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Heterosis studies for yield and yield components using CMS lines in rice (*Oryza sativa* L.)

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Abstract
It is important to know the degree and direction of hybrid vigour for its commercial exploitation. Three lines were crossed with eight testers in line × tester mating design in rice. The resultant 24 F_1s was evaluated along with their parents and check variety (Indira Sona and Karma Mahsuri)) to estimate heterobeltiosis and standard heterosis for yield and yield attributing traits. These crossesshowed marked variations in the expression of heterobeltiosis and standard heterosis for yield andyield components.Six crosses *viz*., IR79156/NPT-4, IR79156/NPT-38, CRMS31/R-1656-2816-9-3223-1, CRMS-31/NPT-1, CRMS 31A/NPT-17 and CRMS 32A/NPT-1 showed significant heterosis heterobeltiosis and standard heterosis for grain yield and yield attributing traits. these identified as promising hybrids for grain yield per plant.

Keywords: New plant type, heterosis, yield & yield attributing traits & rice

Introduction

Rice is a staple food for more than half of the world population. Globally, riceis the most important food grain from a nutritional, food security or economic perspective. The current levels of rice production do not meet the future demand. The world population has been projected at 8.27 billion by 2030, demanding an increased rice production of 771 million tonnes (Badawi, 2004) [4]. According to 2016 world population data sheet (Anonymous, 2016) [3], India's population would increase from 1.329billion in 2016 to 1.708 billion in 2050, surpassing the China's population. Thus, it is a challenging task to ensure food and nutritional security of India's ever-increasing population. India, being the second largest producer of ricein the world next to China, has an area of 44.0 million hectares and production of 104.8 million tonnes of rice (Anonymous, 2015) [2]. Therefore, enhancing productivity of rice through novel genetic approaches like hybrid rice was felt necessary. Exploitation of heterosis is considered to be one of the outstanding achievements of plant breeding. The presence of sufficient hybrid vigour is an important pre-requisite for successful production of hybrid varieties. Hybrid vigour in rice was first reported by Jones (1926) [12]. According to Malthus (1989) [17] the food grains increase in arithmetical progressions while the population increases in geometrical progression, thus improved technologies are required to bridge the gap to feed the increasing population.

Therefore, for breaking the yield barrier level and make rice cultivation more attractive, it is now necessary to explore alternative approaches. Among the all possible alternatives, heterosis is an important approach for increasing rice production. It has not only contributed to food security, but has also benefited the environment (Duvick, 1999) [8]. The various crop species in which hybrid varieties are used commercially, rice ranks very high. Hybrid rice offers an opportunity to boost the yield potential of rice with yield advantage of 15-20% over conventional high-yielding varieties (Dar *et al.* 2014) [5]. Hybrids offer opportunity to break through the yield ceilings of semi dwarf rice varieties. Significant heterosis, heterobiltiosis and standard heterosis have been reported in rice by a number of workers (Devarathinam 1984; Peng and Virmani 1991) [7, 21] Development of heterotic rice hybrids needs careful selection of parental lines to enable exploitation of maximum heterosis. Identification of potential cross combinations with heterotic effects for yield and its component traits also facilitates the conventional breeding programmes to create wide range of variability in segregating generations.

Manifestation of high heterosis for grain yield is of primary importance for commercial exploitation of hybrids. The present study is therefore aimed at estimating the heterotic effects as an aid in selecting desirable parents and crosses for the exploitation of heterosis.

Materials and Methods

This investigation was carried out at the Agricultural Research Farm, department of Genetics and Plant Breeding, IGKV, Raipur (India) during theKharif 2014-15 cropping seasons. Experimental material consisting of 24 hybrids and their 11 parents (3 CMS lines along with their isogenic "B-line" / maintainer line and 8 testers) along with three standard checks *viz.,* Indira Sona, Karma Mahsuri and Rajeswari were planted in Randomized complete block design (RCBD) with two replications during *Kharif 2014* (Table 1). Recommended agronomic practices were followed to raise a good crop observations were recorded on five randomly selected plants for estimation of magnitude of heterosis with respect to fifteen yield and yield attributing traits viz., days to flowering, plant height, effective tillers plant-1, panicle length (cm), spikelets panicle-1, grains panicle-1, sterile spikelets panicle-1, pollen fertility (%), spikelet fertility (%), 1000- grain weight (g), grain yield plant-1 (g), biological yield (g) per plant and harvest index (%). The character means of each replication was subjected for analysis of variance (Panse and Sukhatme, 1967) [18] and estimation of heterosis over mid parent, better parent, standard variety and standard hybrid (Fonseca and Patterson, 1968) [10]. To estimate significant differences among hybrids and parents, the mean data of each character were subjected to Analysis of Variance (ANOVA) as suggested by Steel and Torrie (1980) [28]. The 't' test was applied to determine significant difference of F_1 hybrid means from respective better parent and standard variety values using formulae as reported by Wynne *et al*. (1970) [30].

