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Original Research Article

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

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Keywords

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A B S T R A C T

Thirty early to medium duration genotypes of rice were crossed with male sterile lines *viz.* IR-68897A, IR-68888A and IR-58250A in line x tester fashion. Out of the resultant F_1s, ten restores and four maintainers were isolated for different CMS lines. Heterobeltiosis for head rice recovery was observed in positive as well as negative directions. 12 cross combinations showed higher magnitude of significantly positive heterobeltiosis with a range of 1.89 per cent to 13.33 per cent, whereas none of the hybrids exhibited positive heterosis over both the checks. Two hybrids namely, IR-68897A x HUR-3022 and IR-68888A x URG-51 exhibited positive heterobeltiosis for kernel length. Kernel length of Pusa basmati -1 (check) is extra-long, and all the hybrids showed negative heterosis against it. Most of the hybrids were superior over the check Sarjoo-52 as its kernel length is medium sized. Some of the highly heterotic hybrids with higher magnitude of standard heterosis over sarjoo-52 are IR-68897A x HUR-3022, IR-58025A x HUR-3022, IR-58025A x URG-48, IR-58025A x Pusa-44 and IR-68897A x HUR-105 with a range of heterosis from 80.73 per cent to 75.85 per cent. All the hybrids in the present set of material exhibited significantly positive heterosis over Sarjoo-52. Three hybrids namely IR-68897A x Pusa-44, IR-68888A x URG-19 and IR-58025A x HUR-38 were most promising for kernel L/B ratio. Twelve hybrids exhibited high magnitude of positive and significant heterosis over Sarjoo-52. Kernel elongation of hybrids against the check Pusa Basmati-1 was non-significant. Kernel elongation is influenced by genetic factors and environment factors both, especially temperature at the time of ripening.

Introduction

During last 25 years major increase in rice production has occurred mainly due to large scale adoption of hybrids and high yielding semi dwarf varieties. Improved management practices have made several rice growing countries self-sufficient with huge yield of hybrids. 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. One of the major challenges in indica rice hybrid breeding is to ensure that the heterotic rice hybrids possess grain quality that is at least comparable, if not superior, to that of inbred check varieties grown by farmers. For this, a close linkage with an inbred rice breeding program is important to provide continuous access to newly developed elite inbred lines possessing desired grain quality characteristics. Most IRRI-bred cytoplasmic male sterile and restorer lines have grain quality similar to that of the check varieties. Therefore, grain quality in derived hybrids should be acceptable to farmers (Virmani and Zaman, 1998).

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 cross 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 x15cm 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 p1er 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

Physical quality traits

Hulling, milling and head rice recovery are the most important physical characters from the commercial point of view as it decides the amount of produce to be marketed. Heterobeltiosis for hulling recovery ranged from-10.20 to 3.22 per cent and standard heterosis ranged from -17.58 to 2.63 over NDR-97 and from-18.77 to 1.14 per cent over Sarjoo-52. Most of the hybrids had significant negative heterobeltiosis and standard heterosis over both the checks, indicating that hybrids might have more proportion of negative as compared to positive gene for this character. This finding is in accordance with the earlier report of Singh (2000) who also observed significant and negative magnitude of standard heterosis in majority of the hybrids studied by him. For milling recovery heterobeltiosis ranged from -15.89 per cent to 12.19 per cent and standard heterosis ranged from -22.70 to -0.21 per cent over NDR-97 and -23.56 to -1.32 per cent over sarjoo-52. None of the cross combinations exhibited significantly positive standard heterosis over both checks. Three hybrids namely IR-58025A x BPT-5204, IR-68888A x HUR-3022 and IR-68888A x URG-19displayed significant positive magnitude of heterobeltiosis. The range of heterosis reported by Sarawgi (2000) was in accordance with the present finding.

