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RESEARCH ARTICLE

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Heterosis studies in hybrid rice (*Oryza sativa* L.)

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ABSTRACT : To increase production and productivity in this ecosystem, innovative breeding approaches such as heterosis in hybrid rice.Out of these, hybrid rice technology is the proven technology in China and a more practical one to raise production. Hetrosis study comprises of three CMS lines *viz.*, CRMS 31A, IR 58025A and IR79156A and five testers *viz*., NPT 453-2, NDR 8054 (IR 77768-25-NDR-B-108-14) , CR 2330-3-3-2-1-1, NPT 76-8 and PR-115. Indira Sona (hybrid) and Mahamaya (commercial cultivar) .The crosses were tested as line x tester mating design with two replications. Cross IR 79156A / NPT 76-8 stood for positive significant heterosis over checks for characters grain yield / plant ,test weight, pollen fertility percentage, harvest index.

KEY WORDS : Heterosis, Line x Tester

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INTRODUCTION

Chhattisgarh is an important rice growing state in Eastern India, where it occupies an area around 3.57 million hectares with the production of 5.85 million tones and productivity of 1571 kg per hectare (Anonymous, 2010a).

To meet the demand of increasing population and to maintain self-sufficiency, the present production 100 million tonnes needs to be increased upto 120 million tonnes by the year 2020. This increase in production has to be achieved in the backdrop of declining and deteriorating resources such as land, water and other inputs and without adversely affecting the environment (Viraktamanth *et al.*, 2010). In order to increase production and productivity in this ecosystem, innovative breeding approaches such as heterosis in hybrid rice. Out of these, hybrid rice technology is the proven technology in china and a more practical one to raise production. Exploitation of heterosis (hybrid vigour) is one of the most important applications of genetics in agriculture. It is not only contributing to food security, but also beneficial for environment (Duvick, 1999), soil and water resources. Commercialization of rice hybrids has been started from late 1970s in China. Now, it is dominating in many countries especially in Vietnam, India, Bangladesh, Philippines and Latin America. Erickoson (1969) sought and discovered the plant source of cytoplasmic male sterility (CMS), as did Athwal and Virmani (1972).

Chhattisgarh is now recognized as potential area for hybrid rice cultivation in India. Presently, the state having area under hybrid rice is around 120,000 hectare.

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The first public hybrid Indira Sona developed in Chhattisgarh itself was released during 2006 for shallow low land. It has long slender grain with excellent cooking quality, resistant to gall midge moderately resistant to sheath blight and tolerant to blast (Anonymous, 2010b).

EXPERIMENTAL METHODS

The present study was conducted at the Research cum Intuitional Farm and Laboratories of the Department of Genetics and Plant Breeding, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during *Rabi* season 2010-2011 and *Kharif* 2011. The biological material used in the present study comprises of three CMS lines *viz.*, CRMS 31A, IR 58025A and IR79156A and five testers *viz.*, NPT 453-2, NDR 8054 (IR 77768-25-NDR-B-108-14) , CR 2330-3-3-2-1-1, NPT 76-8 and PR-115. The crosses were attempted during *Rabi* 2010-11 with line x tester mating design. The evaluation of 15 F_1's along with there parents and two checks *viz.*, Indira Sona (hybrid) and Mahamaya (commercial cultivar) were done at *Kharif* 2011 with two replications. The distance between row to row and plant to plant was 20 cm and 15 cm, respectively. A standard agronomic package practices was adopted. Five plants of each line from each replication was randomly selected for observations for the fifteen characters *viz.*, Days to 50 per cent flowering, plant height (cm), number of productive tillers per plant, flag leaf length (FLL), flag leaf width (FLW), leaf area index (LAI), number of filled spikelets per panicle, number of sterile spikelets per panicle, spikelet fertility percentage, pollen fertility percentage, 1000 grain weight, grain yield per plant, harvest index, chlorophyll content.

