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Original Research Article

Exploitation of Heterosis in Rice (*Oryza sativa* L.) using CMS System under Upland Conditions

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Keywords

Upland rice, Restorer, Hybrids and heterosis

A B S T R A C T

Heterotic performance of sixty eight F_1 hybrids and their 33 parents (30 pollen parents and 3 CMS lines) were evaluated in a randomized block design with three replications. The hybrid combinations IR-68897A x Jaya, IR-68897A x HUR-38, IR-68888A x HUR-38, IR-58025A x URG-6, IR-68888A x Pant-12 and IR-58025A x HUR-38 have been identified as early types. In respect to grain yield per plant, at least 20 per cent heterosis is desirable for exploitation of hybrid vigor. Maximum heterobeltiosis have been recorded in IR-68888A x URG-51 (28.48%). 11 cross combinations *viz.* IR-68897A x Jaya, IR-68897A x Shivani, IR-68897A x URG-22, IR-68888A x URG-22, IR-68888A x BPT-5204, IR-68888A x URG-51, IR-68888A x URG-84, IR-58025A x Pant-12, IR-58025A x Jaya, IR-58025A x Sarjoo-52 and IR-58025A x URG-77 had high standard heterosis. Heterosis for grain yield was mainly due to heterosis for 100 grain weight, number of grains per panicle and panicle bearing tillers per plant. Significant negative heterosis was observed in days to 50% flowering, days to maturity and plant height which is desirable for developing early maturing and medium tall varieties.

Introduction

During last 25 years major increase in rice production has occurred mainly due to large scale adoption of high yielding semi dwarf varieties and improved management practices has made several rice growing countries self-sufficient. However, the rate of increase of rice production has slowed down, the rate of population growth of rice consumers in now greater than the rate of increase in rice production. At present the rate of population growth in India is 1.8 percent, the requirement of rice has been estimated around 163 m tones by turn of 2020. The task is no doubt quite challenging and the options available are very limited.

As there is no scope for expansion of agricultural land and yield plateauing is being observed in rice productivity from last two decades. Among the various possible genetic approaches to achieve this target, hybrid rice technology is the most feasible and readily adopted one, as has been clearly demonstrated in the people republic of China, during last two decades by breaking yield barrier of semi-dwarf inbred rice with successful development of F_1 rice hybrids.

Materials and Methods

Three Cytoplasmic male sterile (CMS) lines, *viz.* IR-68897A, IR-68888 A and IR-58025 A and 30 rice genotypes were grown at

Agricultural research farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, in June- November 2010 (*kharif* season) under upland condition. CMS lines were grown on three different dates of sowing at an interval of seven days to ensure synchronous flowering to produce adequate crossed seed. Crosses were made in all possible combinations between CMS lines and pollen parents following line (pollen parents) x tester (CMS lines) fashion. Out of total 90 possible cross combinations only 68 crosses were successful. Sixty eight hybrids, three Cytoplasmic male sterile lines (A line), their respective maintainer lines (B line) and 30 pollen parents along with two checks NDR-97 (Early duration) and Sarjoo-52 (Medium duration) formed the material for the study. All the 68 F_1s and their parents (male and female) along with check were grown in Randomized Block Design with three replications during *kharif* 2011 for the estimation of heterobeltiosis and standard heterosis. Each treatment had one row of two meter length with the spacing of 20 cm x 15cm row to row and plant to plant respectively, in each replication. The recommended agronomic practices were adopted to raise a good crop. Five competitive plants were selected randomly from each treatment per replication and data were recorded on the eight component traits of yield *viz.* days to 50% flowering, days to maturity, plant height, number of effective tillers, panicle length, seeds per panicle, 100 seed weight and plant yield.

Results and Discussions

Earliness in hybrids is considered as the desirable character with the expectation that it enables the hybrids to mature earlier as compared to their parents. It enhances the productivity day^{-1} unit^{-1} area. Significant heterosis for days to 50% flowering ranged from -25.33 to 20.33 per cent over Sarjoo-52, whereas, heterobeltiosis and standard heterosis (over check 1-NDR 97) ranged from 0.00 to 32.23 per cent and 0.92 to 58.56 per cent respectively. Forty two hybrids displayed negative and significant heterosis over Sarjoo-52, of which six hybrids namely IR-68897 A x Jaya, IR-68888 A x Pant-12, IR-58025 A x Jaya, IR-68897 A x HUR-3022, IR-68888 A x Jaya and IR-68888 A x Pusa-370 exhibited higher magnitude of standard heterosis which ranged from -25.33 to -12.67 per cent. Heterobeltiosis in positive directions for days to flowering (50%) have also been reported by Patel *et al.,* (1994), Pandey *et al.,* (1995) and Lingaraju *et al.,* (1999). A wide range between negative and positive values of standard heterosis have been reported by Singh (1989), Mui *et al.,* (1991), Suprihanto *et al.,* (1993) Leena Kumari *et al.,* (1998), Rahimi *et al.,* (2010), Jarwar *et al.,* (2012) and Latha *et al.,* (2013). Some of the workers *viz.* Purohit (1972), Young and Virmani (1990) and Patil *et al.,* (2003) reported only negative standard heterosis in rice hybrids studied by them.