Heterobeltiosis for head rice recovery was observed in positive as well as negative directions. Heterobeltiosis ranged from -21.16 to 19.48 per cent whereas standard heterosis ranged from -24.31 to -2.94 per cent and -24.95 to -3.76 per cent over NDR-97 and sarjoo-52 respectively. 12 cross combinations showed higher magnitude of significantly positive heterobeltiosis with a range of 1.89 per cent to 13.33 per cent, whereas none of the hybrids exhibited positive heterosis over both the checks. Sarawgi (2000) reported range of heterobeltiosis from -5.38 per cent to 24.68 per cent and standard heterosis from -26.02

per cent to -2.68 per cent in his study, this is quite similar to the results of present investigation. Kernel length, kernel breadth, Length to breadth ratio (L/B), kernel length after cooking (KLAC), Kernel breadth after cooking (KBAC) and elongation ratio are the important physical grain quality characters which determine the consumer's preference of rice grain. Two hybrids namely, IR-68897A x HUR-3022 and IR-68888A x URG-51 exhibited positive heterobeltiosis for kernel length. The range of heterobeltiosis varied from -29.71 to 2.10 per cent. Reddy *et al.,* (1991) and Vivekanandan and Giridharan (1996) also reported significant negative as well as positive heterobeltiosis for kernel length. Kernel length of Pusa basmati -1 (check) is extra-long, and all the hybrids showed negative heterosis against it. Most of the hybrids were superior over the check Sarjoo-52 as its kernel length is medium sized. Some of the highly heterotic hybrids with higher magnitude of standard heterosis over sarjoo-52 are IR-68897A x HUR-3022, IR-58025A x HUR-3022, IR-58025A x URG-48, IR-58025A x Pusa-44 and IR-68897A x HUR-105 with a range of heterosis from 80.73 per cent to 75.85 per cent. Earlier rice workers *viz.* Rahimi *et al.,* (2010), Sanghera and Hussain (2012) and Reddy *et al.,* (2012) have also reported high magnitude of standard heterosis for kernel length. In contrast, Sarawgi (2000) reported heterosis only in negative direction when compared against the standard check. Smaller the kernel breadth, better will be the grain fineness, hence negative heterosis for this character is desirable. Most of the cross combinations exhibited higher magnitude of heterobeltiosis and standard heterosis for this character. Range of heterobeltiosis varied from -24.14 to 115.89 per cent. Seven hybrids were at par with the better parent and exhibited significant negative heterosis. Four hybrids namely IR-68897A x Pusa-44, IR-58025A x HUR-38, IR-68888A x URG-72 and IR-68897A x URG-72 exhibited significantly higher magnitude of negative heterosis which ranged from -36.04 per cent to -8.55 per cent. This finding is in agreement with those of Sarawgi (2000), Rahimi *et al.,* (2010), Sanghera and Hussain (2012) and Reddy *et al.,* (2012) who also reported significant negative as well as positive standard heterosis for kernel breadth, where most of the hybrids exhibited significant positive values for heterosis.

Kernel L/B ratio is an important physical grain quality character for determining the quality of rice grain. Higher value for L/B is desirable. Heterobeltiosis ranged from -47.02 to 16.23 per cent, whereas, the range of standard heterosis varied from -50.53 per cent to 118.73 per cent. All the hybrids in the present set of material exhibited significantly positive heterosis over Sarjoo-52. Three hybrids namely IR-68897A x Pusa-44, IR-68888A x URG-19 and IR-58025A x HUR-38 were most promising for kernel L/B ratio. Wide range of heterosis has also been reported by Sanghera and Hussain (2012) and Reddy *et al.,* (2012). None of the hybrids were heterotic over Pusa Basmati-1 for L/B ratio.The findings of Vivekanandan and Giridharan (1996), Sarawgi (2000) and Reddy *et al.,* (2012) have also reported negative standard heterosis for kernel L/B ratio.

Kernel elongation ratio is the most important cooking quality character of the rice grain. Lengthwise elongation with nominal increase in girth is considered most desirable. Heterosis for kernel elongation was noticed in both negative and positive directions over better parent and the check Sarjoo-52. The range of heterosis varied from -24.38 to 2.87 per cent over better parent and -13.62 to 23.35 per cent over Sarjoo-52.

