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Combining ability analysis for yield and its components in hybrid rice

SK Sharma, SK Singh, S Singh, V Kumer, A Singh and R Nandan
Institute of Agricultural Sciences, Banaras Hindu University, Varanasi - 221005

ABSTRACT

Sixteen fertility restorers were selected after screening 60 improved germplasm collections with 3 cytosterile lines. The restorers and their hybrids were evaluated for grain yield and its component traits. The Restorer BPT 5204, Taraori Basmati, Sarju-52, Type-3, and HUBR2-1 were found to be good general combiners for grain yield and other traits. Among CMS lines, IR68897A was found to be good general combiner for days to 50% flowering, days to maturity and number of spikelet panicle^{-1}. Pusa Sugandha-3 and Pusa Sugandha-4 both exhibited better gca for majority of the quality traits. The specific cross combinations characterized with high significant sca effects were Pusa6A Krishna Hansa, Pusa6A Type-3 and IR68897A Type-3 for grain yield plant^{-1}, number of grains panicle^{-1} and number of effective tillers plant^{-1}. BPT 5204 was found to be the best on the basis of per se performance and gca effects for grain yield plant^{-1}, number of spikelets panicle^{-1} and number of grains panicle^{-1}; Narendra-359 and Krishna Hansa for days to 50% flowering, panicle length. Pusa6A Krishna Hansa was found to be the best on the basis of per se performance and sca effects for number of effective tillers plant^{-1}, panicle length and grain yield plant^{-1}. The gca effects of the parents were not reflected in the sca effects of the crosses in all traits studied.

Key words: *rice, combining ability, yield and quality characters*

The concept of general and specific combining ability is useful to characterize inbreds (fertility restorers and CMS lines) for their nicking ability in hybrid breeding programme and elucidate the nature and magnitude of gene action involved for trait of interest. With increasing interest in the exploitation of heterosis in rice, there is a need to subject various CMS lines and restorers to combining ability test, so as to identify the most potential parents to develop heterotic hybrids. Even though, there are many studies conducted on combining ability in rice following diallel and L × T analysis, the studies pertaining to crosses involving CMS lines and restorers are very limited (Banumathi and Prasad 1991). Further, due to non-availability of restorers and maintainers, most of the studies reported earlier pertained to traditional rice varieties as parents.

To develop improved heterotic rice hybrids, we need to adopt new strategies by enhancing the frequency of occurrence of maintainers and restorers ensuring a constant supply of genetically diverse parental lines. Hence, study of maintainers and restorers in large number of parental lines will provide opportunity to breeders for their exploitation in hybrid breeding programmes. Combining ability analysis seems to be the most reliable and quickest method of understanding the genetic nature of quantitatively inherited characteristics. The present investigation on the nature of gene action was taken to characterise restorers and their hybrids for their combining ability.

MATERIALS AND METHODS

Three CMS lines viz., IR58025A, IR68897A and Pusa6A and 60 improved germplasm were used at BHU, Varanasi. Crosses in all combinations between CMS lines and pollen parents were effected. The F_1 seeds of successful crosses were germinated in Petri plates. The experiment was conducted at Institute of Agricultural Sciences, Varanasi during khari 2009 and 2010. The seedlings were transplanted to raised nursery beds after four days of germination as off- season nursery at CRRI, Cuttack Orissa. Thirty day old seedlings were transplanted in the main field at a spacing of 20 x 15 cm with row length 1.5 m. Randomized complete block design (RBD) with two replications was followed. Standard agronomic practices were employed for raising normal crop. To estimate pollen fertility at the time of flowering, panicles from individual F_1 plants were collected and fixed in acetoalcohol (1:3) solution. Deeply stained, fully developed and round pollen grains were considered as fertile. Based on pollen fertility (initial screening) 16 restorers were selected and crossed with 3 CMS lines to produce 1.5-2.0 g hand cross seed cross^{-1} for further use. The forty eight hybrids were raised in 2m long plot at a spacing of 20 x 15 cm with two replication in RBD at Varanasi. Nursery raising and transplating were carried out. Hybrids were grown together followed by parents in contiguous plots randomizing hybrids and parents separately in RCBD. Estimate spikelet fertility (final screening), two panicles per plant selected at random and one from the main culm of five randomly selected plants per hybrid from each replication were harvested maturity. Number of fertile and sterile spikelets were counted and percentage spikelet fetility averaged over replications was computed. The observation were recorded on five randomly selected plants genotype^{-1} replication^{-1} for grain yield plant^{-1}, days to 50% flowering, days to maturity, plant height, number of effective tillers plant^{-1}, panicle length, number of spikelets panicle^{-1}, number of grains panicle^{-1}, 1000 grain weight Combining ability analysis was carried out following Line Tester design (Kempthorne, 1957).

