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Research Article

COMBINING ABILITY ANALYSIS OF THE IMPROVED RESTORER LINES FOR HYBRID RICE DEVELOPMENT

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Abstract: The study was conducted at Instructional cum Research Farm, Department of Genetics and Plant Breeding, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur Chhattisgarh during *Kharif* 2010 and 2011 and *Rabi* 2010-11 and 2011-12 respectively, to evaluate the variability and the *gca* of parents and *sca* of hybrids and also to assess the magnitude of heterosis for various yield and related traits and to identify the maintainer and restorers for different CMS lines. Improving the restorability of swarna and dubraj variety using two approaches *i.e.* Isocytoplasmic (A x R) and Mutagenic approach was one of the objectives of the present study.

Keywords: *Combining ability, GCA & SCA effects, Line x Tester, Hybrid Rice, Restorers, Maintainers*

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Introduction

Zinc deficiency Breeding strategies based on selection of hybrids require expected level of heterosis as well as the specific combining ability (*SCA*). Presence of heterosis and *SCA* effects for yield and its related traits are reported by Nuruzzaman, *et al.,* 2002 [1]; Faiz, *et al.,* 2006 and Saleem, *et al*., (2008).

Materials and Methods

Materials used

List of genotypes used for study

Genotypes	Parentage	Source
Lines		
IR 58025 A	IR 48483A/ Pusa 167-120-3-2	DRR, Hyderabad
CRMS 31 A	V 20A/ Manipur	CRRI, Cuttack
CRMS 32 A	V 20A/ Mirai	CRRI, Cuttack
Testers		
F_5-C1-PL-6-4-1	IR 58025A x Swarna	IGKV, Raipur
F_5-C1-PL-14-2-1	IR 58025A x Swarna	IGKV, Raipur
F_5-C1-PL-25-1-1	IR 58025A x Swarna	IGKV, Raipur
F_5-C1-PL-25-2-1	IR 58025A x Swarna	IGKV, Raipur
F_5-C1-PL-43-1	IR 58025A x Swarna	IGKV, Raipur
F_5-C1-PL-46-1-1	IR 58025A x Swarna	IGKV, Raipur
F_5-C1-PL-20-2-1	IR 58025A x Swarna	IGKV, Raipur
F_5-C1-PL-78-1-1	IR 58025A x Swarna	IGKV, Raipur
F_5-C1-PL-49-1-1	IR 58025A x Swarna	IGKV, Raipur
F_5-C2-PL-51-1-1	CRMS 31A x Swarna	IGKV, Raipur
F_5-C2-PL-53-1-1	CRMS 31A x Swarna	IGKV, Raipur
F_5-C2-PL-50-2-1	CRMS 31A x Swarna	IGKV, Raipur
F_5-C3-PL-57-1-1	DRR 3A x Swarna	IGKV, Raipur
F_5-C3-PL-57-2-1	DRR 3A x Swarna	IGKV, Raipur
F_5-C3-PL-62-1-1	DRR 3A x Swarna	IGKV, Raipur
F_5-C3-PL-63-2-1	DRR 3A x Swarna	IGKV, Raipur
F_5-C4-PL-69-2-1	IR 68902A x Swarna	IGKV, Raipur
F_5-C4-PL-69-1-1	IR 68902A x Swarna	IGKV, Raipur
D-200-GY-1-11-1	Dubraj 200 Gy	IGKV, Raipur
D-200-GY-6-2	Dubraj 200 Gy	IGKV, Raipur
D-200-GY-6-3	Dubraj 200 Gy	IGKV, Raipur
D-200-GY-2-1	Dubraj 200 Gy	IGKV, Raipur
D-300-GY-3-11	Dubraj 300 Gy	IGKV, Raipur

Methods

Combining ability analysis

Crossing block

Twenty-three parents (3 lines and 23 testers) were used for crossing programme. Crosses were done by using Line x Tester mating design.

Mating procedure

Line X Tester mating design was followed in the present investigation. Each male parent was mated to each female parent. Since there were 3 female and 23 male parents, 69 crosses were obtained for evaluation. These crosses were evaluated along with parents in a replicated experiment.

Evaluation of F_1 hybrids and parents

Well preserved seeds from 69 cross combinations along with their parents were sown in raised nursery beds during *Kharif* 2010, *Rabi* 2010-2011 and *Kharif* 2011 and *Rabi* 2011-12.

Making Test crosses and evaluation

Twenty-three advanced restorer lines were selected and fresh test crosses were attempted using three CMS lines during *Kharif* 2011 to study their combining ability and to improve the fertility restoration ability of three CMS lines used.

Biometric Observations

At flowering, in each replication, five competitive plants in the middle rows were selected in each treatment at random and tag labelled. The following biometrical observations were recorded at the time of maturity on all tagged plants as per Rice Standard Evaluation System (1996). Plant height (cm), Days to 50% flowering, Number of productive tillers, Pollen fertility (%), Panicle length (cm), Fertile spikelets per panicle, Sterile spikelets per panicle, Spikelet fertility (%), Biological yield (g), Grain yield per plant (g), Test weight (g) and Harvest index (%) on five randomly selected competitive plant from each treatment in each replication.