Heterosis over better parent and over both the checks (NDR-97 and Sarjoo-52) has been observed in both the directions for days to maturity. Since short duration varieties are preferred by breeders, therefore negative estimates of heterosis are desirable. Most of the hybrids matured at par against their better parents and check (NDR-97) except two crosses exhibiting a heterosis of the range -2.47 to -4.00 per cent. Only five hybrids were significantly early maturing compared to the check (Sarjoo-52) and exhibited standard heterosis to the tune of -27.27 to 16.40 per cent. Significant desirable standard heterosis for earliness has also been reported by Leena Kumari *et al.,* (1998), Jayasudha and Sharma (2009), Rahimi *et al.,* (2010) and Jawahar *et al.,* (2012). For plant height, all the F_1s derived from crosses of CMS and restorers were taller than their better parent. This observation is in conformity with the findings of Pandey *et al.,* (1995) who reported that most of the hybrids studied by them manifested significant heterosis for tallness. Although none of the hybrids showed negative heterosis over better parent but 17 hybrids exhibited significant negative standard heterosis over NDR-97 and 19 hybrids over Sarjoo-52.In the present study, all of the hybrids showed greater tendency towards tallness than their respective better parent and most of the hybrids against standard checks. Most of the rice workers; Singh *et al.,* (1986), Sarawgi *et al.,* (2000), Vaithiyalingan and Nadarajan (2010), Tiwary *et al.,* (2011) and Sanghera and Hussain (2012) reported significant heterobeltiosis and standard heterosis for tallness as is revealed in the present investigation.

Longer panicle length associated with higher panicle density results in higher productivity. Longer panicles are preferred by the breeders, therefore positive heterosis is desirable. However, heterosis over better parent and check varieties for panicle length was relatively low. A wide range for the magnitude of heterobeltiosis (-49.75% to 34.48%) and standard heterosis (-52.12% to 39.55%) was observed. 14 hybrids manifested significant positive heterobeltiosis. Significantly positive standard heterosis was observed in 34 hybrids against NDR-97 and eight hybrids against Sarjoo-52. These findings are in accordance with the findings of Sharma and Mani (1990), Rahimi *et al.,* (2010), Tiwari *et al.*, (2011) and Latha *et al.*, (2013) who also observed desirable standard heterosis for panicle length. It appears from the present study that greater attempts are needed for utilizing this useful trait in the hybrids. Higher number of effective tillers per plant is one of the most important yield attributes for higher yield. In the present investigation, ten hybrids displayed significant positive heterobeltiosis, whereas, 27 hybrids were significantly heterotic over NDR 97 and 18 hybrids over Sarjoo-52. Five hybrids namely IR-58025 A x Pant-12, IR-68888 A x BPT-5204, IR-58025 A x Sarjoo-52, IR-68897 A x URG-22 and IR-58025 A x URG-77 exhibited high degree of significantly positive heterosis over better parent and both the checks. Significantly positive heterosis for number of effective tillers has also been reported by Sarawgi *et al.,* (2000), Mehrajuddin (2009), Vaithiyalingam and Nadarajan (2010) and Latha *et al.,* (2013) which supported the findings of present investigation.

Number of grains per panicle is the major yield attributing character, hence significant positive heterobeltiosis and standard heterosis is desirable. Three hybrids showed significant positive heterobeltiosis. Six hybrids exhibited significant positive standard heterosis over both the checks. The range of standard heterosis for grains per panicle varied from -96.64 to 28.75 per cent. Such wide range of heterosis was also reported by the earlier rice workers *viz.* Sharma and Mani (1990), Leena Kumari *et al.,* (1998), Tiwary *et al.,* (2011) and Latha *et al.,* (2013). However, Sanghera and Hussain (2012) reported negative heterosis for number of grains per panicle. 100 grain weight is an important yield related character and influences the grain yield to a large extent. Six hybrids namely exhibited significant heterobeltiosis, among them three hybrids were significantly heterotic over NDR-97 and Sarjoo-52 with higher magnitude of standard heterosis which ranged from 15.31 per cent to 65.21 per cent (Table 1).