Heterosis for each trait was worked out by utilizing the overall mean of each hybrid over replication for each trait. Relative heterosis was estimated as per cent deviation of hybrid value from its mid parental value. The formula used for estimating relative heterosis is under:

Standard heterosis was, calculated at the deviation of hybrid from the check variety as under:

$$\text{diii} = \frac{\overline{F_1} - \overline{SH}}{\overline{SH}} \times 100$$

where,

diii = Standard heterosis *i.e.* heterosis over check parent,

SH = Average performance of standard check.

The significance of different types of heterosis was carried out by adopting 't' test as suggested by Wynne *et al.* (1970).

$$t\ (\text{standard heterosis}) = \frac{\overline{F_{ij}} - \overline{SH_{ij}}}{\sqrt{(3/8)Me}}$$

where,

$\overline{F}_{ij}$ = Mean of i, j[th] cross,

$\overline{SH}_{ij}$ = Mean of the standard check for i, j[th] cross and

Me= Estimate of error variance.

EXPERIMENTAL RESULTS AND ANALYSIS

Heterosis as per cent increase or decrease over the standard checks of the selected cross combinations for the various yield contributing characters are presented in Table 1-5.

Negative heterosis is desirable for days to 50 per cent flowering because this will make the hybrids to mature earlier as compared to parents. Among fifteen crosses cross IR 58025A/CR 2330-3-3-2-1-1 stood most significant for negative hetrosis over commercial check Indira Sona only Chaudhry *et al*. (2007); Gawas *et al*. (2007); Wang *et al.* (2010) and Jeloder and Bagheri (2010). For plant height also negative heterosis was desirable as the plant height negatively correlated with lodging resistance. The cross combinations CRMS 31A / NPT 453-2, IR 79156A/NPT 453-2, IR 58025 A/NPT 453-2 noted with significant negative heterosis over both the standard checks involved in the study Gawas *et al*. (2007) and Jeloder and Bagheri (2010).

Traits flag leaf length, width, area and chlorophyll content are positively correlated with the carbohydrate synthesis and grain filling in rice spikelet. for flag leaf length hybrid IR 79156A / PR-115 has positive significant value over Indira sona while three crosses *viz.*, IR 79156A/ PR-115, IR 58025 A/CR 2330-3-3-2-1-1 and CRMS 31 A/ PR-115 had significant positive value over another standard check Mahamaya under study. Similar result has been reported by Wang *et al.* (2010).

Flag leaf width for all crosses were significant (IR 58025 A /NPT 76-8, IR 58025 A /PR-115 and IR 79156A / NPT 76-8) over the check Indira sona while the flag leaf width of check Mahamaya always remain higher then all the crosses.

For flag leaf area the crosses IR 79156A / NPT 453-2, IR 58025 A / CR 2330-3-3-2-1-1,IR 58025 A /NPT 76-8, IR 58025 A /PR-115 exhibited significant positive heterosis over one check (Indira sona) out of two (Chaudhary *et al.*, 2007).