Analysis of variances for combining ability

The gene action for grain yield traits general and specific combining ability effects

Table-1 *Analysis of Variance (mean squares) for combining ability for various quantitative characters*

Source of Variance	Characters											
	PH(cm)	DFF	NPT(cm)	PF(%)	PL(cm)	FS/P	SP/P	SF(%)	BY(g)	GY/P(g)	TW(g)	HI(%)
Replication	0.38	1.42	0.20	1.82**	5.75**	14.26**	2.05**	13.56**	9.27**	1.51**	0.05	0.72
Treatments	1099.66**	25.02**	18.11**	124.93**	4.03**	4745.33**	339.39**	129.62**	346.25**	121.27**	0.51	63.60**
Error	1.99	2.36	1.51	2.03	1.52	4.15	3.15	3.80	1.89	1.91	0.17	1.89

**Significant at 5% level, ** Significant at 1% level.*

PH = Plant height (cm), DFF = Days to 50 % flowering, NPT = Number of Productive tillers/Plant, PF = Pollen fertility (%), PL = Panicle length (cm), FS/P = Fertile spikelets/Panicle, SP/P = Sterile spikelets/Panicle, SF=Spikeletfertility(%), BY= Biological yield (g), GY/P =Grain yield/plant (g), TW= Test weight (g), HI = Harvest index (%)

Table-2 *Analysis of Variance for Line x Tester*

Source	df	Characters										
		PH(cm)	DFF	NPT(cm)	PF(%)	PL(cm)	FS/P	SP/P	SF(%)	BY(g)	GY/P(g)	TW(g)	HI(%)
Replication	1	0.39	1.42	0.21	1.83	5.75**	14.27**	2.05	13.57**	9.28**	1.51	0.05	0.73
Parents	25	1033.59**	22.07**	20.22**	44.00**	3.94**	2967.15**	345.34**	38.88**	106.31**	52.84**	0.47	55.79**
Hybrids	68	1139.41**	25.93**	17.24**	153.36**	3.91**	5347.15**	342.16**	161.06**	391.04**	138.84**	0.52	441.76**
Parent vs.hybrids	1	48.44**	36.55**	24.57**	214.91**	13.90**	8276.70**	1.61**	260.10**	3298.67**	637.33**	0.32	67.39**
Lines	2	5.79**	32.09**	12.97	1112.53**	1.12	33537.54**	2037.84**	1294.67**	2046.19**	874.87**	0.13	441.76**
Testers	22	3503.06**	33.51**	41.68**	281.79**	7.46**	11022.85**	596.52**	289.60**	781.70**	287.63**	0.55**	129.27**
Line x Tester	44	9.11**	21.87**	5.22**	45.56**	2.27**	1227.92**	137.92*	45.27**	120.48**	30.99**	0.53**	19.45**
Error	94	1.99	2.36	1.51	2.03	1.52	4.15	3.15	3.80	1.89	1.91	0.17	1.89
Variance of GCA		0.08	1.396	0.56	48.37	0.049	1458.15	88.60	56.28	88.96	38.03	0.006	19.20
Variance of SCA		66.81	481.24	114.84	1002.21	50.00	27014.18	3034.23	996.02	2650.65	681.84	11.75	427.84
Variance of GCA/ Variance of SCA		0.001	0.002	0.004	0.048	0.0009	0.053	0.029	0.056	0.033	0.055	0.0005	0.044

** and ** significant at 5% level and at 1% level, df= Degree of freedom*

Table-3 Genotypic and phenotypic coefficient of variance (GCV and PCV), heritability, (h^2) and genetic advance (GA) as percentage of mean average and range for different characters.

SN	Characters	Average mean	Range		GCV (%)	PCV (%)	h^2 (bs) (%)	GA as % of mean
			Min	Max				
1	Plant height (cm)	101.44	82.70	148.21	23.51	23.55	99	48.34
2	Days to 50% flowering	97.64	89.00	106.50	3.52	3.85	83	6.61
3	Productive tillers per plant	12.97	5.25	18.46	21.43	23.78	81	39.79
4	Pollen fertility percentage	78.87	56.78	94.13	11.03	11.18	97	22.40
5	Panicle length (cm)	23.79	18.96	26.96	4.6	6.93	44	6.29
6	Fertile spikelets per panicle	172.08	100	262.15	30.03	30.06	99	61.82
7	Sterile spikelets per panicle	48.09	24.80	98.00	27.07	27.32	98	55.25
8	Spikelet sterility percentage	76.73	53.45	90.85	11.55	11.84	95	23.22
9	Biological yield (g)	55.42	18.73	93.75	25.16	25.29	99	51.58
10	Grain yield per plant (g)	22.06	6.22	47.35	37.49	38.03	97	76.14
11	Test weight (g)	19.98	18.12	20.89	2.11	2.95	51	3.10
12	Harvest index percentage	38.56	19.79	51.02	14.82	15.29	94	29.60

GCV: Genotypic coefficient of variation; PCV: Phenotypic coefficient of variation; h^2 (bs): Heritability in broad sense; GA: Genetic advance

of the parents and hybrids were assessed by Line x Tester analysis [2-5]. The expected mean squares due to different sources of variation and their genetic expectations were estimated as indicated in the following [Table-1] and [Table-2].

Results and Discussion

Evaluation of parents

Choice of parents is a pioneer step in breeding programmes to get best combination in F_1 hybrids or in segregating generations. Though the performance of parents themselves give some indication regarding their usefulness, their long term potentialities are least known at the beginning of the breeding programme. Hence there is a constant need to screen the parents based on their combining ability and per se performance.