Table.1 Estimates of magnitude of heterobeltiosis and standard heterosis in 68 rice hybrid for yield attributing traits

S.No.	Cross combination	Days to flowering			Days to maturity			Plant height			Tillers/plant		
		Heterobeltiosis	**NDR-97**	**Sarjoo-52**	**Heterobeltiosis**	**NDR-97**	**Sarjoo-52**	**Heterobeltiosis**	**NDR-97**	**Sarjoo-52**	**Heterobeltiosis**	**NDR-97**	**Sarjoo-52**
1.	IR-68888 A x Pant-12	09.48**	04.05**	-23.00**	16.96**	10.33**	-16.41**	19.17**	10.02**	07.33**	-24.24**	-10.71	-16.67*
2.	IR-58025 A x Pant-12	27.49**	21.17**	-10.33**	18.37**	11.67**	-15.40**	31.61**	13.90**	11.11**	32.56**	103.57**	90.00**
3.	IR-68897 A x Pant-16	14.68**	30.18**	-03.67**	16.01**	28.00**	-03.03**	30.91**	21.17**	18.21**	-12.90	-03.57	-10.00
4.	IR-58025 A x Pant-16	08.06**	32.88**	-01.67*	04.66**	27.33**	-03.54**	44.28**	24.86**	21.81**	-18.60**	25.00**	16.67*
5.	IR-68897 A x Pusa-370	07.14**	21.62**	-10.00**	12.69**	24.33**	-05.81**	47.10**	36.16**	32.83**	-05.71	17.86*	10.00
6.	IR-68888 A x Pusa-370	01.55	18.02**	-12.67**	04.76**	17.33**	-11.11**	29.77**	19.80**	16.87**	-02.86	21.43*	13.33
7.	IR-68897 A x Pusa-44	13.89**	29.28**	-04.33**	10.57**	22.00**	-07.58**	02.19*	-07.63**	-09.89**	-23.08*	-28.57**	-33.33**
8.	IR-68888 A x Pusa-44	13.95**	32.43**	-02.00*	13.99**	27.67**	-03.28**	03.29**	-06.63**	-08.91**	-30.30**	-17.86*	-23.33**
9.	IR-58025 A x Pusa-44	07.33**	31.98**	-02.33**	08.36**	29.67**	-01.77*	07.08**	-07.33**	-09.60**	-37.21**	-03.57	-10.00
10.	IR-68897 A x Jaya	02.75*	0.90	-25.33**	0.70	-04.00**	-27.27**	09.37**	01.23**	-01.24	91.67**	64.29**	53.33**
11.	IR-68888 A x Jaya	20.18**	18.02**	-12.67**	22.73**	17.00**	-11.36**	07.34**	-0.91	-03.33**	-39.39**	-28.57**	-33.33**

12.	IR-58025 A x Jaya	14.22**	12.16**	-17.00**	17.13**	11.67**	-15.40**	20.18**	04.00**	01.46	-46.51**	-17.86*	-23.33**
13.	IR-68897 A x Shivani	18.65**	34.68**	-0.33	23.26**	36.00**	03.03**	21.74**	12.68**	09.92**	44.00**	28.57**	20.00*
14.	IR-68888 A x Shivani	07.36**	24.77**	-07.67**	10.71**	24.00**	-06.06**	15.38**	06.51**	03.91**	-33.33**	-21.43*	-26.67**
15.	IR-58025 A x Shivani	09.52**	34.68**	-0.33	05.48**	28.33**	-02.78**	28.41**	11.13**	08.41**	-30.23**	07.14	0.00
16.	IR-68897 A x HUR-105	11.90**	27.03**	-06.00**	14.50**	26.33**	-04.29**	23.97**	14.74**	11.94**	-11.43	10.71	03.33
17.	IR-68888 A x HUR-105	09.30**	27.03**	-06.00**	11.61**	25.00**	-05.30**	27.57**	17.77**	14.89**	-02.86	21.43*	13.33
18.	IR-68897 A x HUR-3022	03.57**	17.57**	-13.00**	01.81*	12.33**	-14.90**	0.81	-07.77**	-10.03**	0.00	10.71	03.33
19.	IR-68888 A x HUR-3022	09.38**	26.13**	-06.67**	13.60**	25.33**	-05.05**	12.99**	03.37**	0.85	-03.03	14.29	06.67
20	IR-58025 A x HUR-3022	03.52**	19.37**	-11.67**	03.02**	13.67**	-13.89**	08.96**	-05.71**	-08.01**	-23.26**	17.86*	10.00
21.	IR-68888 A x BPT-5204	18.99**	38.29**	02.33**	18.75**	33.00**	0.76	15.62**	06.73**	04.12**	30.30**	53.57**	43.33**
22.	IR-58025 A x BPT-5204	28.94**	58.56**	17.33**	15.89**	41.00**	06.82**	15.73**	0.16	-02.29*	-46.51**	-17.86*	-23.33**
23.	IR-68897 A x HUR-36	0.00	12.61**	-16.67**	05.66**	12.00**	-15.15**	34.82**	24.79**	21.73**	16.00	03.57	-03.33
24.	IR-68888 A x HUR-36	03.60**	16.67**	-13.67**	15.72**	22.67**	-07.07**	38.53**	27.89**	24.76**	-24.24**	-10.71	-16.67*