Result and discussion

The analysis of variance revealed highly significant differences among treatment, crosses and line × tester for all the characters while, variance among parents were highly significant for most of the traits. In the case of parents vs. crosses, most of the characters showed highly significant mean sum of squares except days to50% flowering, panicle bearing tiller per plant, panicle length, 1000 grain weight and grains yield per plant. The mean squares due to lines were significant for the characters plant height, panicle length, 1000 grain weight and grain yield per plant. Similar finding also reported by Janardhan *et al*. (2000) [11], Panwar (2005) [19], Kumar *et al*. (2006) [13] and Salgotra *et al*. (2009) [24].

Estimation of heterosis

Heterosis was computed as per cent increase or decrease in F_1value over better parent (heterobeltiosis) and over best commercial variety (standard heterosis) are accessible in Table 2. The nature and magnitude of hybrid vigour differed for different traits in various hybrid combinations.

Days to 50 % flowering

IR79156A/Swarnasub-1, IR79156A/NPT-38,CRMS31A/R-1656-2816-3223-1,and RMS32A/NPT-4 were identified as good performing hybrids for days to 50% flowering. Negative heterosis is desirable for days to flowering because this will make the hybrids to mature earlier as compared to parents. Most promising cross combination was CRMS 32/NPT -4, its shows heterobeltiosis, relative heterosis and standard heterosis in negative direction. Heterosis in both negative and positive directions for days to flowering have also been reported by Eradasappa *et al*. (2007) [9] and Srijan *et al.* (2016) [27].

Plant height (cm)

Semi-dwarf plant height (80-100 cm) is desirable for recording high yield in rice varieties as vigour in plant height may lead to unfavourable grain/straw ratios and reduces optimum yield due to lodging. Crosses CRMS31A/Swarna sub-1 and CRMS32A/NPT-2 showed significant negative estimates of standard heterosis which indicates that this cross can be used for dwarf hybrid. IR79156A/Swarna sub-1, CRMS31A/Swarna sub-1 and CRMS32A/NPT-2 were identified as good performing hybrids for plant height. Present observations are in close agreement with earlier report of several workers Nuruzzaman *et al*. (2002) [17], Alam *et al.* (2004) [1] and Deoraj *et al.* (2007) [6].

Productive tillers per Plant

IR79156A/ NPT-38, CRMS31A/NPT-38 and CRMS32A/NPT-4 were identified as good performing hybrids for productive tillers per plant.

Panicle Length (cm)

Generally, larger panicle is associated with high number ofgrains per panicle resulting into higher productivity, therefore, hybrids with positive heterosis for panicle length aredesirable. Among the entire cross combinations, three cross combinations *viz.,* IR79156A/Jawaphool CRMS31A/Jawaphool and CRMS32A/Jawaphool were identified as good performing hybrids for panicle length. Sanjeev Kumar *et al*. (2010) [25] reported similar results for panicle length trait.

Total number of spikelets per panicle

For number of spikelets per panicle, the hybrids with positive heterosis are desirable. Three cross combinations *viz.,* IR79156A/R-1656-2816-3223-1, CRMS31A/NPT-1 and CRM. S32A/NPT-1 were identified as good performing hybrids for total spikelets per panicle.

Number of fertile Spikelets per panicle

The number of fertile spikelets directly contributes to the seed yield hence positive heterotic effect would be highly desirable. In the present study, more number of fertile spikelets is closely associated with high yield per plant resulting in high productivity. Therefore, the main interest is to find out the cross combinations with more number of grains per panicle. Among the entire cross combinations, three cross combinations *viz.,* IR79156A/R-1656, CRMS31A/R-1656-2816-9-3223-1 and CRMS32A/NPT-4 were identified as good performing hybrids for fertile spikelets per panicle.

Spikelet fertility (%)

Spikelet fertility is very important in hybrid breeding programme. Since this trait has a direct attitude on the yield, hence manifestation of heterosis in positive direction is desirable for this trait. Among the entire cross combinations, three cross combinations *viz.,* IR79156A/Jawaphool, CRMS31A/NPT-4 and CRMS32A/NPT-4 were identified as good performing hybrids for spikelet fertility %. Both positive and negative standard heterosis was observed by earlier researchers like Tiwari *et al.* (2011) [29] and Saidaaiah *et al.* (2012) [23].

Biological Yield (g) per plant

Among the entire cross combinations, three cross combinations *viz.*, IR79156A/ Swarna sub-1, CRMS31A/R-1656-2816-9-3223-1 and CRMS32A/Swarna sub-1 were identified as good performing hybrids for biological yield per plant. Crosses having high grain yield per plant and high biological yield per plant indicate that these crosses may be utilized in developing high yield potential hybrids. Similar results have been reported by Kumar *et al.* (2012) [15] and Pratap *et al.* (2013) [22].