General combining ability effects of hybrids

The promising parents for different traits could be used in hybridization programme considering its *gca* effects. Besides per se performance, *gca* effects are also important in selection components [Table-1 to 4]. In the current investigation, the experimental material in present study comprised of three CMS lines *viz*., IR58025A, CRMS 31A and CRMS 32A and twenty-three improved versions of Swarna and Dubraj background (used as testers) and their 69 F_1 hybrids. Observations were recorded for plant height (cm), days to 50% flowering, number of productive tillers, pollen fertility (%), panicle length (cm), fertile spikelets per panicle, sterile spikelets per panicle, spikelet fertility (%), biological yield (g), grain yield per plant (g), test weight (g) and harvest index (%) on five randomly selected competitive plant from each treatment in each replication.

Line x tester analysis was carried out [3]. Both positive and negative heterosis is useful in crop improvement, depending on the breeding objectives and nature of the trait [4]. Analysis of variance revealed that variance due to lines and testers was significant for all the characters except for test weight in lines while variance due to line x tester was significant for all the characters studied. Combining ability analysis revealed the predominance of non-additive gene action for all the traits. The line CRMS 31A was found as good general combiner for days to 50% flowering, number of productive tillers, pollen fertility percent, fertile spikelets per panicle, sterile spikelets per panicle, spikelet fertility percent, biological yield, grain yield per plant and harvest index as it exhibited significant *gca* effects for these traits.

Among the testers, F5-C1-PL-25-2-1, F5-C1-PL-20-2-1, F5-C2-PL-51-1-1, F5-C2-PL-53-1-1, D-200-GY-1-11-1, D-200-GY-2-1 and D-200-GY-3-11 were found good general combiner for the traits like pollen and spikelet fertility percent. Tester F5-C3-PL-57-1-1 was recognized as good combiner for plant height (dwarfness). Beside these tester F5-C1-PL-25-2-1 were good general combiner for nine characters like plant height (dwarfness), days to 50% flowering, number of productive tillers, fertile spikelets per panicle, sterile spikelets per panicle, spikelet fertility percent, biological yield per plant, grain yield and harvest index percent. while F5-C2-PL-51-1-1 were good general combiner for ten characters like days to 50% flowering, number of productive tillers, pollen fertility percent, panicle length, fertile spikelets per panicle, sterile spikelets per panicle, spikelet fertility percent, biological yield per plant, grain yield and harvest index percent. Similarly, tester F5-C2-PL-53-1-1 and D-200-GY-2-1 were good general combiner for eight characters like number of productive tillers, pollen fertility percent, fertile spikelets

Table-4 *General Combining Ability (gca) effects of lines and testers for seed yield and its components in hybrid rice*

Parents	PH (cm)	DFF	NPT (cm)	PF (%)	PL (cm)	FS/P	SP/P	SF (%)	BY (g)	GY/P (g)	TW (g)	HI (%)
Lines												
IR58025A	0.35**	0.45**	-0.61**	-4.36**	0.07	-23.09**	6.66**	-4.72**	-7.35**	-4.60**	-0.03	-2.81**
CRMS 31A	0.02	0.51**	0.34**	5.33**	-0.18	29.69**	-6.65**	5.74**	5.66**	4.08**	0.06	3.32**
CRMS 32A	-0.36**	-0.96**	0.27	-0.97	0.11	-6.60**	-0.02	-1.02**	1.69**	0.52	-0.03	-0.51**
Testers												
F_5-C1-PL-6-4-1	-13.19**	-0.47	0.6	-0.77	-0.08	20.66**	14.27**	-1.2	-3.12**	-2.20**	-0.36	-0.65
F_5-C1-PL-14-2-1	-13.33**	-1.30*	-0.49	7.56**	-3.08**	55.46**	-9.70**	8.73**	-9.49**	-4.58**	0.02	-0.76
F_5-C1-PL-25-1-1	-14.59**	-2.97**	-1.76**	5.92**	-2.31**	47.33**	-5.43**	6.61**	-0.55	-1.08	0.16	-0.45
F_5-C1-PL-25-2-1	-12.88**	-2.30**	4.71**	9.29**	0.01	65.53**	-11.41**	9.77**	17.64**	10.67**	0.18	6.36**
F_5-C1-PL-43-1	-10.46**	0.2	-1.69**	-11.54**	-0.27	-36.07**	22.60**	-11.62**	-15.07**	-10.91**	-0.54	-10.81**
F_5-C1-PL-46-1-1	-12.99**	1.20**	-1.34**	-9.48**	-0.86**	-33.43**	17.72**	-9.70**	-5.66**	-7.00**	0.16	-8.84**
F_5-C1-PL-20-2-1	-13.99**	4.53**	0.61	2.74**	0.82**	-2.12	-6.76**	3.62**	-4.01**	-2.93**	-0.15	-2.28**
F_5-C1-PL-78-1-1	-13.94**	-1.47**	-1.14**	-6.96**	0.18	-58.34**	-0.25	-6.67**	-8.36**	-3.88**	-0.36	-0.18
F_5-C1-PL-49-1-1	-15.51**	-0.14	0.59	-6.68**	0.36	-47.47**	2.07**	-6.46**	1.59	-1	-0.31	-2.27**
F_5-C2-PL-51-1-1	-0.58	-1.30**	3.16**	8.02**	1.16**	34.50**	-15.48**	7.56**	20.51**	14.16**	0.27	8.71**
F_5-C2-PL-53-1-1	-2.63	-0.8	3.76**	9.19**	0.57	45.06**	-14.61**	9.23**	21.31**	12.96**	0.22	6.41**
F_5-C2-PL-50-2-1	-15.73**	-0.3	0.32	-4.33**	-0.61	-33.37**	1.47**	-3.57**	4.70**	-0.74	-0.11	-3.67**
F_5-C3-PL-57-1-1	-15.21**	-0.64	-0.39	-1.49*	-0.06	-4.81**	7.25**	-1.66	-3.59**	-3.18**	0.03	-2.11**
F_5-C3-PL-57-2-1	-14.44**	-0.47	-6.24**	-5.35**	0.02	-47.67**	-1.88**	-4.91**	-26.11**	-11.48**	0.07	-2.83**
F_5-C3-PL-62-1-1	-13.91**	-1.30**	-0.03	-1.68*	1.14**	-41.99**	-3.03**	-3.47**	-5.15**	-2.92**	0.33	-0.48
F_5-C3-PL-63-2-1	-13.34**	-3.30**	0.34	-4.27**	-0.26	-31.22**	1.09**	-3.54**	-5.18**	-2.53**	-0.72**	0.05
F_5-C4-PL-69-2-1	-14.79**	1.53**	-0.99	-8.94**	-0.27	-48.32**	9.94**	-9.43**	-7.51**	-3.73**	-0.05	-0.46
F_5-C4-PL-69-1-1	-9.98**	4.86**	-5.96**	-8.12**	-0.19	-40.21**	10.09**	-8.08**	-7.59**	-4.64**	-0.13	-2.17**
D-200-GY-1-11-1	46.44**	-4.30**	0.16	7.58**	1.27**	68.26**	-0.31	6.59**	12.96**	8.92**	0.09	6.59**
D-200-GY-6-2	45.14**	1.53**	-1.21**	6.40**	-0.47	35.29**	-7.25**	7.11**	6.26**	5.87**	0.29	0.74
D-200-GY-6-3	43.64**	1.53**	2.95**	3.68**	2.30**	-19.26**	-4.78**	0.64	8.09**	3.26**	0.12	0.98
D-200-GY-2-1	41.84**	2.03**	3.01**	6.90**	0.18	43.13**	-7.36**	7.13**	8.71**	5.82**	0.54	4.68**
D-200-GY-3-11	44.39**	3.70**	1.01*	2.34**	0.44	29.06**	1.74**	3.29**	-0.34	1.13*	0.26	3.45**
SE (Lines)	0.98	1.22	0.76	1.02	0.85	3.61	1.87	1.9	0.95	0.96	0.14	0.95
SE (Testers)	0.16	2.04	0.97	0.64	1.2	0.6	0.81	0.58	0.74	0.57	5.51	0.63