Table.1 Estimates of magnitude of heterobeltiosis and standard heterosis (NDR-97 and Sarjoo-52) for physical quality attributing traits) in 63 rice hybrid

S.No.	Cross Combinations (Hybrids)	Hulling Percent			Milling Percent			Head Rice Recovery		
		Heterobeltiosis	NDR-97	Sarjoo-52	Heterobeltiosis	NDR-97	Sarjoo-52	Heterobeltiosis	NDR-97	Sarjoo-52
1.	IR-68888 A x Pant-12	-02.20**	-06.49**	-07.85**	-11.80**	-21.18**	-22.06**	02.16**	-24.31**	-24.95**
2.	IR-58025 A x Pant-12	-04.97**	-09.13**	-10.45**	-11.23**	-20.68**	-21.56**	06.75**	-20.91**	-21.58**
3.	IR-68897 A x Pant-16	-02.76**	-05.84**	-07.21**	-08.60**	-15.84**	-16.78**	-07.44**	-14.77**	-15.49**
4.	IR-58025 A x Pant-16	01.28*	-01.94**	-03.36**	-07.38**	-14.72**	-15.67**	-09.81**	-16.95**	-17.66**
5.	IR-68897 A x Pusa-370	-03.43**	-05.48**	-06.85**	-08.39**	-16.23**	-17.16**	0.03	-17.01**	-17.71**
6.	IR-68888 A x Pusa-370	-0.80	-02.91**	-04.32**	-03.94**	-12.15**	-13.13**	19.48**	-13.86**	-14.59**
7.	IR-68897 A x Pusa-44	-03.19**	-08.42**	-09.75**	-02.00**	-12.36**	-13.34**	04.45**	-13.34**	-14.07**
8.	IR-68888 A x Pusa-44	01.04	-04.42**	-05.81**	-06.38**	-16.28**	-17.21**	12.03**	-17.96**	-18.65**
9.	IR-58025 A x Pusa-44	-01.67**	-06.99**	-08.34**	-05.35**	-15.36**	-16.30**	13.33**	-16.64**	-17.34**
10.	IR-68897 A x Jaya	-06.07**	-05.50**	-06.88**	-14.29**	-12.33**	-13.31**	-14.61**	-11.48**	-12.23**
11.	IR-58025 A x Jaya	-05.11**	-04.53**	-05.92**	-17.38**	-15.49**	-16.43**	-20.81**	-17.90**	-18.60**
12.	IR-68897 A x Shivani	-04.97**	-01.89**	-03.31**	-14.21**	-12.27**	-13.25**	-13.60**	-10.10**	-10.86**
13.	IR-68888 A x Shivani	-02.69**	0.46	-01.00	-11.48**	-09.48**	-10.48**	-11.02**	-07.42**	-08.20**
14.	IR-58025 A x Shivani	-10.20**	-07.29**	-08.63**	-18.50**	-16.66**	-17.59**	-19.03**	-15.75**	-16.46**