Grain Yield (g) per plant

Grain yield per plant is the ultimate product of hybrids. A Grain yield is a complex trait that is multiplicative end product of several attributes of yield. Hybrid showing high heterosis for grain yield per plant, also manifested heterotic effect for productive tillers per plant, panicle length, number of grains per panicle and test weight. Among twenty-four hybrids six hybrids showed significant positive standard heterosis. Among the entire cross combinations, three cross combinations *viz.*, IR79156A/NPT-4, CRMS31A/R-1656-2816-9-3223-1 andCRMS32A/NPT-1 were identified as good performing hybrids for grain yield per plant. Increase yield in rice is in close conformity the finding observed by other workers Patil *et al*. (2012) [20], Pratap *et al*. (2013) [22] and Shinde and Patel (2014) [26].

Harvest Index (%)

Harvest index which indirectly influences the grain yield through controlling the mechanism of distribution ofphotosynthates to economic and non-economic organs as such is not a yield component. Therefore, it is an importantconsideration for genetic improvement. Among the crosses with line IR79156A, hybrid IR79156A/NPT-38 (48.95 %) recorded the highest harvest index followed by IR79156A/NPT-4 (47.55 %) and IR79156A/Swarna sub-1 (41.72). Among the entire cross combinations, three cross combinations *viz.*, IR79156A/NPT-38, CRMS31A/NPT-1 and CRMS32A/NPT-1 were identified as good performing hybrids for harvest index. Average heterosis, heterobeltiosis and standard heterosis for grain yield per plant, biological yield per plant and harvest index (Table 2).

From the above results observed and discussion made, it is clear that heterosis for grain yield per plant is mainly because of simultaneous manifestation of heterosis for yield component traits. Out of 24 hybrids studied, the significant standard heterosis for grain yield is observed in six hybrids crosses *viz.*, CRMS 31A/R 1656-2816-3223-1, IR79156/NPT-4, CRMS 31A/NPT-1, IR 79156/NPT-38, CRMS 32A/NPT-1 and CRMS 31A/NPT-17 were identified as promising hybrids based on mean performance, and heterosis estimation for grain yield per plant. Hence, these hybrids may be further tested over locations and years for commercial exploitation.

Table 1: Genotypes used in the study

Genotypes	Source
IR 79156A (WA)	IRRI, Manila, Philippines
CRMS 31A (Kalinga)	CRRI, Cuttack
CRMS 32A (Kalinga)	CRRI, Cuttack
Male Parents	
Jawaphool	IGKV, Raipur, C.G.
Swarna-sub-1	IRRI, Manila, Philippines
R-1656-2816-9-3223-1	IGKV, Raipur, C.G.
NPT-1	IGKV, Raipur C.G.
NPT-2	IGKV, Raipur C.G.
NPT-4	IGKV, Raipur C.G.
NPT-17	IGKV, Raipur C.G.
NPT-38	IGKV, Raipur C.G.
Checks	
Indira Sona	IGKV, Raipur (C.G.)
Karma Mahsuri	IGKV, Raipur (C.G.)

Table 2: Average Heterosis, Heterobeltiosis and Standard Heterosis for Yield and yield attributing traits