** and ** significant at 5% level and at 1% level*

per panicle, sterile spikelets per panicle, spikelet fertility percent, biological yield per plant, grain yield and harvest index percent. In Dubraj background, tester D-200-GY-1-11-1 were good general combiner for nine characters like plant height (tallness), days to 50% flowering, pollen fertility percent, panicle length, fertile spikelets per panicle, spikelet fertility percent, biological yield per plant, grain yield and harvest index percent. Tester D-200-GY-6-2 were good general combiner for seven characters like plant height (tallness), pollen fertility percent, fertile spikelets per panicle, sterile spikelets per panicle, spikelet fertility percent, biological yield per plant and grain yield. Tester D-200-GY-6-3 were good general combiner for seven characters like plant height (tallness), number of productive tillers, pollen fertility percent, panicle length, sterile spikelets per panicle, biological yield per plant and grain yield. Tester D-200-GY-3-11 were good general combiner for seven characters like plant height (tallness), number of productive tillers, pollen fertility percent, fertile spikelets per panicle, spiklelet fertility percent, grain yield and harvest index. Other testers showed differential pattern of *gca* effects for different traits and were identified as good or poor general combiners accordingly.

Beside these tester F5-C2-PL-51-1-1 had shown pollen and spikelet fertility percent more than 90 percent (93.75% and 92.18%) respectively and proved as the effective restorer, In addition, the two testers which had shown high pollen and spikelet fertility percent *viz*., F5-C2-PL-53-1-1(91.42% and 89.32%) and F5-C2-PL-25-2-1 (89.12% and 88.60%) respectively and was also showed by their per se performances. Testers F5-C1-PL-25-2-1, F5-C2-PL-51-1-1 and F5-C2-PL-53-1-1 showed high fertile spikelets per panicle and spikelet fertility, while F5-C2-PL-51-1-1, F5-C2-PL-53-1-1, F5-C1-PL-25-2-1, F5-C1-PL-25-2-1, D-200-GY-1-11-1, D-200-GY-2-1 and D-200-GY-6-2 were considered good general combiners for grain yield and harvest index.