15.	IR-68897 A x HUR-105	-02.98**	-09.30**	-10.61**	0.44	-14.23**	-15.19**	02.04**	-14.44**	-15.16**
16.	IR-68888 A x HUR-105	-03.40**	-11.35**	-12.64**	-06.19**	-19.89**	-20.79**	-07.83**	-22.71**	-23.36**
17.	IR-68897 A x HUR-3022	02.37**	-04.29**	-05.68**	-03.07**	-15.67**	-16.61**	-0.49	-17.45**	-18.14**
18.	IR-68888 A x HUR-3022	-02.67**	-12.15**	-13.43**	04.51**	-09.07**	-10.09**	11.72**	-10.06**	-10.82**
19.	IR-58025 A x HUR-3022	03.22**	-06.84**	-08.19**	-04.47**	-16.89**	-17.82**	01.35*	-18.41**	-19.10**
20	IR-68888 A x BPT-5204	0.01	-03.93**	-05.33**	-09.59**	-14.13**	-15.09**	-11.87**	-13.34**	-14.07**
21.	IR-58025 A x BPT-5204	-03.23**	-07.05**	-08.40**	03.81**	-01.40**	-02.50**	-01.29**	-02.94**	-03.76**
22.	IR-68897 A x HUR-36	-05.03**	-05.88**	-07.24**	-08.38**	-13.27**	-14.23**	-08.56**	-08.69**	-09.46**
23.	IR-68888 A x HUR-36	-02.04**	-02.91**	-04.32**	-08.78**	-13.65**	-14.61**	-14.62**	-14.73**	-15.45**
24.	IR-58025 A x HUR-36	02.49**	01.58**	0.11	-03.00**	-08.17**	-09.20**	-10.86**	-10.98**	-11.74**
25.	IR-68897 A x HUR-38	-0.28	-06.78**	-08.13**	-02.70**	-17.02**	-17.95**	-03.39**	-17.96**	-18.65**
26.	IR-68888 A x HUR-38	-01.42*	-08.11**	-09.44**	-07.49**	-21.11**	-21.98**	-09.48**	-23.13**	-23.79**
27.	IR-58025 A x HUR-38	-01.30*	-08.00**	-09.33**	-03.96**	-18.10**	-19.01**	-02.55**	-17.25**	-17.95**
28.	IR-68888 A x Sarjoo-52	-04.65**	-05.28**	-06.65**	-15.68**	-16.58**	-17.51**	-21.16**	-21.62**	-22.29**
29.	IR-58025 A x Sarjoo-52	-01.10*	-01.76**	-03.19**	-13.09**	-14.03**	-14.98**	-15.11**	-15.61**	-16.32**
30.	IR-68897 A x URG-6	-03.65**	-04.54**	-05.93**	-07.88**	-13.46**	-14.42**	-04.31**	-11.66**	-12.40**
31.	IR-58025 A x URG-6	-0.74	-01.66**	-03.09**	-05.23**	-10.97**	-11.96**	-06.70**	-13.86**	-14.59**