25.	IR-58025 A x HUR-36	12.00**	26.13**	-06.67**	04.72**	11.00**	-15.91**	36.26**	17.92**	15.04**	-37.21**	-03.57	-10.00
26.	IR-68897 A x HUR-4-3	20.24**	36.49**	01.00	22.36**	35.00**	02.27**	33.46**	23.53**	20.51**	-13.33	-07.14	-13.33
27.	IR-68897 A x HUR-38	02.83**	14.41**	-15.33**	0.63	06.67**	-19.19**	18.15**	09.35**	06.68**	30.00**	39.29**	30.00**
28.	IR-68888 A x HUR-38	06.88**	18.92**	-12.00**	02.52**	08.67**	-17.68**	21.17**	11.87**	09.13**	-27.27**	-14.29	-20.00*
29.	IR-58025 A x HUR-38	07.69**	19.82**	-11.33**	04.40**	10.67**	-16.16**	32.76**	14.89**	12.08**	-23.26**	17.86*	10.00
30.	IR-68888 A x Sarjoo-52	0.78	17.12**	-13.33**	08.63**	21.67**	-07.83**	10.38**	01.90*	-0.59	-27.27**	-14.29	-20.00*
31.	IR-58025 A x Sarjoo-52	10.99**	36.49**	01.00	07.67**	31.00**	-0.76	10.25**	-04.59**	-06.93**	-09.30	39.29**	30.00**
32.	IR-68897 A x URG-6	07.94**	22.52**	-09.33**	03.63**	14.33**	-13.38**	03.03**	-04.64**	-06.97**	-17.24*	-14.29	-20.00*
33.	IR-58025 A x URG-6	0.73	23.87**	-08.33**	-01.50	09.67**	-16.92**	10.75**	-04.16**	-06.50**	-27.91**	10.71	03.33
34.	IR-68897 A x URG-12	12.30**	27.48**	-05.67**	16.92**	29.00**	-02.27**	14.77**	-06.45**	-08.73**	-11.43	10.71	03.33
35.	IR-68888 A x URG-12	17.44**	36.49**	01.00	15.18**	29.00**	-02.27**	17.58**	-04.16**	-06.50**	0.00	25.00**	16.67*
36.	IR-58025 A x URG-12	09.89**	35.14**	0.00	06.03**	29.00**	-02.27**	04.14**	-15.11**	-17.19**	-18.60**	25.00**	16.67*
37.	IR-68897 A x URG-19	16.67**	32.43**	-02.00*	19.34**	31.67**	-0.25	05.07**	-10.36**	-12.55**	-02.78	25.00**	16.67*

38.	IR-68888 A x URG-19	16.67**	35.59**	0.33	16.96**	31.00**	-0.76	09.40**	-06.67**	-08.95**	11.11	42.86**	33.33**
39.	IR-58025 A x URG-19	07.69**	32.43**	-02.00*	01.10	23.00**	-06.82**	13.12**	-03.49**	-05.85**	-13.95*	32.14**	23.33**
40.	IR-68897 A x URG-22	15.87**	31.53**	-02.67**	09.06**	20.33**	-08.84**	31.11**	21.35**	18.39**	46.88**	67.86**	56.67**
41.	IR-68888 A x URG-22	03.49**	20.27**	-11.00**	04.46**	17.00**	-11.36**	32.69**	22.50**	19.50**	30.30**	53.57**	43.33**
42.	IR-58025 A x URG-22	16.29**	38.29**	02.33**	07.23**	23.67**	-06.31**	42.57**	23.38**	20.37**	-44.19**	-14.29	-20.00*
43.	IR-68888 A x URG-36	14.73**	33.33**	-01.33	20.24**	34.67**	02.02**	10.86**	02.34*	-0.16	-15.15*	0.00	-06.67
44.	IR-58025 A x URG-36	03.30**	27.03**	-06.00**	-02.74**	18.33**	-10.35**	23.30**	06.70**	04.09**	-48.84**	-21.43*	-26.67**
45.	IR-68897 A x URG-48	10.71**	25.68**	-07.00**	16.01**	28.00**	-03.03**	05.50**	-02.35*	-04.74**	-25.71**	-07.14	-13.33
46.	IR-58025 A x URG-48	0.37	22.52**	-09.33**	01.37	23.33**	-06.57**	24.66**	07.88**	05.24**	37.21**	110.71**	96.67**
47.	IR-68897 A x URG-51	05.56**	19.82**	-11.33**	03.02**	13.67**	-13.89**	33.66**	23.72**	20.69**	-28.13**	-17.86*	-23.33**
48.	IR-68888 A x URG-51	18.60**	37.84**	02.00*	16.37**	30.33**	-01.26	40.93**	30.10**	26.92**	33.33**	57.14**	46.67**
49.	IR-58025 A x URG-51	08.79**	33.78**	-01.00	02.47**	24.67**	-05.56**	32.76**	14.89**	12.08**	-16.28**	28.57**	20.00*
50.	IR-68897 A x URG-60	15.08**	30.63**	-03.33**	23.87**	36.67**	03.54**	06.02**	-01.87*	-04.27**	-13.79	-10.71	-16.67*