Specific combining ability effects of hybrids

The usefulness of a particular cross in the exploitation of heterosis is judged by *sca* effects. On the basis of *sca* effects and per se performances, out of sixty nine hybrids, twenty one hybrids namely IR 58025A/ F5-C1-PL-6-4-1, IR 58025A/ F5-C1-PL-14-2-1, IR 58025A/ F5-C1-PL-25-1-1, IR 58025A/ F5-C1-PL-25-2-1, IR 58025A/ F5-C1-PL-20-2-1, IR 58025A/ F5-C3-PL-57-1-1, IR 58025A/ D-200-GY-1-11-1, IR 58025A/ D-200-GY-2-1, IR 58025A/ D-200-GY-3-11, CRMS 31A/ F5-C1-PL-43-1, CRMS 31A/ F5-C1-PL-46-1-1, CRMS 31A/ F5-C3-PL-57-2-1, CRMS 31A/ F5-C3-PL-62-1-1, CRMS 31A/ F5-C4-PL-69-2-1, CRMS 31A/ F5-C4-PL-69-1-1, CRMS 32A/ F5-C1-PL-14-2-1, CRMS 32A/ F5-C1-PL-25-2-1, CRMS 32A/ F5-C2-PL-51-1-1, CRMS 32A/ F5-C2-PL-53-1-1, CRMS 32A/ F5-C2-PL-50-2-1 and CRMS 32A/ D-200-GY-6-2 were found superior for pollen fertility percent and spikelet fertility percent.

Sixteen hybrids namely IR 58025A/ F5-C1-PL-6-4-1, IR 58025A/ F5-C1-PL-20-2-1, IR 58025A/ F5-C3-PL-57-1-1, IR 58025A/ F5-C4-PL-69-2-1, IR 58025A/ D-200-GY-2-1, IR 58025A/ D-200-GY-3-11, CRMS 31A/ F5-C1-PL-43-1, CRMS 31A/ F5-C1-PL-46-1-1, CRMS 31A/ F5-C3-PL-57-2-1, CRMS 31A/ F5-C3-PL-62-1-1, CRMS 31A/ F5-C4-PL-69-2-1, CRMS 31A/ F5-C4-PL-69-1-1, CRMS 32A/ F5-C1-PL-14-2-1, CRMS 32A/ F5-C1-PL-25-2-1, CRMS 32A/ F5-C2-PL-51-1-1 and CRMS 32A/ F5-C2-PL-53-1-1 were found superior for fertile spikelets per panicle and spikelet fertility percent.

Twenty six hybrids *viz*., IR 58025A/ F5-C1-PL-14-2-1, IR 58025A/ F5-C1-PL-25-1-1, IR 58025A/ F5-C1-PL-25-2-1, IR 58025A/ F5-C1-PL-43-1, IR 58025A/ F5-C3-PL-57-1-1, IR 58025A/ F5-C3-PL-62-1-1, IR 58025A/ F5-C4-PL-69-2-1, IR 58025A/ F5-C4-PL-69-1-1, IR 58025A/ D-200-GY-3-11, CRMS 31A/ F5-C1-PL-6-4-1, CRMS 31A/ F5-C1-PL-20-2-1, CRMS 31A/ F5-C1-PL-49-1-1, CRMS 31A/ F5-C2-PL-51-1-1, CRMS 31A/ F5-C2-PL-53-1-1, CRMS 31A/ F5-C2-PL-50-2-1, CRMS 32A/ F5-C3-PL-57-2-1, CRMS 31A/ D-200-GY-6-2, CRMS 31A/ D-200-GY-6-3, CRMS 32A/ F5-C1-PL-46-1-1, CRMS 32A/ F5-C1-PL-20-2-1, CRMS 32A/ F5-C1-PL-49-1-1, CRMS 32A/ F5-C3-PL-57-1-1, CRMS 32A/ F5-C4-PL-69-2-1, CRMS 32A/ D-200-GY-6-2, CRMS 32A/ D-200-GY-2-1 and CRMS 32A/ D-200-GY-3-11 were found superior for biological yield and grain yield as they had shown positive significant *sca* effects. Five hybrids with IR 58025A *viz*., IR 58025A/ F5-C1-PL-14-2-1, IR 58025A/ F5-C1-PL-25-1-1, IR 58025A/ F5-C3-PL-57-1-1, IR 58025A/ F5-C3-PL-62-1-1 and IR 58025A/ F5-C4-PL-69-1-1 while five hybrids with CMS 31A *viz*., CRMS 31A/ F5-C1-PL-6-4-1, CRMS 31A/ F5-C1-PL-20-2-1, CRMS 31A/ F5-C2-PL-53-1-1, CRMS 31A/ D-200-GY-1-11-1 and CRMS 31A/ D-200-GY-6-2 were found superior for grain yield and harvest index percent. On the other hand, two hybrids with CRMS 32A namely CRMS 32A/ F5-C1-PL-25-1-1 and CRMS 32A/ D-200-GY-3-11 were found superior for biological yield, grain yield and harvest index percent.

Table-5 *Specific Combining Ability (sca) effects of lines and testers for seed yield and its components in hybrid rice*