Table 1 : Mid parent heterosis, heterobeltiosis and standard heterosis

58025 A	Day's to 50% flowering				Flag leaf length				Flag leaf width			
	I.S		MAH		I.S		MAH		I.S		MAH	
NPT 453-2	2.16	**	9.88	**	-7.87	**	16.11	**	6.73	*	-47.48	**
IVT-SDW-703	5.95	**	13.95	**	-17.10	**	4.48		4.97	*	-48.35	**
IVT-SDW-703-1	-5.41	**	1.74	*	1.48		27.90	**	36.84	**	-32.66	**
NPT 76-8	3.24	**	11.05	**	-16.93	**	4.69	*	66.96	**	-17.84	**
PR-115	-1.62	*	5.81	**	-11.22	**	11.89	**	52.05	**	-25.18	**
79156 A												
NPT 453-2	4.32	**	12.21	**	-15.34	**	6.70	**	69.01	**	-16.83	**
IVT-SDW-703	5.41	**	13.37	**	-13.39	**	9.16	**	17.54	**	-42.16	**
IVT-SDW-703-1	5.95	**	13.95	**	-20.98	**	-0.41		38.60	**	-31.80	**
NPT 76-8	3.24	**	11.05	**	-17.61	**	3.84		52.92	**	-24.75	**
PR-115	-2.16	**	5.23	**	5.03	*	32.36	**	11.70	**	-45.04	**
CRMS 31 A												
NPT 453-2	1.62	*	9.30	**	-19.07	**	2.00		9.36	**	-46.19	**
IVT-SDW-703	8.11	**	16.28	**	-20.84	**	-0.24		2.34		-49.64	**
IVT-SDW-703-1	-0.54		6.98	**	-1.34		24.34	**	30.99	**	-35.54	**
NPT 76-8	1.08		8.72	**	-16.29	**	5.50	*	36.84	**	-32.66	**
PR-115	2.70	**	10.47	**	0.87		27.13	**	0.58		-50.50	**

* and ** indicate significance of values at P=0.05 and 0.01, respectively, I.S= Indira sona, MAH= Mahamaya

Table 2: Mid parent heterosis, heterobeltiosis and standard heterosis

58025 A	Leaf area index				Plant height (cm)			Productive tillers			
	I.S		MAH		I.S		MAH	I.S		MAH	
NPT 453-2	-1.71		-39.05	**	-6.49	**	-8.80	-34.09	**	-5.69	
IVT-SDW-703	-12.96	**	-46.03	**	2.02		-0.51	-25.00	*	7.32	
IVT-SDW-703-1	38.85	**	-13.90	**	-5.08	**	-7.44	-22.73	*	10.57	
NPT 76-8	38.97	**	-13.83	**	-9.58	**	-11.82	-25.57	**	6.50	
PR-115	35.01	**	-16.28	**	-3.59	*	-5.98	-18.18		17.07	
79156 A											
NPT 453-2	43.10	**	-11.26	**	-16.91	**	-18.97	4.55		49.59	**
IVT-SDW-703	1.82		-36.86	**	12.62	**	9.83	-18.18		17.07	
IVT-SDW-703-1	9.52	**	-32.09	**	9.73	**	7.01	-43.18	**	-18.70	
NPT 76-8	26.11	**	-21.80	**	-0.76		-3.22	-34.66	**	-6.50	
PR-115	17.30	**	-27.26	**	-12.97	**	-15.13	-48.86	**	-26.83	*
CRMS 31 A											
NPT 453-2	-11.51	**	-45.13	**	-21.03	**	-22.99	-13.64		23.58	
IVT-SDW-703	-16.20	**	-48.03	**	5.52	**	2.91	-20.45	*	13.82	
IVT-SDW-703-1	29.23	**	-19.86	**	-2.19		-4.62	-29.55	**	0.81	
NPT 76-8	14.61	**	-28.93	**	-10.43	**	-12.65	-2.27		39.84	**
PR-115	1.47		-37.08	**	-16.30	**	-18.38	5.68		51.22	**

* and ** indicate significance of values at P=0.05 and 0.01, respectively, I.S= Indira sona, MAH= Mahamaya