RESULT AND DISCUSSION

Analysis of variance for combining ability revealed significant differences among lines for days to 50% flowering, plant height, panicle length, and days to maturity indicating significant contribution of lines towards combining ability of these characters (Table 1). Contribution of testers towards combining ability was significant. The significant variances due to line × tester interaction for all the traits suggested the presence of significant SCA variances among the hybrids. These results emphasized the importance of combining ability studies and indicating good prospects for the selection of suitable parents and crosses for the development of appropriate varieties and hybrids. The significant GCA and SCA variances indicated the importance of both additive and non-additive gene effects in the expression of these characters. Variance for specific combining ability (σ^2_{sca}) were greater than general combining ability (σ^2_{gca}) for all the characters except plant height, number of spikelets panicle^{-1} and 1000-grain weight.

The ratio of $\sigma^2_{gca} / \sigma^2_{sca}$ is less than unity for all the characters except plant height, number of spikelets panicle^{-1} and 1000-grain weight, which also indicated preponderance of non-additive genetic variance. It suggested greater importance of non-additive gene action in their expression and indicated better prospects for the exploitation of non additive genetic variation for grain yield and quality traits through hybrid breeding.

Importance of non-additive effects for days to flowering, plant height, effective tillers plant^{-1}, panicle length, days to maturity, number of spikelets panicle^{-1}, number of grain panicle^{-1} have also been reported by Shreedhara and Vidyachandra (2002), Roy and Mandal (2001) and Saxena *et al*., 2002. The information regarding general combining ability (gca) effects of the

Table 1. Analysis of variance (mean squares) for combining ability for nine characters in rice

Source of Variations	df	Day to 50% flowering	Plant height (cm)	Number of effective tillers Plant^{-1}	Panicle length (cm)	Days to maturity panicle^{-1}	Number of spilklets panicle^{-1}	Number of grains wt (g)	1000 grain plant^{-1} (g)	Grain yield
Replicates	2	0.44	5.52	0.06	0.13	0.74	5.10	2.69	0.09	1.43
Crosses	47	298.31**	905.92**	13.26**	22.89**	282.67**	6844.27**	5393.46**	23.80**	183.84**
Line Effect	2	730.10**	594.39*	6.30	30.77*	626.93**	926.84	108.10	2.77	8.52
Tester Effect	15	637.03**	2468.88**	27.09**	49.08**	613.83**	19309.71**	14872.54**	66.78**	415.27**
Line × Tester Eff.	30	100.16**	145.21**	6.81**	9.28**	94.14**	1006.05**	1006.27**	3.71**	79.81**
Error	94	17.59	21.80	0.59	2.09	29.06	82.06	62.58	0.85	6.67
Total	143	109.61	312.16	4.75	8.90	112.02	2303.53	1813.85	8.38	64.83

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

parents is of prime importance, as it helps in successful prediction of genetic potentiality of crosses, which yield desirable individuals in segregating populations of self pollinated crops. Estimates of gca effects showed that it was difficult to choose a good combiner for all the traits, as the combining ability effects were not consistent for all the yield and quality traits simultaneously. It might be possible due to low negative association of different traits. The data fairly showed that none of the parent was good general combiner for all the characters (Table 3). However, it was noted that top two males, CR2340-1 and Krishna Hansa proved to be the best general combiner for days to 50% flowering (earliness) and days to maturity, MTU-7029 and BPT-5204 for plant height and kernel breadth. Badshahbhog and Type 3 for number of effective tillers plant^{-1}, Narendra 359, and Type-3 for panicle length, Malviya-36 and BPT-5204 for number of spikelets panicle^{-1}, Pusa Sugandha-4 and Malviya-36 for number of grains panicle^{-1}, Taraori Basmati and Pusa Sugandha-4 for 1000-grain weight, BPT5204 and Taraori Basmati for grain yield plant^{-1} (Table 4). Similar findings are also reported by Singh and Kumar (2004), Rosamma and Vijayakumar (2005), Munhat *et al.* (2000), Panwar and Ranwah (2008).

Among the female parental lines, IR68897A having 'WA' type of cytoplasm was observed as a good general combiner for days to 50% flowering, days to maturity and number of spikelet panicle^{-1}, whereas Pusa6A as good general combiner for plant height and number of effective tillers plant^{-1} and IR58025A for days to 50% flowering and panicle length, indicating the need for transferring the male sterility into genetic background of locale elite lines having good general combining ability for major components. These results are supported by Singh and Kumar (2004). The gca effects together with relative *per se* performance is useful for selecting desirable parent with favorable

Table 2. Estimates of general combining ability (gca) effects of parents (males and females) for different characters in rice