Hybrids	PH(cm)	DFF	NPT(cm)	PF(%)	PL(cm)	FS/P	SP/P	SF(%)	BY(g)	GY/P(g)	TW(g)	HI(%)
IR58025A/												
F_5-C1-PL-6-4-1	1.20**	1.38**	-1.61**	6.09**	-0.08	43.29**	-5.58**	6.22**	-6.66**	-0.91	0.52	2.39**
F_5-C1-PL-14-2-1	-0.11	0.72	0.7	1.70**	-1.76**	1.39	-2.86*	2.23**	10.31**	6.04**	0.19	3.70**
F_5-C1-PL-25-1-1	-2.00**	-0.12	2.20**	2.11**	-2.60**	-10.38**	-6.08**	2.50**	9.17**	5.11**	-0.05	2.62**
F_5-C1-PL-25-2-1	2.49**	1.22**	-0.07	1.32**	0.02	0.92	-0.6	1.65**	11.88**	3.31**	0.03	-1.59**
F_5-C1-PL-43-1	-2.93**	-1.78**	-2.52**	-6.20**	0.22	-0.43	20.64**	-6.95**	12.05**	3.57**	-1.29	-2.48**
F_5-C1-PL-46-1-1	0.5	7.22**	-1.33**	-6.32**	0.06	-8.09**	12.82**	-5.59**	1.48**	-1.77**	0.04	-7.12**
F_5-C1-PL-20-2-1	0.2	-0.62	-1.12**	3.46**	0.21	25.12**	-4.70*	4.22**	-4.61**	-3.29**	-0.11	-4.96**
F_5-C1-PL-78-1-1	0.35	-1.62**	-0.92	1.24**	0.16	11.34**	-2.26*	0.77	1.43**	0.61	-0.73**	-1.07**
F_5-C1-PL-49-1-1	1.12**	-1.45**	2.65**	-4.18**	0.61	-1.53	4.47*	-3.57**	-3.77**	-3.32**	0.5	-4.84**
F_5-C2-PL-51-1-1	-1.96**	0.22	-1.39**	-7.11**	-0.91	-68.05**	6.22**	-7.85**	-3.98**	-3.48**	-0.05	-0.9
F_5-C2-PL-53-1-1	-0.71	-0.28	-1.85**	-5.04**	1.17**	-29.82**	8.17**	-3.99**	-7.64**	-4.86**	-0.14	-0.77
F_5-C2-PL-50-2-1	-0.71	-6.78**	-0.45	-0.69	-0.08	-2.63	-5.33**	0.49	-12.15**	-3.41**	0.54	0.71
F_5-C3-PL-57-1-1	-3.88**	3.05**	0.14	4.26**	-0.02	24.74**	-2.16*	3.47**	4.22**	3.81**	-0.28	3.52**
F_5-C3-PL-57-2-1	-0.45	0.88	3.27**	-0.36	-0.48	-0.98	-1.08	-1.16*	-3.24**	0.69	0.12	3.74**
F_5-C3-PL-62-1-1	1.37**	-0.28	-1.20**	-2.23**	1.96**	-0.66	1.72	-2.00**	2.67**	2.68**	0.06	2.51**
F_5-C3-PL-63-2-1	1.10**	2.22**	-0.39	0.37	-0.92	4.02*	-2.45*	1.04**	2.42**	1.16**	0.03	-0.28
F_5-C4-PL-69-2-1	0.85	-0.12	0.13	0.6	0.29	4.77*	-3.20*	0.57	0.74	0.99	-0.27	0.36
F_5-C4-PL-69-1-1	6.89**	-3.95**	1.66**	-4.05**	0.24	-0.94	8.15**	-4.31**	4.66**	2.86**	0.66**	1.17**
D-200-GY-1-11-1	-0.58	1.72**	2.26**	3.66**	1.18**	-3.51*	-7.25**	3.30**	-2.53**	-0.74	-0.32	1.50**
D-200-GY-6-2	0.22	-2.62**	0.18	0.78	-0.14	-3.29*	1.24	1.12**	-8.98**	-6.49**	-0.03	0.66
D-200-GY-6-3	-0.23	0.38	0.59	5.47**	-0.4	-15.94**	-8.13**	0.45	-7.17**	-2.25**	0.36	0.97
D-200-GY-2-1	-1.83**	-3.12**	-0.73	1.38**	0.68	21.32**	-3.55**	3.16**	-3.14**	-1.93**	0.01	-0.64
D-200-GY-3-11	-0.9	3.72**	-0.18	3.75**	0.6	9.34**	-8.20**	4.19**	2.81**	1.62**	0.22	0.78
CRMS 31A/												
F_5-C1-PL-6-4-1	-1.57**	-0.18	1.05**	-4.08**	0.1	-42.99**	-1.37**	-4.53**	1.30**	1.14**	0.34	1.07**
F_5-C1-PL-14-2-1	-0.73	-2.35**	-0.75	-3.51**	-1.52**	-14.34**	3.55**	-3.90**	-4.33**	-1.38**	-0.39	1.57**
F_5-C1-PL-25-1-1	0.58	-0.18	2.20**	-1.93**	1.01**	-12.26**	2.83**	-3.20**	-8.36**	-6.86**	-0.07	-6.54**
F_5-C1-PL-25-2-1	-0.58	-1.35**	-0.43	-2.85**	0.04	-5.46**	2.71**	-3.37**	-7.43**	-1.27**	0.03	1.61**
F_5-C1-PL-43-1	2.60**	1.65**	2.38**	12.37**	-0.44	21.09**	-25.75**	12.12**	-1.86**	-1.02**	0.71**	1.09**
F_5-C1-PL-46-1-1	0.23	-1.35**	1.23**	9.66**	1.09**	24.80**	-20.37**	10.49**	-5.03**	-0.86	-0.04	3.22**
F_5-C1-PL-20-2-1	1.13**	0.32	-0.07	-1.81**	0.44	-17.26**	4.11**	-3.65**	1.02**	1.44**	0.23	2.81**
F_5-C1-PL-78-1-1	-0.82	-0.18	-0.32	-1.18**	-0.49	-7.04**	2.75**	-0.18	-2.78**	-2.16**	0.44	-1.47**
F_5-C1-PL-49-1-1	-1.50**	-1.01**	-1.58**	4.10**	-0.44	17.54**	-0.12	3.81**	-4.58**	-0.75	0.43	2.38**
F_5-C2-PL-51-1-1	0.17	-2.85**	-0.24	1.90**	0.97	25.87**	0.43	0.81	8.90**	5.87**	0.18	0.42
F_5-C2-PL-53-1-1	0.02	-2.85**	0.62	-0.01	-0.48	13.37**	0.51	-1.23**	11.35**	8.25**	-0.02	2.20**