51.	IR-68888 A x URG-60	15.50**	34.23**	-0.67	20.24**	34.67**	02.02**	14.90**	06.07**	03.48**	-12.12	03.57	-03.33
52.	IR-58025 A x URG-60	09.89**	35.14**	0.00	09.86**	33.67**	01.26	22.18**	05.74**	03.15**	-13.95*	32.14**	23.33**
53.	IR-68897 A x URG-67	11.90**	27.03**	-06.00**	11.48**	23.00**	-06.82**	14.12**	05.63**	03.04**	-06.25	07.14	0.00
54.	IR-68888 A x URG-67	12.79**	31.08**	-03.00**	16.96**	31.00**	-0.76	32.05**	21.91**	18.93**	-06.06	10.71	03.33
55.	IR-58025 A x URG-67	04.03**	27.93**	-05.33**	05.48**	28.33**	-02.78**	45.56**	25.97**	22.89**	-44.19**	-14.29	-20.00*
56.	IR-68897 A x URG-72	31.35**	49.10**	10.33**	19.94**	32.33**	0.25**	19.03**	10.17**	07.47**	-13.89*	10.71	03.33
57.	IR-68888 A x URG-72	30.23**	51.35**	12.00**	20.83**	35.33**	02.53**	30.17**	20.17**	17.23**	-08.33	17.86*	10.00
58.	IR-58025 A x URG-72	32.23**	62.61**	20.33**	15.89**	41.00**	06.82**	33.36**	15.41**	12.59**	-16.28**	28.57**	20.00*
59.	IR-68897 A x URG-76	15.48**	31.08**	-03.00**	16.01**	28.00**	-03.03**	36.10**	25.97**	22.89**	-19.35*	-10.71	-16.67*
60.	IR-68888 A x URG-76	16.28**	35.14**	0.00	16.96**	31.00**	-0.76	15.90**	06.99**	04.38**	-42.42**	-32.14**	-36.67**
61.	IR-58025 A x URG-76	12.09**	37.84**	02.00*	07.12**	30.33**	-01.26	26.11**	09.13**	06.46**	-41.86**	-10.71	-16.67*
62.	IR-68888 A x URG-77	14.73**	33.33**	-01.33	19.35**	33.67**	01.26	12.70**	04.04**	01.49	03.03	21.43*	13.33
63.	IR-58025 A x URG-77	06.23**	30.63**	-03.33**	03.29**	25.67**	-04.80**	19.11**	03.08**	0.56	16.28**	78.57**	66.67**

64.	IR-68888 A x URG-83	20.16**	39.64**	03.33**	19.94**	34.33**	01.77*	22.64**	06.70**	04.09**	-18.18*	-03.57	-10.00
65.	IR-58025 A x URG-83	10.62**	36.04**	0.67	05.48**	28.33**	-02.78**	01.28	-12.35**	-14.49**	-41.86**	-10.71	-16.67*
66.	IR-68897 A x URG-84	32.14**	50.00**	11.00**	25.38**	38.33**	04.80**	52.13**	40.81**	37.36**	-32.14**	-32.14**	-36.67**
67.	IR-68888 A x URG-84	14.73**	33.33**	-01.33	09.82**	23.00**	-06.82**	36.06**	25.61**	22.53**	-09.09	07.14	0.00
68.	IR-58025 A x URG-84	22.34**	50.45**	11.33**	13.15**	37.67**	04.29**	40.44**	21.54**	18.57**	-46.51**	-17.86*	-23.33**

Cross combination			Panicle length	Seeds/panicle			100 seed wt.			Yield/plant		
	Hb	**NDR-97**	**Sarjoo-52**	**Hb**	**NDR-97**	**Sarjoo-52**	**Hb**	**NDR-97**	**Sarjoo-52**	**Hb**	**NDR-97**	**Sarjoo-52**
IR-68888 A x Pant-12	09.99**	13.32**	01.88	-88.43**	-87.47**	-87.30**	-06.17*	-13.58**	13.27**	-79.17**	-74.58**	-75.43**
IR-58025 A x Pant-12	08.89**	12.20**	0.86	15.24**	26.85**	28.57**	06.49**	-04.81*	24.76**	13.45**	36.49**	31.94**
IR-68897 A x Pant-16	02.79	05.99*	-04.71*	-51.69**	-48.99**	-48.30**	01.54	-10.74**	16.99**	-31.06**	-13.71**	-16.58**
IR-58025 A x Pant-16	-18.95**	-16.42**	-24.87**	-54.88**	-50.34**	-49.66**	01.40	-10.86**	16.83**	-41.47**	-29.58**	-31.93**
IR-68897 A x Pusa-370	-13.51**	05.57*	-05.10*	-46.82**	-43.85**	-43.08**	-0.29	-14.07**	12.62**	-25.39**	-06.61*	-09.72**
IR-68888 A x Pusa-370	-16.52**	01.90	-08.39**	-59.50**	-56.15**	-55.56**	-21.31**	-27.53**	-05.02	-33.55**	-18.89**	-21.60**
IR-68897 A x Pusa-44	07.50**	12.76**	01.37	-71.19**	-69.57**	-69.16**	-17.05**	-28.52**	-06.31*	-35.47**	-19.24**	-21.93**
IR-68888 A x Pusa-44	01.99	06.98**	-03.83	-47.52**	-43.18**	-42.40**	-17.83**	-24.32**	-0.81	-26.90**	-10.77**	-13.75**
IR-58025 A x Pusa-44	03.87	08.95**	-02.05	-92.07**	-91.28**	-91.16**	-10.14**	-28.89**	-06.80*	-91.26**	-89.48**	-89.83**
IR-68897 A x Jaya	19.11**	20.37**	08.21**	-18.22**	-13.65**	-12.47**	-0.27	36.54**	78.96**	19.69**	80.31**	74.30**