32.	IR-68897 A x URG-12	-01.18*	-02.61**	-04.02**	-02.82**	-10.65**	-11.64**	-03.16**	-10.52**	-11.27**
33.	IR-68897 A x URG-19	01.14*	-04.54**	-05.93**	-05.49**	-15.95**	-16.88**	01.18*	-16.06**	-16.77**
34.	IR-68888 A x URG-19	-01.28*	-06.83**	-08.18**	12.19**	-0.21	-01.32**	12.94**	-06.78**	-07.57**
35.	IR-58025 A x URG-19	-0.81	-06.38**	-07.74**	-07.03**	-17.31**	-18.23**	01.89**	-15.90**	-16.61**
36.	IR-68897 A x URG-22	-0.67	0.61	-0.85	-05.60**	-08.15**	-09.17**	-07.37**	-10.49**	-11.24**
37.	IR-68888 A x URG-22	-02.89**	-01.65**	-03.08**	-14.84**	-17.14**	-18.07**	-18.51**	-21.25**	-21.92**
38.	IR-58025 A x URG-22	-03.03**	-01.79**	-03.21**	-05.48**	-08.03**	-09.05**	-04.32**	-07.54**	-08.33**
39.	IR-68888 A x URG-36	-03.75**	01.48**	0.01	-08.41**	-07.84**	-08.86**	-07.16**	-11.49**	-12.24**
40.	IR-58025 A x URG-36	-02.66**	02.63**	01.14*	-07.24**	-06.65**	-07.69**	-04.11**	-08.59**	-09.36**
41.	IR-68897 A x URG-48	01.32*	0.82	-0.64	-04.69**	-06.65**	-07.69**	-07.14**	-08.20**	-08.98**
42.	IR-58025 A x URG-48	0.45	-0.04	-01.49**	-04.56**	-06.53**	-07.57**	-08.03**	-09.09**	-09.86**
43.	IR-68897 A x URG-51	-02.82**	-04.54**	-05.93**	-10.20**	-16.89**	-17.82**	-11.59**	-14.25**	-14.98**
44.	IR-68888 A x URG-51	-02.70**	-04.43**	-05.82**	-08.66**	-15.46**	-16.40**	-10.36**	-13.06**	-13.79**
45.	IR-58025 A x URG-51	-04.97**	-06.65**	-08.01**	-09.88**	-16.60**	-17.53**	-16.50**	-19.02**	-19.70**
46.	IR-68888 A x URG-60	-07.30**	-06.76**	-08.12**	-14.98**	-17.04**	-17.96**	-09.05**	-14.62**	-15.34**
47.	IR-58025 A x URG-60	-06.05**	-05.50**	-06.88**	-11.39**	-13.53**	-14.49**	-08.71**	-14.31**	-15.03**
48.	IR-68897 A x URG-67	-04.65**	-05.90**	-07.27**	-09.52**	-16.28**	-17.21**	-07.48**	-14.34**	-15.06**
49.	IR-68888 A x URG-67	-07.92**	-09.13**	-10.45**	-14.53**	-20.92**	-21.80**	-17.26**	-23.39**	-24.04**
50.	IR-58025 A x URG-67	-04.55**	-05.80**	-07.17**	-05.46**	-12.53**	-13.50**	-07.89**	-14.71**	-15.44**
51.	IR-68897 A x URG-72	-04.28**	-05.74**	-07.11**	-12.39**	-17.29**	-18.21**	-03.41**	-14.61**	-15.34**
52.	IR-68888 A x URG-72	-03.05**	-04.53**	-05.92**	-09.81**	-14.85**	-15.79**	-04.79**	-15.84**	-16.55**
53.	IR-58025 A x URG-72	-02.91**	-04.39**	-05.78**	-06.70**	-11.91**	-12.89**	-01.46**	-12.89**	-13.63**
54.	IR-68897 A x URG-76	-07.23**	-13.28**	-14.53**	-08.16**	-25.08**	-25.91**	-19.08**	-21.85**	-22.51**
55.	IR-68888 A x URG-76	0.76	-12.03**	-13.30**	-0.91*	-19.92**	-20.81**	-18.73**	-21.51**	-22.17**
56.	IR-58025 A x URG-76	-08.20**	-17.58**	-18.77**	-02.45**	-22.70**	-23.56**	-20.34**	-23.06**	-23.71**
57.	IR-68888 A x URG-77	-05.10**	-04.88**	-06.26**	-14.43**	-16.20**	-17.13**	-08.70**	-17.01**	-17.71**
58.	IR-58025 A x URG-77	-02.86**	-02.64**	-04.05**	-06.03**	-07.98**	-09.00**	-02.18**	-11.08**	-11.83**
59.	IR-68888 A x URG-83	-02.30**	-04.63**	-06.01**	-09.37**	-14.20**	-15.15**	-06.52**	-12.89**	-13.63**
60.	IR-58025 A x URG-83	02.77**	0.32	-01.13*	-02.71**	-07.89**	-08.92**	-04.97**	-11.44**	-12.19**
61.	IR-68897 A x URG-84	-04.30**	-04.22**	-05.61**	-10.70**	-13.20**	-14.16**	-04.89**	-14.49**	-15.21**
62.	IR-68888 A x URG-84	-02.69**	-02.61**	-04.02**	-11.66**	-14.13**	-15.09**	-03.12**	-12.89**	-13.63**
63.	IR-58025 A x URG-84	-01.81**	-01.73**	-03.15**	-07.01**	-09.61**	-10.61**	-04.94**	-14.53**	-15.26**