F_5-C2-PL-50-2-1	2.12**	2.65**	-0.2	-1.42**	-0.06	10.44**	9.38**	-1.54**	12.11**	4.60**	0.23	0.29
F_5-C3-PL-57-1-1	2.95**	-3.01**	-1.21**	-4.55**	-0.14	-16.46**	4.10**	-3.46**	-7.20**	-4.81**	0.04	-3.69**
F_5-C3-PL-57-2-1	0.28	6.32**	-1.83**	4.77**	0.34	15.84**	-1.62	4.17**	15.52**	4.19**	-0.37	-1.73**
F_5-C3-PL-62-1-1	-1.60**	-0.35	0.13	2.25**	-0.91	17.21**	-0.62	3.39**	-5.54**	-3.54**	-0.23	-2.35**
F_5-C3-PL-63-2-1	-0.22	2.15**	0.05	0.69	0.66	23.39**	6.21**	0.97	1.34**	0.44	-1.00**	0.07
F_5-C4-PL-69-2-1	0.63	-0.68	0.48	2.83**	-0.13	9.04**	0.41	2.77**	-3.32**	-2.27**	0.06	-1.34**
F_5-C4-PL-69-1-1	-2.98**	1.49**	-0.54	3.57**	0.11	13.28**	-2.29**	3.60**	-5.32**	-3.37**	-0.93**	-2.06**
D-200-GY-1-11-1	0.31	-2.35**	-1.20**	-6.78**	0.33	-8.19**	5.16**	-4.11**	0.75	2.09**	0.26	1.18**
D-200-GY-6-2	1.50**	0.82	0.71	-2.22**	-0.19	2.93**	5.70**	-3.85**	7.40**	2.34**	0.06	3.33**
D-200-GY-6-3	0.31	0.82	-0.07	-2.65**	1.03**	4.33**	-1.07**	0.87	5.82**	2.91**	-0.33	0.22
D-200-GY-2-1	-2.09**	5.32**	0.39	-2.79**	-0.83	-25.21**	0.81	-3.32**	-4.79**	-1.81**	0.31	-0.2
D-200-GY-3-11	-0.75	-2.85**	-0.8	-6.38**	-0.51	-49.94**	4.51**	-6.64**	-5.00**	-3.17**	0.07	-2.12**
CRMS 32A/												
F_5-C1-PL-6-4-1	0.36	-1.20**	0.56	-2.01**	-0.03	-0.3	6.95**	-1.69**	5.36**	-0.23	-0.86	-3.46**
F_5-C1-PL-14-2-1	0.85	1.63**	0.06	1.81**	3.28**	12.95**	-0.68	1.66**	-5.98**	-4.66**	0.2	-5.27**
F_5-C1-PL-25-1-1	1.41**	0.3	-4.39**	-0.18	1.58**	22.63**	3.25**	0.69	-0.81	1.75**	0.12	3.92**
F_5-C1-PL-25-2-1	-1.90**	0.13	0.5	1.53**	-0.04	4.53**	-2.12**	1.71**	-4.46**	-2.04**	-0.03	-0.02
F_5-C1-PL-43-1	0.33	0.13	0.15	-6.17**	0.22	-20.67**	5.12**	-5.18**	-10.19**	-2.55**	0.59	1.39**
F_5-C1-PL-46-1-1	-0.74	-5.87**	0.1	-3.34**	-1.15**	-16.71**	7.55**	-4.90**	3.54**	2.63**	0	3.89**
F_5-C1-PL-20-2-1	-1.34**	0.3	1.20**	-1.65**	-0.65	-7.87**	0.58	-0.57	3.59**	1.85**	-0.12	2.15**
F_5-C1-PL-78-1-1	0.46	1.80**	1.25**	-0.06	0.33	-4.30**	-0.48	-0.58	1.34**	1.55**	0.29	2.54**
F_5-C1-PL-49-1-1	0.38	2.46**	-1.07**	0.08	-0.17	-16.02**	-4.35**	-0.25	8.34**	4.07**	-0.94**	2.46**
F_5-C2-PL-51-1-1	1.80**	2.63**	1.63**	5.20**	-0.06	42.19**	-6.65**	7.04**	-4.92**	-2.39**	-0.14	0.48
F_5-C2-PL-53-1-1	0.7	3.13**	1.22**	5.05**	-0.68	16.46**	-8.67**	5.22**	-3.72**	-3.39**	0.16	-1.43**
F_5-C2-PL-50-2-1	-1.40**	4.13**	0.64	2.11**	0.14	-7.82**	-4.05**	1.05**	0.04	-1.19**	-0.77**	-1.00**
F_5-C3-PL-57-1-1	0.93	-0.04	1.07**	0.29	0.15	-8.27**	-1.93**	-0.01	2.98**	1.00**	0.24	0.16
F_5-C3-PL-57-2-1	0.16	-7.20**	-1.44**	-4.41**	0.14	-14.87**	2.70**	-3.02**	-12.28**	-4.88**	0.25	-2.02**
F_5-C3-PL-62-1-1	0.23	0.63	1.07**	-0.02	-1.05**	-16.55**	-1.10**	-1.38**	2.87**	0.86	0.17	-0.16
F_5-C3-PL-63-2-1	-0.89	-4.37**	0.34	-1.06**	0.26	-27.42**	-3.77**	-2.00**	-3.77**	-1.60**	0.96**	0.2
F_5-C4-PL-69-2-1	-1.49**	0.8	-0.61	-3.43**	-0.15	-13.82**	2.78**	-3.33**	2.58**	1.28**	0.21	0.98
F_5-C4-PL-69-1-1	-3.90**	2.46**	-1.12**	0.48	-0.35	-12.33**	-5.87**	0.71	0.66	0.51	0.27	0.88
D-200-GY-1-11-1	0.28	0.63	-1.06**	3.12**	-1.51**	11.70**	2.08**	0.8	1.78**	-1.35**	0.06	-2.68**
D-200-GY-6-2	-1.72**	1.80**	-0.89	1.44**	0.32	0.37	-6.93**	2.74**	1.58**	4.15**	-0.02	-4.00**
D-200-GY-6-3	-0.07	-1.20**	-0.52	-2.82**	-0.63	11.62**	9.20**	-1.32**	1.35**	-0.66	-0.03	-1.20**
D-200-GY-2-1	3.93**	-2.20**	0.34	1.41**	0.15	3.88**	2.73**	0.17	7.92**	3.74**	-0.32	0.84
D-200-GY-3-11	1.65**	-0.87	0.98	2.63**	-0.09	40.60**	3.68**	2.45**	2.18**	1.55**	-0.29	1.34**