Cross	Days to 50% Flowering					Productive Tiller/ Plant				
	Standard Heterosis			Mid	Better	Standard Heterosis			Mid	Better
IR-79156A	Indira Sona	Karma Mahsuri	Rajeswari			Indira Sona	Karma Mahsuri	Rajeswari		
IR-79156A*Jawaphool	3.28*	1.07	2.16	2.44	9.88**	1.73	-4.35	25.71	-19.27	-40.14**
IR-79156A*Swarna sub 1	0.00	-2.14	-1.08	-1.88	6.40**	-2.89	-8.70	20.00	-34.88**	42.86**
IR-79156A*R-1656	3.83*	1.60	2.70	2.98*	10.47**	-22.54	-27.17	-4.29	-44.63**	54.42**
IR-79156A*NPT-1	3.83*	1.60	2.70	1.33	10.47**	-8.67	-14.13	12.86	-27.69*	46.26**
IR-79156A*NPT-2	1.09	-1.07	0.00	-1.33	7.56**	-17.92	-22.83	1.43	-24.06	51.70**
IR-79156A*NPT-4	8.74**	6.42**	7.57**	6.70**	15.70**	1.73	-4.35	25.71	-20.36	40.14**
IR-79156A*NPT-17	3.28*	1.07	2.16	5.29**	9.88**	-21.97	-26.63	-3.57	-32.84*	54.08**
IR-79156A*NPT-38	0.00	-2.14	-1.08	4.87**	6.40**	4.05	-2.17	28.57	-20.35	38.78**
CRMS-31A										
CRMS-31A* Jawaphool	10.93**	8.56**	9.73**	6.01**	9.14**	-13.29	-18.48	7.14	9.49	5.63
CRMS-31A* Swarna sub 1	7.65**	5.35**	6.49**	1.81	5.91**	-34.49	-38.41	-19.05	-35.97*	-48.95**
CRMS-31A*R-1656-2816-9-3223-1	4.37**	2.14	3.24*	-0.26	2.69	-22.54	-27.17	-4.29	-16.77	-29.47
CRMS-31A* NPT-1	9.84**	7.49**	8.65**	3.34*	8.06**	-37.57*	-41.30*	-22.86	-21.45	-24.48
CRMS-31A* NPT-2	8.74**	6.42**	7.57**	2.31	6.99**	-26.01	-30.43	-8.57	20.75	-3.03
CRMS-31A* NPT-4	8.20**	5.88**	7.03**	2.33	6.45**	-20.23	-25.00	-1.43	-1.43	-6.76
CRMS-31A* NPT-17	5.46**	3.21*	4.32**	3.49*	3.76*	-14.45	-19.57	5.71	23.33	12.12
CRMS-31A* NPT-38	12.02**	9.63**	10.81**	12.95**	15.82**	-0.58	-6.52	22.86	18.62	8.86
CRMS-32A										
CRMS-32A* Jawaphool	6.56**	4.28**	5.41**	-1.76	-1.02	-16.76	-21.74	2.86	6.67	1.40
CRMS-32A* Swarna sub 1	9.84**	7.49**	8.65**	0.25	0.50	-24.86	-29.35	-7.14	-25.71*	-41.44**
CRMS-32A*R-1656-2816-9-3223-1	6.01**	3.74*	4.86**	-2.27	-1.52	-36.42	-40.22	-21.43	-30.82	-42.10*
CRMS-32A* NPT-1	7.65**	5.35**	6.49**	-2.23	-1.50	-13.29	-18.48	7.14	10.70	4.89
CRMS-32A* NPT-2	12.57**	10.16**	11.35**	2.23	3.00*	-28.32	-32.61	-11.43	19.23	-3.12
CRMS-32A* NPT-4	-1.64	-3.74*	-2.70	-10.23**	-10**	-7.51	-13.04	14.29	15.94	8.10
CRMS-32A* NPT-17	3.83*	1.60	2.70	-1.81	1.60	-58.38**	-60.87**	-48.57*	-38.98	-43.75
CRMS-32A* NPT-38	4.37**	2.14	3.24*	1.33	7.91**	-20.23	-25.00	-1.43	-3.50	-12.65

*Significant at p=0.05% level, **Significant at p=0.01% level

Cross	Plant Height (cm)					Panicle Length (cm)				
	Standard Heterosis			Mid	Better	Standard Heterosis			Mid	Better
IR-79156A	Indira Sona	Karma Mahsuri	Rajeswari			Indira Sona	Karma Mahsuri	Rajeswari		
IR-79156A*Jawaphool	15.17**	30.05**	18.06**	22.17**	30.18**	12.49*	28.54**	34.79**	17.23**	5.80
IR-79156A*Swarna sub 1	-17.02**	-6.29	-14.93**	1.04	9.49	-16.88**	-5.02	-0.40	-10.23*	-21.82**
IR-79156A*R-1656-2816-9-3223-1	3.66*	17.06**	6.27	16.64**	17.17**	-6.72	6.59	11.78	4.60	-12.27*
IR-79156A*NPT-1	1.59	14.72**	4.15*	9.87**	14.84**	11.90*	27.86**	34.09**	13.55**	5.25
IR-79156A*NPT-2	3.84	17.26**	6.45	17.98**	18.58**	7.31	22.63**	28.60**	10.39*	0.94
IR-79156A*NPT-4	0.13	13.07**	2.65	18.54**	24.43**	1.48	15.96*	21.60**	10.54*	-4.55
IR-79156A*NPT-17	-8.30*	3.55	-5.99	12.46**	22.89**	0.66	15.03*	20.63**	2.44	-5.32
IR-79156A*NPT-38	-3.08	9.44*	-0.65	4.66	9.55*	9.53	25.16**	31.25**	5.48	3.02
CRMS-31A										
CRMS-31A* Jawaphool	10.49**	24.77**	13.27**	23.70**	40.62**	7.87	23.26**	29.26**	20.49**	15.42*
CRMS-31A* Swarna sub 1	-18.19**	-7.61*	-16.13**	6.00	7.95	-7.03	6.23	11.41	7.90	-0.53
CRMS-31A*R-1656-2816-9-3223-1	1.23	14.31**	3.78	20.62**	28.83**	-11.19*	1.48	6.42	7.32	-4.98
CRMS-31A* NPT-1	-9.02**	2.74	-6.73*	3.95	15.79**	-1.92	12.07	17.53**	6.48	4.94
CRMS-31A* NPT-2	-10.32**	1.27	-8.06*	7.95*	14.13**	-6.54	6.80	12.00	2.95	0.00
CRMS-31A* NPT-4	-12.42**	-1.10	-10.22**	10.13**	11.46**	-9.86	3.00	8.01	5.58	-3.56
CRMS-31A* NPT-17	-15.72**	-4.82*	-13.59**	10.04**	12.95**	-4.82	8.76	14.05*	3.64	1.84
CRMS-31A* NPT-38	15.17**	30.05**	18.06**	31.38**	46.57**	-0.26	13.97*	19.52**	2.39	-1.60
CRMS-32A										
CRMS-32A* Jawaphool	11.03**	25.38**	13.82**	28.51**	52.66**	6.46	21.65**	27.58**	24.28**	24.17**
CRMS-32A* Swarna sub 1	-10.55**	1.02	-8.29*	20.46**	22.99**	-12.26*	0.25	5.14	6.60	2.33
CRMS-32A*R-1656-2816-9-3223-1	-11.44**	0.00	-9.22**	9.32**	21.76**	-7.15	6.10	11.27	17.70**	8.29
CRMS-32A* NPT-1	-3.98	8.43*	-1.57	13.50**	32.01**	-2.36	11.57	17.00*	10.63*	7.57
CRMS-32A* NPT-2	-17.02**	-6.29	-14.93**	3.53	14.09**	-1.92	12.07	17.53**	12.83*	11.32
CRMS-32A* NPT-4	-9.65**	2.03	-7.37*	17.95**	24.23**	-3.21	10.60	15.98*	18.74**	12.88*
CRMS-32A* NPT-17	-7.85*	4.06	-5.53	25.08**	26.70**	-5.02	8.53	13.81*	7.96	5.28
CRMS-32A* NPT-38	-3.62	8.83*	-1.20	13.74**	32.51**	0.22	14.52*	20.10**	7.13	-1.13