Table 3 : Mid parent heterosis, heterobeltiosis and standard heterosis

58025 A	Pollen fertility				Total empty spikelet				Total filled spikelet			
	I.S		MAH		I.S		MAH		I.S		MAH	
NPT 453-2	-22.62	**	-24.52	**	41.01	**	124.11	**	-51.47	**	-35.59	**
IVT-SDW-703	-11.68	**	-13.85	**	38.20	**	119.64	**	-32.87	**	-10.89	**
IVT-SDW-703-1	-14.76	**	-16.86	**	51.12	**	140.18	**	-30.03	**	-7.12	**
NPT 76-8	-4.63	**	-6.98	**	58.15	**	151.34	**	18.98	**	57.94	**
PR-115	-39.65	**	-41.13	**	152.53	**	301.34	**	-53.57	**	-38.36	**
79156 A												
NPT 453-2	-89.16	**	-89.43	**	638.48	**	1073.66	**	-88.66	**	-84.95	**
IVT-SDW-703	-41.69	**	-43.12	**	121.91	**	252.68	**	-70.19	**	-60.43	**
IVT-SDW-703-1	-14.93	**	-17.02	**	37.36	**	118.30	**	-30.19	**	-7.33	**
NPT 76-8	1.11		-1.37		24.21	**	97.41	**	26.72	**	68.21	**
PR-115	-92.34	**	-92.53	**	340.25	**	599.69	**	-93.71	**	-91.65	**
CRMS 31 A												
NPT 453-2	-22.62	**	-24.52	**	54.49	**	145.54	**	-48.95	**	-32.24	**
IVT-SDW-703	-87.63	**	-87.93	**	642.84	**	1080.58	**	-84.99	**	-80.07	**
IVT-SDW-703-1	-38.81	**	-40.31	**	115.17	**	241.96	**	7.83	**	43.13	**
NPT 76-8	-11.24	**	-13.42	**	76.69	**	180.80	**	2.90	**	36.58	**
PR-115	-99.96	**	-99.96	**	505.90	**	862.95	**	-99.20	**	-98.93	**

*and ** indicate significance of values at P=0.05 and 0.01, respectively, I.S= Indira sona, MAH= Mahamaya

Table 4 : Mid parent heterosis, heterobeltiosis and standard heterosis

58025 A	Spikelet fertility				Panicle length (cm)				1000 grain weight (g)			
	I.S		MAH		I.S		MAH		I.S		MAH	
NPT 453-2	-23.48	**	-25.88	**	-8.72	*	9.28		1.36		-3.68	
IVT-SDW-703	-10.49	**	-13.30	**	-1.04		18.47	**	-1.25		-6.17	*
IVT-SDW-703-1	-15.82	**	-18.47	**	-7.40		10.86	*	-8.78	**	-13.32	**
NPT 76-8	-5.00	**	-7.99	**	-14.12	**	2.81		-4.87		-9.60	**
PR-115	-41.57	**	-43.41	**	1.49		21.51	**	3.25		-1.89	
79156 A												
NPT 453-2	-50.82	**	-52.36	**	-12.65	**	4.58		-4.13		-8.90	**
IVT-SDW-703	-13.43	**	-16.15	**	-7.75		10.44	*	-3.93		-8.71	**
IVT-SDW-703-1	0.33		-2.82	*	-1.91		17.43	**	-0.04		-5.01	*
NPT 76-8	-92.27	**	-92.51	**	-9.90	*	7.86		13.80	**	8.13	**
PR-115	-50.82	**	-52.36	**	-2.50		16.72	**	-15.12	**	-19.35	**
CRMS 31 A												
NPT 453-2	-23.52	**	-25.93	**	-13.00	**	4.16		-10.70	**	-15.14	**
IVT-SDW-703	-88.72	**	-89.08	**	-2.71		16.47	**	-0.41		-5.36	*
IVT-SDW-703-1	-12.28	**	-15.04	**	-4.17		14.73	**	-4.50		-9.25	**
NPT 76-8	-9.38	**	-12.23	**	-5.39		13.27	*	-5.27	*	-9.99	**
PR-115	-98.98	**	-99.01	**	-10.98	*	6.57		0.77		-4.24	

* and ** indicate significance of values at P=0.05 and 0.01, respectively, I.S= Indira sona, MAH= Mahamaya

The character chlorophyll content of hybrids during grain filling stage signifies photosynthesis activity of plant which leads to rapid and completely filled grains the crosses IR 58025 A /NPT 76-8, IR 79156A / NPT 453-2, IR 79156A / NDR 8054 (IR 77768-25-NDR-B-108-14), IR 79156A / CR 2330-3-3-2-1-1, CRMS 31 A / NPT 76-8 performed significant positive heterosis over both the checks (Murchie *et al*., 2002).

