubraj (19.73), Dagrikajar (16.09) and Dhaniyadhan (6.58) had significant positive GCA values and hence were identified as good general combiners for biological yield (g). Among the 60 hybrids, 29 hybrids have shown significant SCA effects; among these 14 hybrids have shown the positive significant SCA effects and 15 hybrids have shown the negative significant effect for biological yield per plant. The highest positive significant SCA effect has shown by cross CRMS31A × Dhaniyadhan (7.23), IR58025A × Chinnor (5.21) and CRMS31A × Tarunbhog (3.35).

For grain yield (g) out of the three lines evaluated in our study, only CRMS31A (0.61) showed highly significant positive GCA effects for this trait. Hence it is found to be good general combiner for grain yield per plant. Among the testers, five (05) had significant positive GCA values for grain yield. These were Indrabhes Dubraj (38.81), Nagri Dubraj (28.18), Barhasal (8.81), Tarunbhog (5.55) and Kalimuch (2.56). The other 15 testers were seen to have significant negative GCA values for this trait. Among the 60 hybrids, 48 hybrids have shown significant SCA effects; among these 24 hybrids have shown the positive significant SCA effects and 24 hybrids have shown the negative significant effect for grain yield. The highest positive significant SCA effect for this trait has shown by cross CRMS31A × Tarunbhog (14.6), CRMS31A × Barhasal (13.8), IR58025A × Indrabhes Dubraj (7.92), CRMS32A × Dhaniyadhan (7.9), IR58025A × Jawaphool (7.3) and CRMS31A × Indrabhes Dubraj (6.48). These crosses are good specific combiner for grain yield per plant may be used as good hybrids (Fig. 1).

Biological yield associated with high harvest index is the ultimate goal of plant breeders. Harvest index in rice is hardly 40-45 per cent, that to be increased up to 55 per cent by introgression of genes from new plant type and increasing the spikelet fertility by adapting improved production technologies. Among the lines, IR58025A (0.41) and CRMS31A (0.33) were found to have positive

significant GCA effects for harvest index (%). Among testers, Indrabhes Dubraj (31.51), Kalimuch (4.84), Tarunbhog (8.93), Nagri Dubraj (27.83) and Barhasal (5.09) had significant positive GCA values and therefore, these can be considered as good general combiner for harvest index (%). Among the 60 hybrids, 48 hybrids have shown significant SCA effects; among these 25 hybrids have shown the positive significant SCA effects and 23 hybrids have shown the negative significant effect for percent of harvest index. The highest positive significant SCA effect has shown by cross CRMS31A × Tarunbhog (18.78) followed by the cross CRMS31A × Barhasal (12.70), IR58025A × Indrabhes Dubraj (11.56) and IR58025A × Kaljeera (11.27). Similar findings have been reported by Gopikannan and Ganesh (2013), Ali *et al.* (2014), Thorat *et al.* (2017), Santha *et al.* (2017), Patel *et al.* (2019).

Conclusion

Among the lines CRMS31A was identified as good general combiner. This line has shown positive significant GCA effect for grain yield per plant and other characters namely, number of tillers per plant, number of productive tillers per plant, total spikelets per panicle, biological yield per plant and harvest index and it also had negative significant GCA effect for days to 50% flowering, which is a desirable aspect because it implies early flowering. Thus, it would combine well with other parents and give superior progenies for seed yield and its contributing trait. High GCA value shows that the parental mean of this genotype is superior to the general mean. This indicates a potent evidence of desirable gene flow from this genotype to offspring at high intensity if used in hybridization programme and represents information regarding the concentration of predominantly additive genes. A high GCA estimate indicates higher heritability and less environmental effects. It may also result in less gene interactions and higher achievement in selection. Out of 20 testers, Indrabhes Dubraj, Nagri Dubraj, Kalimuch, Tarunbhog and Barhasal identified good general combiner for grain yield per plant and other contributing traits. These testers have shown highly positive significant GCA effect for grain yield per plant.

Specific combing ability should be use in combination with hybrid means and GCA of the respective parents for the better hybrid selection. Out of 60 crosses, IR58025A × Indrabhes Dubraj, CRMS32A × Indrabhes Dubraj, CRMS31A × Indrabhes Dubraj, CRMS31A × Nagri Dubraj, CRMS32A × Nagri Dubraj, CRMS31A × Barhasal, CRMS31A × Tarunbhog identified as good specific combiner for grain yield per plant and other characters. This specific combining ability effect represents dominance and epistatic gene effects which can be used as an index to determine the usefulness of a particular cross combination for exploitation through heterosis breeding and hybridization programme. These cross combination may be used for development of good high yielding hybrids.

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