IR-68888 A x Jaya	-03.86	-01.62	-11.56**	-90.85**	-89.93**	-89.80**	-0.36	36.42**	78.80**	-23.55**	15.16**	11.32**
IR-58025 A x Jaya	-02.91	-01.34	-11.31**	-04.03*	01.34	02.72	-06.16*	-19.14**	05.99*	02.48	28.27**	23.99**
IR-68897 A x Shivani	07.73**	21.78**	09.48**	-81.61**	-80.09**	-79.82**	-09.12**	-16.30**	09.71**	-25.61**	-09.20**	-12.23**
IR-68888 A x Shivani	-06.11**	06.13*	-04.59	-79.88**	-77.85**	-77.55**	-0.61	-19.75**	05.18	-30.93**	-16.90**	-19.67**
IR-58025 A x Shivani	01.75	15.01**	03.40	-91.53**	-91.05**	-90.93**	-12.18**	-24.32**	-0.81	-59.90**	-49.81**	-51.49**
IR-68897 A x HUR-105	-02.76	04.44	-06.11*	-90.70**	-89.93**	-89.80**	-26.41**	-32.22**	-11.17**	-85.85**	-82.73**	-83.31**
IR-68888 A x HUR-105	-01.18	06.13*	-04.59	-78.39**	-77.18**	-76.87**	25.03**	18.40**	55.18**	-24.95**	-06.07	-09.20**
IR-68897 A x HUR-3022	-0.82	02.75	-07.63**	-90.70**	-89.93**	-89.80**	-05.61*	-10.62**	17.15**	-74.53**	-68.91**	-69.94**
IR-68888 A x HUR-3022	-02.45	01.06	-09.15**	-90.65**	-89.71**	-89.57**	-48.63**	-51.36**	-36.25**	-84.93**	-81.88**	-82.48**
IR-58025 A x HUR-3022	02.18	05.85*	-04.84*	02.69	11.19**	12.70**	17.19**	15.31**	51.13**	20.38**	46.94**	42.04**
IR-68888 A x BPT-5204	03.39	05.79*	-04.89*	-52.24**	-47.43**	-46.71**	-09.03**	-10.49**	17.31**	-28.44**	-13.91**	-16.78**
IR-58025 A x BPT-5204	-13.60**	-12.20**	-21.06**	-71.61**	-70.02**	-69.61**	46.28**	26.05**	65.21**	-39.98**	-24.88**	-27.38**
IR-68897 A x HUR-36	-05.09	-02.75	-12.57**	-59.09**	-55.70**	-55.10**	-02.82	-10.49**	17.31**	-31.80**	-16.76**	-19.53**
IR-68888 A x HUR-36	11.56**	14.31**	02.76	-53.46**	-48.77**	-48.07**	01.49	-16.17**	09.87**	-42.41**	-30.72**	-33.03**
IR-58025 A x HUR-36	-04.68	-02.33	-12.19**	-89.41**	-88.81**	-88.66**	03.30	-10.99**	16.67**	-72.43**	-65.49**	-66.64**
IR-68897 A x HUR-4-3	-0.87	07.54**	-03.32	-92.77**	-92.17**	-92.06**	-16.62**	-23.21**	0.65	-74.29**	-68.62**	-69.67**
IR-68897 A x HUR-38	-03.90	-06.13*	-15.61**	-91.06**	-90.16**	-90.02**	0.62	-20.37**	04.37	-83.75**	-80.45**	-81.10**
IR-68888 A x HUR-38	0.69	03.03	-07.38**	-94.01**	-93.51**	-93.42**	-08.98**	-16.17**	09.87**	-88.33**	-85.75**	-86.23**
IR-58025 A x HUR-38	-21.78**	-20.51**	-28.54**	05.69**	16.33**	17.91**	-05.62*	-25.31**	-02.10	08.30**	30.29**	25.95**
IR-68888 A x Sarjoo-52	-02.61	06.84*	-03.95	-86.23**	-85.46**	-85.26**	-05.44*	-14.20**	12.46**	-26.09**	-07.50*	-10.58**
IR-58025 A x Sarjoo-52	20.65**	32.36**	18.99**	-78.05**	-75.84**	-75.51**	-01.50	-10.62**	17.15**	-39.57**	-27.30**	-29.72**
IR-68897 A x URG-6	03.86	06.13*	-04.59	-93.01**	-92.62**	-92.52**	-08.67**	04.07	36.41**	-88.09**	-85.10**	-85.59**