Characters which have positive significant correlation with yield are Productive tillers / plant, panicle length, number of filled spikelets/ panicle, spikelet fertility percentage, grain yield / plant, test weight, pollen fertility percentage and harvest index. More productive tillers produce more seeds hence, enhanced yield crosses IR 79156A / NPT 453-2 and CRMS 31 A/ PR-115 gave significant positive results over both checks and similar findings were also reported by Soni *et al*. (2005) for productive tillers per plant. Character panicle length signifies the accumulations of grains and cross IR 58025 A /PR-115 withstand positive standard heterosis over the checks under study and similar findings were recorded by Soni *et al*. (2005); Pandya and Tripathi (2006); Singh (2005); Jeloder and Bagheri (2010) and Rahimi *et al.* (2010).Observation filled spikelet / panicle is taken to determine the total number of filled grains in a panicle, cross IR 58025 A /NPT 76-8 and IR 79156A / NPT 76-8 were superior over the commercial checks. Similar type of results have also been reported by Singh (2005) and Li *et al.* (2008). Spikelet fertility percentage determines the reproducing ability of the cross, no hybrid was recorded under significant positive standard heterosis for spikelet fertility over checks and similar results have also been reported by Singh (2005); Soni *et al.* (2005); Shanthi *et al.* (2006) and Jeloder and Bagheri (2010).Cross IR 79156A / NPT 76-8 stood for positive significant heterosis over checks for characters Grain yield/plant (Munisonnappa and Vidyachandra, 2007) and Rahimi *et al*., 2010), test weight (Wang *et al.*, 2010) and Rahimi *et al.*, 2010), pollen fertility percentage (Jayashudha, 2008), and harvest index (Sarawgi *et al.*,1991) and Munhot *et al.*, 2000).

Table 5 : Mid parent heterosis, heterobeltiosis and standard heterosis

58025 A	Grain yield/ plant (g)				Chlorophyll content				Harvest index			
	I.S		MAH		I.S		MAH		I.S		MAH	
NPT 453-2	-67.32	**	-66.86	**	4.11		-18.06	**	56.42	**	-2.98	
IVT-SDW-703	-59.31	**	-58.74	**	25.27	**	-1.41		18.37	**	-26.58	**
IVT-SDW-703-1	-48.04	**	-47.31	**	6.04		-16.54	**	11.47		-30.86	**
NPT 76-8	-48.12	**	-47.39	**	31.49	**	3.49		-6.33		-41.90	**
PR-115	-61.03	**	-60.48	**	-42.24	**	-54.54	**	31.35	**	-18.53	**
79156 A												
NPT 453-2	-62.42	**	-61.89	**	30.91	**	3.04		-62.54	**	-76.77	**
IVT-SDW-703	-74.84	**	-74.48	**	32.56	**	4.33		16.60	**	-27.68	**
IVT-SDW-703-1	-36.44	**	-35.54	**	34.85	**	6.13		-15.45	*	-47.56	**
NPT 76-8	4.12	*	5.58	**	-25.75	**	-41.56	**	79.53	**	11.36	**
PR-115	-59.80	**	-59.24	**	3.07		-18.87	**	3.90		-35.55	**
CRMS 31 A												
NPT 453-2	-65.03	**	-64.54	**	30.06	**	2.36		-16.72	**	-48.35	**
IVT-SDW-703	-67.97	**	-67.52	**	26.48	**	-0.45		4.47		-35.20	**
IVT-SDW-703-1	-70.59	**	-70.17	**	24.91	**	-1.69		-4.20		-40.58	**
NPT 76-8	-13.96	**	-12.75	**	17.69	**	-7.37		62.31	**	0.67	
PR-115	-45.92	**	-45.15	**	14.72	*	-9.70	*	4.67		-35.08	**

* and ** indicate significance of values at P=0.05 and 0.01, respectively, I.S= Indira sona, MAH= Mahamaya

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