Table.2 Estimates of magnitude of heterobeltiosis and standard heterosis (Sarjoo-52 and Pusa Basmati-1) for cooking quality traits) in 63 rice hybrid

S. No.	Cross Combinations (Hybrids)	L/B Ratio			Elongation Ratio			Alkali Digestion velue	Gelatinization Temperature	Amylose content	
		Heterobeltiosis	Sarjoo-52	Pusa Basmati-1	Heterobeltiosis	Sarjoo-52	Pusa Basmati-1				
1.	IR-68888 A x Pant-12	-10.06**	41.13**	-37.15**	-03.03	07.80**	-13.80**	6.00	Low	23.85	Intermediate
2.	IR-58025 A x Pant-12	-11.29**	86.81**	-16.81**	-10.99**	-01.98	-21.63**	3.00	High	21.65	Intermediate
3.	IR-68897 A x Pant-16	-39.26**	22.79**	-45.32**	-13.40**	03.84	-16.98**	5.00	Intermediate	18.32	Low
4.	IR-58025 A x Pant-16	-40.90**	24.46**	-44.58**	-17.34**	-01.65	-21.36**	4.00	Intermediate	22.65	Intermediate
5.	IR-68897 A x Pusa-370	-09.14**	83.68**	-18.21**	-13.21**	08.60**	-13.17**	5.00	Intermediate	22.54	Intermediate
6.	IR-68888 A x Pusa-370	-09.10**	68.97**	-24.75**	-15.59**	05.62*	-15.55**	5.00	Intermediate	19.62	Low
7.	IR-68897 A x Pusa-44	16.23**	221.13**	43.00**	-05.41*	13.43**	-09.31**	5.00	Intermediate	22.63	Intermediate
8.	IR-68888 A x Pusa-44	-53.00**	29.85**	-42.17**	-12.14**	-02.31	-21.89**	6.00	low	25.30	High
9.	IR-58025 A x Pusa-44	-22.00**	115.49**	-04.04*	-12.19**	-03.31	-22.69**	4.00	Intermediate	24.92	Intermediate
10.	IR-68897 A x Jaya	-40.81**	19.66**	-46.71**	02.87	23.35**	-01.37	4.00	Intermediate	23.00	Intermediate
11.	IR-58025 A x Jaya	-41.92**	22.30**	-45.54**	-06.07*	03.44	-17.29**	4.00	Intermediate	24.63	Intermediate
12.	IR-68897 A x Shivani	-34.48**	32.45**	-41.02**	-18.26**	-01.98	-21.63**	4.00	Intermediate	22.00	Intermediate
13.	IR-68888 A x Shivani	-01.73	41.72**	-36.89**	-17.07**	-07.80**	-26.28**	6.00	low	22.54	Intermediate
14.	IR-58025 A x Shivani	-29.28**	48.92**	-33.68**	-10.03**	-0.93	-20.78**	4.00	Intermediate	23.64	Intermediate
15.	IR-68897 A x HUR-105	-05.94**	90.15**	-15.32**	-05.46*	13.36**	-09.36**	4.00	Intermediate	22.03	Intermediate
16.	IR-68888 A x HUR-105	-09.75**	66.13**	-26.02**	-15.05**	-05.56	-24.48**	6.00	low	21.63	Intermediate
17.	IR-68897 A x HUR-3022	-01.29	99.56**	-11.13**	-07.56**	10.85**	-11.37**	4.00	Intermediate	22.63	Intermediate
18.	IR-68888 A x HUR-3022	-06.51**	71.18**	-23.77**	-14.93**	-05.42	-24.38**	6.00	low	23.45	Intermediate
19.	IR-58025 A x HUR-3022	-11.38**	86.62**	-16.90**	-13.39**	-04.63	-23.74**	4.00	Intermediate	25.88	High
20	IR-68888 A x BPT-5204	-15.36**	22.06**	-45.65**	-03.87	06.88*	-14.54**	6.00	low	19.47	Low
21.	IR-58025 A x BPT-5204	-27.75**	52.16**	-32.24**	-20.90**	-12.90**	-30.35**	4.00	Intermediate	24.92	Intermediate
22.	IR-68897 A x HUR-36	-36.78**	27.79**	-43.09**	-12.41**	05.03	-16.02**	4.00	Intermediate	21.63	Intermediate
23.	IR-68888 A x HUR-36	-06.36*	35.05**	-39.86**	-15.11**	-05.62*	-24.54**	6.00	low	25.42	High
24.	IR-58025 A x HUR-36	-35.41**	36.03**	-39.42**	-07.57**	01.79	-18.61**	4.00	Intermediate	22.32	Intermediate
25.	IR-68897 A x HUR-38	-35.18**	31.03**	-41.65**	-03.97	15.15**	-07.93**	4.00	Intermediate	22.63	Intermediate
26.	IR-68888 A x HUR-38	-13.29**	25.05**	-44.31**	0.56	18.98**	-04.87*	6.00	low	26.40	High
27.	IR-58025 A x HUR-38	03.86*	118.73**	-02.60	-12.52**	03.51	-17.24**	4.00	Intermediate	23.63	Intermediate
28.	IR-68888 A x Sarjoo-52	-13.97**	24.07**	-44.75**	-04.88	05.75*	-15.44**	6.00	low	23.57	Intermediate
29.	IR-58025 A x Sarjoo-52	-33.52**	40.00**	-37.66**	-08.47**	0.79	-19.41**	4.00	Intermediate	24.65	Intermediate
30.	IR-68897 A x URG-6	-27.50**	46.57**	-34.73**	-18.42**	-02.18	-21.79**	6.00	low	23.62	Intermediate