IR-58025 A x URG-6	03.86	06.13*	-04.59	-63.14**	-61.07**	-60.54**	-05.30*	-18.40**	06.96*	-20.38**	-0.34	-03.66
IR-68897 A x URG-12	-05.06*	-01.90	-11.81**	-79.75**	-78.08**	-77.78**	-11.39**	-18.40**	06.96*	-39.04**	-25.59**	-28.07**
IR-68888 A x URG-12	-06.56*	-03.45	-13.21**	-91.26**	-90.38**	-90.25**	0.92	-18.89**	06.31*	-79.60**	-75.46**	-76.28**
IR-58025 A x URG-12	-01.79	01.48	-08.77**	19.49**	26.17**	27.89**	-15.13**	-10.00**	17.96**	24.57**	55.91**	50.72**
IR-68897 A x URG-19	01.31	01.62	-08.64**	-59.09**	-55.70**	-55.10**	01.98	08.15**	41.75**	03.95	28.90**	24.60**
IR-68888 A x URG-19	-11.16**	-09.09**	-18.28**	-45.12**	-39.60**	-38.78**	-44.24**	-40.86**	-22.49**	-54.93**	-44.12**	-45.98**
IR-58025 A x URG-19	01.78	03.43	-07.02**	-74.38**	-72.26**	-71.88**	-22.79**	-28.89**	-06.80*	-62.62**	-54.37**	-55.90**
IR-68897 A x URG-22	30.27**	39.55**	25.45**	-60.77**	-56.82**	-56.24**	-10.30**	-29.01**	-06.96*	-14.94**	02.34	-01.07
IR-68888 A x URG-22	-0.39	06.70*	-04.08	-52.97**	-50.34**	-49.66**	-03.30	-16.67**	09.22**	-29.80**	-12.14**	-15.07**
IR-58025 A x URG-22	-04.08	02.75	-07.63**	-22.36**	-14.54**	-13.38**	0.00	-19.38**	05.66	-52.88**	-43.32**	-45.21**
IR-68888 A x URG-36	-0.66	05.43*	-05.22*	-47.67**	-44.74**	-43.99**	0.14	-13.70**	13.11**	-88.14**	-85.15**	-85.65**
IR-58025 A x URG-36	08.29**	14.93**	03.32	-22.73**	-16.33**	-15.19**	13.27**	04.32	36.73**	28.48**	56.83**	51.60**
IR-68897 A x URG-48	-02.54	0.21	-09.91**	-93.09**	-92.39**	-92.29**	-12.65**	-29.26**	-07.28*	-17.30**	-0.51	-03.83
IR-58025 A x URG-48	20.36**	23.76**	11.25**	-61.78**	-58.61**	-58.05**	-17.29**	-23.83**	-0.16	-50.95**	-40.13**	-42.12**
IR-68897 A x URG-51	-06.54*	-05.29*	-14.85**	-58.54**	-54.36**	-53.74**	-05.93*	-25.56**	-02.43	-46.67**	-35.84**	-37.98**
IR-68888 A x URG-51	05.92*	08.39**	-02.56	-83.26**	-82.33**	-82.09**	-03.68	0.12	31.23**	-31.90**	-14.76**	-17.60**
IR-58025 A x URG-51	-02.19	-0.61	-10.65**	-91.32**	-90.60**	-90.48**	01.07	05.06*	37.70**	-85.13**	-81.85**	-82.45**
IR-68897 A x URG-60	-10.78**	-02.61	-12.45**	-91.06**	-90.16**	-90.02**	-03.68	0.12	31.23**	-90.81**	-88.94**	-89.31**
IR-68888 A x URG-60	-03.16	05.71*	-04.97*	-75.42**	-74.05**	-73.70**	-20.77**	-31.73**	-10.52**	-58.77**	-48.39**	-50.11**
IR-58025 A x URG-60	01.34	10.63**	-0.54	-46.69**	-42.28**	-41.50**	-19.30**	-25.68**	-02.59	-29.65**	-14.14**	-17.00**
IR-68897 A x URG-67	-13.19**	-01.90	-11.81**	-50.41**	-45.41**	-44.67**	-05.93*	-25.56**	-02.43	-38.36**	-25.85**	-28.32**
IR-68888 A x URG-67	-01.83	10.93**	-0.28	-88.14**	-87.47**	-87.30**	06.96**	-03.21	26.86**	-33.04**	-16.19**	-18.98**