*Significant at p=0.05% level, **Significant at p=0.01% level

Cross	Total Spikelets/ panicle				
	Standard Heterosis			Mid	Better
IR-79156A	Indira Sona	Karma Mahsuri	Rajeswari		
IR-79156A*Jawaphool	-9.94	-25.50**	-4.66	-30.47**	-35.65**
IR-79156A*Swarna sub 1	24.22*	2.76	31.50**	2.87	1.47
IR-79156A*R-1656-2816-9-3223-1	55.50**	28.64**	64.62**	16.43*	5.05
IR-79156A*NPT-1	0.20	-17.11*	6.07	-23.21**	-29.38**
IR-79156A*NPT-2	11.21	-8.00	17.73	-6.95	-7.29
IR-79156A*NPT-4	35.99**	12.50	43.96**	18.34*	14.20
IR-79156A*NPT-17	8.41	-10.32	14.76	-18.83**	-26.77**
IR-79156A*NPT-38	28.55**	6.35	36.09**	21.92*	7.96
CRMS-31A					
CRMS-31A* Jawaphool	12.81	-6.68	19.42	-24.61**	-29.19**
CRMS-31A* Swarna sub 1	27.20*	5.22	34.65**	-9.70	-20.16**
CRMS-31A*R-1656-2816-9-3223-1	77.12**	46.52**	87.50**	15.26*	11.18
CRMS-31A* NPT-1	78.12**	47.35**	88.56**	18.27**	11.81
CRMS-31A* NPT-2	13.14	-6.40	19.77	-18.97**	-28.98**
CRMS-31A* NPT-4	18.68	-1.82	25.64*	-12.11	-25.50**
CRMS-31A* NPT-17	19.61	-1.05	26.62*	-22.16**	-24.92**
CRMS-31A* NPT-38	24.62*	3.09	31.92**	-0.74	-21.78**
CRMS-32A					
CRMS-32A* Jawaphool	40.69**	16.39	48.94**	-1.66	-3.74
CRMS-32A* Swarna sub 1	40.09**	15.89	48.31**	4.32	-4.15
CRMS-32A*R-1656-2816-9-3223-1	18.75	-1.77	25.71*	-19.27**	-19.78**
CRMS-32A* NPT-1	47.63**	22.13*	56.29**	2.50	4.04
CRMS-32A* NPT-2	27.62**	5.57	35.10**	-4.09	-12.69
CRMS-32A* NPT-4	24.08*	2.65	31.36**	-3.41	-15.11*
CRMS-32A* NPT-17	6.47	-11.92	12.71	-27.62**	-28.08**
CRMS-32A* NPT-38	37.56**	13.80	45.62**	15.62*	-5.89