31.	IR-58025 A x URG-6	-23.46**	61.18**	-28.23**	-12.07**	-03.17	-22.58**	4.00	Intermediate	25.00	High
32.	IR-68897 A x URG-12	-36.66**	28.04**	-42.98**	-13.73**	03.44	-17.29**	5.00	Intermediate	19.63	Low
33.	IR-68897 A x URG-19	-27.38**	46.81**	-34.62**	-21.95**	-06.42*	-25.17**	6.00	low	25.80	High
34.	IR-68888 A x URG-19	05.27*	51.81**	-32.39**	-06.84**	03.57	-17.19**	6.00	low	18.63	Low
35.	IR-58025 A x URG-19	-24.21**	59.61**	-28.92**	-15.98**	-07.47**	-26.02**	4.00	Intermediate	18.44	Low
36.	IR-68897 A x URG-22	-42.07**	17.11**	-47.85**	-12.24**	05.22	-15.86**	4.00	Intermediate	23.62	Intermediate
37.	IR-68888 A x URG-22	03.16	48.77**	-33.75**	-10.65**	-0.66	-20.57**	6.00	low	24.58	Intermediate
38.	IR-58025 A x URG-22	-26.91**	53.92**	-31.46**	-11.89**	-02.98	-22.42**	4.00	Intermediate	24.41	Intermediate
39.	IR-68888 A x URG-36	-12.78**	25.78**	-43.99**	-10.41**	-0.40	-20.36**	6.00	low	23.75	Intermediate
40.	IR-58025 A x URG-36	-29.84**	47.75**	-34.21**	-14.23**	-05.56	-24.48**	4.00	Intermediate	23.23	Intermediate
41.	IR-68897 A x URG-48	-18.06**	65.64**	-26.24**	-19.08**	-02.98	-22.42**	4.00	Intermediate	23.51	Intermediate
42.	IR-58025 A x URG-48	-12.22**	84.85**	-17.68**	-20.84**	-12.83**	-30.30**	4.00	Intermediate	23.64	Intermediate
43.	IR-68897 A x URG-51	-35.06**	31.27**	-41.54**	-11.20**	06.48*	-14.86**	5.00	Intermediate	22.62	Intermediate
44.	IR-68888 A x URG-51	-11.01**	28.33**	-42.85**	-12.14**	-02.31	-21.89**	7.00	low	19.22	Low
45.	IR-58025 A x URG-51	-47.02**	11.57**	-50.32**	-09.19**	0.00	-20.04**	5.00	Intermediate	22.75	Intermediate
46.	IR-68888 A x URG-60	-9.55**	30.44**	-41.91**	-12.91**	-03.17	-22.58**	5.00	Intermediate	24.84	Intermediate
47.	IR-58025 A x URG-60	-29.24**	49.02**	-33.64**	-14.29**	-05.62*	-24.54**	4.00	Intermediate	24.63	Intermediate
48.	IR-68897 A x URG-67	-37.22**	26.91**	-43.48**	-21.51**	-05.89*	-24.75**	4.00	Intermediate	18.50	Low
49.	IR-68888 A x URG-67	-16.49**	20.44**	-46.37**	-13.98**	-04.37	-23.53**	6.00	low	24.63	Intermediate
50.	IR-58025 A x URG-67	-33.64**	39.75**	-37.76**	-21.14**	-13.16**	-30.57**	4.00	Intermediate	24.12	Intermediate
51.	IR-68897 A x URG-72	-01.26	99.61**	-11.11**	-24.38**	-09.33**	-27.50**	3.00	High	17.66	Low
52.	IR-68888 A x URG-72	03.83	72.84**	-23.03**	-06.25*	04.23	-16.66**	4.00	Intermediate	18.57	Low
53.	IR-58025 A x URG-72	-11.96**	85.39**	-17.44**	-13.87**	-05.16	-24.17**	3.00	High	18.63	Low
54.	IR-68897 A x URG-76	-30.07**	41.37**	-37.04**	-22.61**	-07.21*	-25.81**	4.00	Intermediate	19.30	Low
55.	IR-68888 A x URG-76	-22.98**	11.08**	-50.53**	-10.23**	-0.20	-20.20**	6.00	low	17.64	Low
56.	IR-58025 A x URG-76	-23.51**	61.08**	-28.27**	-14.17**	-05.49	-24.43**	4.00	Intermediate	18.43	Low
57.	IR-68888 A x URG-77	-09.93**	29.90**	-42.15**	-12.20**	-02.38	-21.95**	7.00	low	23.64	Intermediate
58.	IR-58025 A x URG-77	-23.51**	61.08**	-28.27**	-21.56**	-13.62**	-30.94**	4.00	Intermediate	22.43	Intermediate
59.	IR-68888 A x URG-83	-04.72	38.38**	-38.38**	-16.36**	-07.01*	-25.65**	6.00	low	23.65	Intermediate
60.	IR-58025 A x URG-83	-28.65**	50.25**	-33.09**	-11.29**	-02.31	-21.89**	4.00	Intermediate	23.49	Intermediate
61.	IR-68897 A x URG-84	-24.59**	52.45**	-32.11**	-18.04**	-01.72	-21.42**	4.00	Intermediate	24.82	Intermediate
62.	IR-68888 A x URG-84	-01.46	42.11**	-36.72**	-16.66**	-07.34**	-25.91**	6.00	low	24.72	Intermediate
63.	IR-58025 A x URG-84	-19.09**	70.39**	-24.12**	-14.83**	-06.22*	-25.01**	4.00	Intermediate	24.17	Intermediate