** Significance at 5% level, **Significance at 1% level*

Table-6 *Per se performance, sca effects and heterosis of F_1 hybrids and gca estimates of the parents for grain yield per plant*

Cross combination	*Per se* performance (Yield/ plant) (g)	*sca* effects	*gca* effects of female	*gca* effects of male	Heterosis (over better parent)
IR 58025A/ F_5-C1-PL-25-2-1	31.45	3.31*	-4.60**	10.67**	17.90**
CRMS 31A/ F_5-C2-PL-53-1-1	47.35	8.25*	4.08**	12.96**	65.16**
CRMS 31A/ F_5-C2-PL-51-1-1	46.18	5.87*	4.08**	14.16**	41.22**
CRMS 31A/ D-200-GY-1-11-1	37.15	2.09*	4.08**	8.92**	70.49**
CRMS 32A/ D-200-GY-6-2	32.60	4.15*	0.52	5.87**	79.32**
CRMS 32A/ D-200-GY-2-1	32.14	3.74*	0.52	5.82**	54.71**

High degree of relative heterosis and heterobeltiosis were observed for twenty-three hybrids for grain yield per plant. Few promising hybrids *viz*., IR 58025A/ F5-C1-PL-25-2-1, CRMS 31A/ F5-C2-PL-53-1-1, CRMS 31A/ F5-C2-PL-51-1-1, CRMS 31A/ D-200-GY-1-11-1, CRMS 32A/ D-200-GY-6-2 and CRMS 32A/ D-200-GY-2-1 showed high positive relative heterosis and heterobeltiosis for grain yield per plant which can be further tested for commercial cultivation in different ecologies.

Further, potential restorers and maintainer were identified based on pollen and spikelet fertility of 69 hybrid combinations evaluated in present study. Data revealed that based on pollen fertility percentage none of the parent was found as potential maintainers for all the CMS lines. However, thirteen testers were identified as potential restorers for IR 58025A, twenty-three testers for CRMS 31A and sixteen for CRMS 32A [Table-5 and 6]. Among 69 F1 hybrids, four combinations *viz*., CRMS 31A/ F5-C2-PL-51-1-1, CRMS 31A/ F5-C2-PL-53-1-1, CRMS 32A/ F5-C2-PL-51-1-1 and CRMS 32A/ F5-C2-PL-53-1-1 recorded spikelet fertility more than 90 percent. Thus, these combinations were identified as putative hybrids and should be evaluated further for their yield superiority and other economic traits on large areas.

Conclusion

Based on per se performance and *gca* effects, CRMS 31A was found the best general combiner for single plant yield and yield contributing characters. Among testers F5-C1-PL-25-2-1, F5-C1-PL-20-2-1, F5-C2-PL-51-1-1, F5-C2-PL-53-1-1, D-200-GY-1-11-1, D-200-GY-2-1 and D-200-GY-3-11 were found good general combiner for the traits like pollen and spikelet fertility percent. Tester F5-C2-PL-51-1-1 and F5-C2-PL-53-1-1 had shown spikelet fertility percent more than 90 percent and proved as the effective restorers, which is also showed by them per se performances.

Application of research: Restorability of Swarna and Dubraj varieties was improved more than 90 percent by adopting A X R technique in Swarna genotype and by mutagenic breeding approach in Dubraj genotype in the present study.

Research Category: Plant Breeding

Abbreviations: *GCA*: General combining ability, *SCA*: Specific combining ability

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Study area / Sample Collection: Department of Plant Breeding, Indira Gandhi Agriculture University, IGKVV, Raipur, 492012, India.

Cultivar / Variety / Breed name: Swarna and Dubraj

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