IR-58025 A x URG-67	-14.49**	-03.37	-13.13**	-93.18**	-92.62**	-92.52**	-15.42**	-22.10**	02.10	-87.58**	-84.84**	-85.34**
IR-68897 A x URG-72	-03.94	05.43*	-05.22*	-67.68**	-64.43**	-63.95**	-07.91**	-16.67**	09.22**	-08.87**	09.63**	05.98
IR-68888 A x URG-72	-09.72**	-0.92	-10.93**	-96.49**	-96.20**	-96.15**	-17.56**	-24.07**	-0.49	-90.29**	-88.14**	-88.54**
IR-58025 A x URG-72	04.84*	15.07**	03.45	-0.61	09.40**	10.88**	-04.68	-24.57**	-01.13	06.88**	28.58**	24.30**
IR-68897 A x URG-76	-16.12**	-10.36**	-19.42**	-91.12**	-90.38**	-90.25**	-02.01	-09.75**	18.28**	-40.21**	-27.02**	-29.45**
IR-68888 A x URG-76	-30.11**	-25.31**	-32.85**	-44.51**	-38.93**	-38.10**	-0.89	-17.78**	07.77**	-40.38**	-28.27**	-30.66**
IR-58025 A x URG-76	14.13**	21.97**	09.65**	-96.82**	-96.64**	-96.60**	-28.12**	-11.98**	15.37**	-70.38**	-62.92**	-64.16**
IR-68888 A x URG-77	-49.75**	-46.74**	-52.12**	-01.24	06.94**	08.39**	-02.02	20.00**	57.28**	-05.30*	15.59**	11.74**
IR-58025 A x URG-77	30.46**	38.28**	24.31**	-96.54**	-96.20**	-96.15**	-35.69**	-21.23**	03.24	-75.91**	-71.02**	-71.98**
IR-68888 A x URG-83	-15.95**	-11.98**	-20.87**									
IR-58025 A x URG-83	02.18	07.01**	-03.80									
IR-68897 A x URG-84	-19.46**	-21.33**	-29.28**									
IR-68888 A x URG-84	-0.34	01.97	-08.33**									
IR-58025 A x URG-84	34.48**	36.66**	22.85**									

Rice workers namely, Virmani *et al.*, (1981), Ish Kumar and Saini (1983), Tseng and Huang (1987), Rahimi (2010), and Tiwari *et al.*, (2011) have also reported nearly similar trend of heterosis in their studies. In contrast to the present finding Vaithiyalingan and Nadarajan (2010) and Latha *et al.*, (2013) reported lesser test weight for all the hybrids under their study.

Grain yield is the ultimate concern of breeder for judging the worth of a hybrid. Minimum of 20 per cent heterosis is desirable for exploitation of hybrid vigor in rice. Most of the hybrids derived from CMS line x restorer crosses in the present study, recorded poor grain yield. However, ten hybrids out of 68 hybrids, exhibited significant standard heterosis for grain yield per plant. Out of these ten hybrids, five hybrids namely, IR 68897A x Jaya, IR 68888A x URG-51, IR 68897A x URG-22, IR 68888A x BPT-5204 and IR 58025A x Pant-12 exhibited more than 30 per cent standard heterosis (over both check). These hybrids also exhibited desirable heterosis for traits *viz.* number of effective tillers per plant, panicle length, grains per panicle and 100 grain weight. High magnitude of standard heterosis for grain yield as observed in the present study, have been also reported by Pandey *et al.*, (1995), Rahimi *et al.*, (2010) and Reddy *et al.*, (2013). Further, a wide range between negative and positive values of standard heterosis for grain yield in rice have been reported by Lingaraju *et al.*, (1999), Vaithiyalingan and Nadarajan (2010), Tiwari *et al.*, (2011) and Latha *et al.*, (2013).

Among the best five hybrids for yield, the hybrid namely, IR 68897A x Jaya was highest yielder, and exhibited significant and desirable heterosis for days to 50% flowering (-25.33%), days to maturity (-27.27%), plant height (-1.24%), grains per panicle (13.65%) and 100 seed weight (78.00%). It was observed that some of the hybrids with comparatively lower yield exhibited higher magnitude of standard heterosis for effective tillers and grains per panicle. Their low yielding ability may be due to poor standard heterosis for the traits such as plant height, panicle length and test weight. Remaining four promising hybrids recorded significant and desirable standard heterosis for yield components namely, number of effective tillers per plant, 100 seed weight, grains per panicle and panicle length. It is observed that the standard heterosis in the present set of desirable hybrids was highly influenced by traits like number of effective tillers per plant, 100 seed weight, grains per panicle and panicle length. Earlier workers have reported high heterosis for grain yield in hybrids due to increased number of effective tillers per plant (Yamauchi and Yoshida, 1985; Patnaik *et al*., 1990; Sarial *et al*., 2006 and Pandey and Tripathy, 2006), panicle length (Singh and Richarya, 1980 and Usha Kumari *et al.*, 2006), number of grains per panicle (Sarial and Singh, 2000 and Sarvanan *et al*., 2006; Bhanumathy *et al.*, 2007) and 100 grain weight (Alam *et al*., 2004 and Usha Kumari *et al*., 2006 and Reddy *et al.*, 2013). Grain yield *per se* is a complex heritable character which is an end product of multiplicative interaction of various yield components and hence heterosis for yield may be attributed to heterosis of individual yield components or alternatively due to multiplicative effects of component characters.

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