Twelve hybrids exhibited high magnitude of positive and significant heterosis over Sarjoo-52. Kernel elongation of hybrids against the check Pusa Basmati-1 was non-significant. Sarawgi (2000) reported a wide range of heterosis both for heterobeltiosis and standard heterosis which is in accordance to the present finding. Kernel elongation is influenced by genetic factors and environment factors both, especially temperature at the time of ripening (Table 1 and 2).

The ambient temperature of about 25^{o}C during day time and 21^{o}C during night at ripening has been found to have maximum elongation after cooking (Dela Cruz *et al.*, 1989). Khush *et al.*, (1979) also reported maximum elongation in grains which matured at temperature between 21^{0}C to 25^{0}C. He further suggested that during storage, grain hardness and gelatinization temperature increases which allows more swelling and length wise elongation during cooking.

Cooking and eating traits

Gelatinization temperature (GT) is the physical property of starch. It refers to the range of temperature within which starch granules start swelling irreversibly in hot water. Thus, GT determines the time taken to cook the rice. Gelatinization temperature is determined on the basis of alkali spread value of the polished kernels of rice. The rice varieties with intermediate GT (70^{0}C to 74^{0}C) is preferred all over the world. High GT rice remains undercooked and low GT rice gets overcooked under standard cooking procedures. The rice varieties with intermediate GT and alkali spread value (4-5) are preferred as they exhibit desirable volume expansion and linear kernel elongation under standard cooking procedures without being undercooked and/or overcooked. Therefore, the evaluation of hybrids in the present study has been done on the basis of their scores for alkali spread value and GT. Observations based on *per se* performance revealed that 40 hybrids (65%) exhibited intermediate alkali spread values with the score of 4 and 5, these hybrids were considered superior for gelatinization temperature also. The rice workers Tomar and Nanda (1985) and Delta (1991) also observed that most of the hybrids fell under the category of intermediate alkali digestion value and gelatinization temperature in their studies.

Amylose content in rice is considered to be one of most important indices of rice cooking and processing behavior, as it determines the hardness, gloss and rice to water ratio of cooked rice. Rice with low amylose content is waxy, sticky and remains firm after cooking. In contrast, non-waxy, non-sticky rice which cooks moist and tender and does not become hard upon cooking is the consequence of intermediate amylose content (20-25%). The mean values of the hybrids for amylose content revealed that majority of hybrids exhibited the amylose content within the desirable range of 20-25 per cent. These findings are in the close conformity with the earlier findings of Stansel (1966), Kumar and Khush (1987), and Reddy *et al.*, (2009) who also reported intermediate amylose content in most of the hybrids studied by them.

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