*Significant at p=0.05% level, **Significant at p=0.01% level

Cross	Fertile Spikelets / panicle					Spikelet Fertility %				
	Standard Heterosis			Mid	Better	Standard Heterosis			Mid	Better
	Indira Sona	Karma Mahsuri	Rajeswari			Indira Sona	Karma Mahsuri	Rajeswari		
IR-79156A										
IR-79156A*Jawaphool	-4.68	0.21	-19.31*	-29.36**	-40.19**	4.79	34.65*	-16.92	7.61	-6.23
IR-79156A*Swarna sub 1	6.01	11.46	-10.26	-12.89	-20.23*	-17.09	6.54	-34.27**	-12.75	-22.55
IR-79156A*R-1656-2816-9-3223-1	49.19**	56.85**	26.29**	57.36**	35.02**	-5.51	21.42	-25.09*	38.93*	13.83
IR-79156A*NPT-1	-9.16	-4.50	-23.10*	-22.10*	-25.98**	-10.43	15.10	-28.99**	4.71	1.70
IR-79156A*NPT-2	1.53	6.75	-14.05	-15.15	-21.19*	-11.39	13.86	-29.75**	-6.35	-16.59
IR-79156A*NPT-4	35.79**	42.77**	14.96	18.68*	14.74	-1.89	26.08	-22.21*	4.82	-5.83
IR-79156A*NPT-17	-4.79	0.11	-19.40*	-20.15*	-25.62**	-49.24**	-34.78*	-59.76**	-40.18**	-41.45**
IR-79156A*NPT-38	26.88*	33.40**	7.41	27.21**	14.84	-5.35	21.62	-24.96*	5.70	-1.49
CRMS-31A										
CRMS-31A* Jawaphool	-4.18	0.75	-18.88	-42.27**	-44.48**	-17.46	6.06	-34.56**	-24.51*	-26.14*
CRMS-31A* Swarna sub 1	30.86**	37.58**	10.78	-14.33*	-24.19**	-17.19	6.41	-34.35**	-22.59*	-22.64
CRMS-31A*R-1656-2816-9-3223-1	70.06**	78.80**	43.97**	35.11**	-1.47	-5.51	21.42	-25.09*	18.17	-11.61
CRMS-31A* NPT-1	67.82**	76.45**	42.07**	13.66*	-2.77	-6.96	19.56	-26.23*	-4.56	-12.97
CRMS-31A* NPT-2	22.91*	29.23*	4.05	-18.45**	-28.79**	7.32	37.90*	-14.92	0.70	0.38
CRMS-31A* NPT-4	43.48**	50.86**	21.47*	-1.37	-16.87*	19.60	53.68**	-5.18	13.31	11.87
CRMS-31A* NPT-17	1.43	6.64	-14.14	-32.52**	-41.24**	-15.97	7.99	-33.38**	-13.19	-21.39
CRMS-31A* NPT-38	1.73	6.96	-13.88	-22.23**	-41.06**	-20.90	1.64	-37.29**	-22.07*	-26.01*
CRMS-32A										
CRMS-32A* Jawaphool	-46.64**	-43.90**	-54.83**	-65.19**	-66.52**	-62.74**	-52.12**	-70.46**	-64.59**	-66.66**
CRMS-32A* Swarna sub 1	44.60**	52.03**	22.41*	3.24	-1.80	1.87	30.90	-19.24	-0.98	-4.83
CRMS-32A*R-1656-2816-9-3223-1	11.00	16.70	-6.03	-1.93	-24.62**	-9.20	16.68	-28.01*	19.68	-8.02
CRMS-32A* NPT-1	39.41**	46.57**	18.02	3.28	-5.33	-6.94	19.58	-26.22*	-0.36	11.26
CRMS-32A* NPT-2	-36.56**	-33.30**	-46.29**	-54.04**	-56.92**	-48.72**	-34.10*	-59.34**	-49.95**	-51.72**
CRMS-32A* NPT-4	45.62**	53.10**	23.28*	9.65	-1.11	16.33	49.49**	-7.77	14.66	11.65
CRMS-32A* NPT-17	-17.21	-12.96	-29.91**	-39.84**	-43.78**	-23.72	-1.97	-39.52**	-17.71	-22.73
CRMS-32A* NPT-38	15.48	21.41	-2.24	-2.24	-21.58**	-2.70	25.03	-22.86*	-0.10	-1.44

*Significant at p=0.05% level, **Significant at p=0.01% level Cont.

Cross	Pollen Fertility %				
	Standard Heterosis			Mid	Better
	Indira Sona	Karma Mahsuri	Rajeswari		
IR-79156A					
IR-79156A*Jawaphool	-41.15**	-39.79**	-41.06**	19.09**	-40.43**
IR-79156A*Swarna sub 1	-22.09**	-20.28**	-21.97**	75.95**	-11.99**
IR-79156A*R-1656-2816-9-3223-1	-37.28**	-35.83**	-37.18**	33.47**	-33.24**
IR-79156A*NPT-1	-42.90**	-41.57**	-42.81**	20.49**	-39.73**
IR-79156A*NPT-2	-22.78**	-20.98**	-22.65**	69.14**	-15.39**
IR-79156A*NPT-4	-21.15**	-19.32**	-21.02**	63.29**	-18.32**
IR-79156A*NPT-17	-48.99**	-47.80**	-48.90**	17.68**	-41.13**
IR-79156A*NPT-38	-14.29**	-12.30**	-14.15**	74.17**	-12.88**
CRMS-31A					
CRMS-31A* Jawaphool	-30.58**	-28.97**	-30.47**	39.92**	-29.73**
CRMS-31A* Swarna sub 1	-35.20**	-33.69**	-35.09**	45.70**	-26.79**
CRMS-31A*R-1656-2816-9-3223-1	-20.32**	-18.47**	-20.19**	68.86**	-15.18**
CRMS-31A* NPT-1	-36.75**	-35.28**	-36.65**	32.91**	-33.24**
CRMS-31A* NPT-2	-21.15**	-19.32**	-21.02**	71.96**	-13.61**
CRMS-31A* NPT-4	-16.58**	-14.64**	-16.44**	72.05**	-13.59**
CRMS-31A* NPT-17	-21.51**	-19.69**	-21.38**	80.25**	-9.42**
CRMS-31A* NPT-38	-22.03**	-20.22**	-21.90**	57.81**	-20.74**
CRMS-32A					
CRMS-32A* Jawaphool	-56.91**	-55.91**	-56.84**	-12.76**	-56.38**
CRMS-32A* Swarna sub 1	-26.19**	-24.48**	-26.07**	66.77**	-16.61**
CRMS-32A*R-1656-2816-9-3223-1	-30.91**	-29.30**	-30.79**	47.10**	-26.45**
CRMS-32A* NPT-1	-32.41**	-30.84**	-32.30**	42.69**	-28.66**
CRMS-32A* NPT-2	-49.84**	-48.68**	-49.76**	9.91	-45.05**
CRMS-32A* NPT-4	-36.02**	-34.54**	-35.92**	32.54**	-33.73**
CRMS-32A* NPT-17	-65.73**	-64.94**	-65.68**	-20.91**	-60.45**
CRMS-32A* NPT-38	-29.92**	-28.29**	-29.81**	42.46**	-28.77**

*Significant at p=0.05% level, **Significant at p=0.01% level Cont.

Cross	Grain Yield (g) / plant					Biological Yield (g) / plant				
	Standard Heterosis			Mid	Better	Standard Heterosis			Mid	Better
IR-79156A	Indira Sona	Karma Mahsuri	Rajeswari			Indira Sona	Karma Mahsuri	Rajeswari		
IR-79156A*Jawaphool	28.38	22.30	-29.98**	29.70	26.30	34.73**	66.00**	15.32	-6.13	-14.54*
IR-79156A*Swarna sub 1	10.78	5.54	-39.57**	-17.14	-35.24**	37.21**	69.05**	17.44*	9.80	6.04
IR-79156A*R-1656-2816-9-3223-1	27.50	21.46	-30.46**	40.84*	32.38	24.60**	53.52**	6.65	-9.18	-14.07*
IR-79156A*NPT-1	-16.70	-20.64	-54.56**	-1.39	-13.51	-9.07	12.03	-22.17**	-40.70**	-48.71**
IR-79156A*NPT-2	9.50	4.32	-40.27**	9.75	6.06	-3.00	19.51	-16.97*	-43.13**	-54.19**
IR-79156A*NPT-4	80.61**	72.06**	-1.49	108.41**	87.52**	29.21**	59.19**	10.60	-16.62**	-28.44**
IR-79156A*NPT-17	-49.84**	-42.75*	-18.27	-89.32**	-55.57**	-2.20	20.50	-16.28*	-31.18**	-36.83**
IR-79156A*NPT-38	60.83**	53.22**	-12.28	95.01**	66.98**	10.58	36.25**	-5.34	-28.25**	-38.17**
CRMS-31A										
CRMS-31A* Jawaphool	-17.28	-21.20	-54.88**	-14.70	-18.62	57.56**	94.12**	34.86**	3.38	-0.06
CRMS-31A* Swarna sub 1	-16.83	-20.77	-54.64**	-36.85**	-51.39**	-13.12	7.04	-25.63**	-35.09**	-40.96**
CRMS-31A*R-1656-2816-9-3223-1	117.09**	106.81**	18.41	145.24**	135.18**	73.18**	113.37**	48.23**	18.55**	17.68**
CRMS-31A* NPT-1	78.00**	69.58**	-2.91	115.83**	92.84**	23.71*	52.43**	5.89	-23.74**	-30.22**
CRMS-31A* NPT-2	11.89	6.59	-38.97**	14.43	8.37	36.76**	68.50**	17.06*	-23.78**	-35.40**
CRMS-31A* NPT-4	23.12	17.29	-32.85**	45.43*	33.38	26.19**	55.48**	8.02	-22.98**	-30.11**
CRMS-31A* NPT-17	42.78*	36.02*	-22.12*	85.09**	54.68**	16.71	43.79**	-0.10	-22.70**	-24.62**
CRMS-31A* NPT-38	-11.20	-15.40	-51.56**	10.36	-3.80	-16.35	3.07	-28.39**	-48.68**	-53.22**
CRMS-31A										
CRMS-32A* Jawaphool	-54.96**	-57.09**	-75.43**	-56.18**	-56.66**	28.67**	58.53**	10.14	-13.02*	-18.38**
CRMS-32A* Swarna sub 1	-0.36	-5.08	-45.65**	-27.53*	-41.76**	53.36**	88.96**	31.27**	18.54**	10.96
CRMS-32A*R-1656-2816-9-3223-1	-14.21	-18.27	-53.21**	-9.06	-17.45	20.23*	48.13**	2.91	-15.09*	-17.08*
CRMS-32A* NPT-1	47.84*	40.84*	-19.36	67.46**	42.25*	21.69*	49.93**	4.16	-22.86**	-31.36**
CRMS-32A* NPT-2	-7.21	-11.61	-49.39**	-10.43	-10.72	27.89**	57.58**	9.47	-26.90**	-39.59**
CRMS-32A* NPT-4	7.21	2.14	-41.52**	18.51	3.16	32.34**	63.06**	13.28	-16.96**	-26.70**
CRMS-32A* NPT-17	-15.70	-19.69	-54.02**	1.63	-18.88	-28.75**	-12.22	-39.01**	-51.37**	-53.98**
CRMS-32A* NPT-38	-17.55	-21.45	-55.03**	-4.43	-20.66	36.03**	67.60**	16.43*	-14.19**	-23.94**

*Significant at p=0.05% level, **Significant at p=0.01% level

Cross	Harvest Iidex (%)				
	Standard Heterosis			Mid	Better
IR-79156A	Indira Sona	Karma Mahsuri	Rajeswari		
IR-79156A*Jawaphool	-6.42	-25.98*	-39.19**	40.03	33.15
IR-79156A*Swarna sub 1	22.76	-2.90	-20.23	16.97	-12.07
IR-79156A*R-1656-2816-9-3223-1	1.18	-19.97	-34.25**	58.18*	43.98
IR-79156A*NPT-1	-11.27	-29.82*	-42.34**	60.60*	26.26
IR-79156A*NPT-2	2.71	-18.76	-33.25**	73.23**	46.16*
IR-79156A*NPT-4	39.94*	10.69	-9.06	150.30**	99.13**
IR-79156A*NPT-17	-11.09	-29.68*	-42.23**	-62.33*	-26.51**
IR-79156A*NPT-38	44.05**	13.94	-6.39	166.36**	104.98**
CRMS-31A					
CRMS-31A* Jawaphool	-51.06**	-61.29**	-68.20**	-29.19	-34.61
CRMS-31A* Swarna sub 1	15.03	-9.01	-25.25*	7.28	-17.60
CRMS-31A*R-1656-2816-9-3223-1	22.21	-3.33	-20.58	84.47**	63.30**
CRMS-31A* NPT-1	39.86*	10.62	-9.11	143.10**	86.88**
CRMS-31A* NPT-2	-18.34	-35.41**	-46.94**	32.62	9.11
CRMS-31A* NPT-4	2.08	-19.26	-33.66***	75.43**	36.41
CRMS-31A* NPT-17	17.14	-7.34	-23.88*	105.33**	56.53*
CRMS-31A* NPT-38	4.79	-17.11	-31.90**	85.93**	40.03
CRMS-31A					
CRMS-32A* Jawaphool	-66.39**	-73.41**	-78.16**	-52.54*	-57.06**
CRMS-32A* Swarna sub 1	-36.14*	-49.49**	-58.50**	-41.38**	-54.26**
CRMS-32A*R-1656-2816-9-3223-1	-30.96	-45.39**	-55.14**	1.57	-11.81
CRMS-32A* NPT-1	19.30	-5.64	-22.48*	101.33**	52.40*
CRMS-32A* NPT-2	-33.37	-47.29**	-56.70**	5.28	-14.88
CRMS-32A* NPT-4	-20.11	-36.81**	-48.09**	33.34	2.05
CRMS-32A* NPT-17	14.81	-9.19	-25.39*	95.35**	46.66*
CRMS-32A* NPT-38	-41.07*	-53.39**	-61.70**	1.46	-24.72

*Significant at p=0.05% level, **Significant at p=0.01% level

Table 3: Promising hybrids based on mean performance and heterosis

Hybrids	Mean value	Heterosis			
	(g/plant)	MP	BP	Indira Sona	Karma Mahsuri
CRMS-31A/R-1656-2816-9-3223-1	27.09	145.24**	135.18**	117.09**	106.81**
IR79156A/NPT-4	22.54	108.41**	87.52**	80.61**	72.06**
CRMS-31A/ NPT-1	22.22	115.83**	92.84**	78.00**	69.58**
IR-79156A/NPT-38	20.07	95.01**	66.98**	60.83**	53.22**
CRMS-32A/ NPT-1	18.45	67.46**	42.25*	47.84*	40.84*
CRMS-31A/NPT-17	17.82	19.13**	-10.7**	5.46**	6.52**

*Significant at p=0.05% level, **Significant at p=0.01% level

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