Genotypes	Days to 50% flowering	Plant height (cm)	Number of effective tillers plant^{-1}	Panicle length (cm)	Days to maturity	Number of spikelets panicle^{-1}	Number of grains panicle^{-1}	1000-grain wt (g)	Grain yield plant^{-1} (g)
IR58025A	-1.45*	3.60**	-0.33**	0.51 *	-1.51	-4.58 **	-0.32	0.02	0.46
IR68897A	-2.97**	-0.17	-0.06	0.41	-2.62 **	4.18**	1.63	0.23	-0.11
Pusa6A	4.42**	-3.43**	0.39 **	-0.92 **	4.12 **	0.39	-1.32	-0.25	-0.36
S.E	0.61	0.71	0.11	0.21	0.79	1.27	1.14	0.13	0.34
CR 2340-1	-15.41 **	-8.42**	-0.06	0.82	-14.31 **	18.72**	20.12**	0.40	-7.19 **
Type-3	-3.04 *	33.53**	1.85**	2.39 **	-2.38	-30.86 **	-27.23 **	1.86 **	-6.23 **
Basmati-370	7.17**	10.57**	1.21**	-1.22 *	7.86**	-26.22 **	-21.70 **	-1.44 **	-5.69 **
Pant Dhan-11	-8.92 **	-6.72**	1.09**	-1.81 **	-10.03 **	-95.93 **	-81.61 **	-3.62 **	-10.85 **
Pusa Sugandha-3	-5.47**	5.54**	-1.85**	1.03 *	-6.39 **	-8.03 **	-7.29 **	-2.25 **	-3.80 **
Krishna Hansa	-10.50**	-14.21**	1.70 **	1.41**	-11.78 **	-34.26 **	-24.95 **	-1.82 **	0.81
HUBR 2-1	-0.22	-9.13**	-0.91 **	1.20 *	0.99	17.43**	11.20**	1.40 **	4.24**
Narendra-359	-9.77**	-8.50**	-0.10	2.42 **	-9.36 **	-9.95 **	-14.96 **	3.25 **	2.51**
HUR 3022	-0.01	6.77**	1.24 **	1.99 **	0.93	35.08**	41.70**	2.32 **	-1.17
Taraori Basmati	9.51**	-9.15**	0.22	1.08 *	6.40**	-4.84	-4.24	4.19 **	9.48 **
M T U-7029	8.58**	-25.52**	-3.87 **	-2.19 **	5.61**	-61.91 **	-50.12 **	-2.17 **	-5.17 **
BPT 5204	11.26**	-19.25**	1.14 **	-1.84 **	12.21**	62.89 **	52.05 **	-2.01 **	12.62 **
Sarju-52	-0.12	-1.00	-0.28	-1.15 *	4.14*	-27.08 **	-26.16 **	-0.29 **	8.10 **
Malviya-36	8.31**	16.63**	-2.87 **	0.66	8.11**	66.54 **	60.00 **	1.26 **	-5.24 **
Badshahbhog	9.37**	30.69**	2.27 **	-6.50 **	8.74**	36.89**	8.81**	-4.88 **	1.25
Pusa Sugandha-4	-0.75	-1.86	-0.78 **	1.72 **	-0.76	61.53 **	64.38 **	3.80 **	1.27
	1.41	1.65	0.25	0.49	1.82	2.93	2.64	0.31	0.80

Table 3. Estimates of specific combining ability (sca) effects of 48 hybrids for different characters in rice

Genotypes	Days to 50% flowering	Plant height (cm)	Number of effective tillers plant^{-1}	Panicle length (cm)	Days to maturity	Number of spikelets panicle^{-1}	Number of grains panicle^{-1}	1000-grain wt (g)	Grain yield plant^{-1} (g)
IR58025A x CR 2340-1	-1.67	8.40**	1.45**	0.20	-0.67	-3.33	1.25	-0.35	2.24
IR58025A x Type-3	1.54	4.17	-2.42**	-3.31**	2.09	-31.81**	-33.15**	-1.75**	-8.53**
IR58025A x Basmati-370	0.68	2.08	1.33**	0.57	0.07	16.22**	12.22**	-0.50	-2.47
IR58025A x Pant Dhan-11	-2.97	-8.26**	-0.06	-0.62	-1.54	8.26	6.63	0.02	-5.21**
IR58025A x Pusa Sugandha-3	-6.28*	1.47	0.47	-0.39	-7.01*	21.46**	18.81**	0.74	0.39
IR58025A x Krishna Hansa	0.85	-4.28	-0.52	0.33	-0.29	-7.16	-4.63	-0.07	-10.17**
IR58025A x HUBR 2-1	-6.46**	-2.17	-0.95*	-1.54	-6.36*	3.41	8.52	-0.80	3.80**
IR58025A x Narendra-359	7.88**	-1.18	0.13	0.20	8.05*	15.28**	14.18**	-1.35*	4.53**
IR58025A x HUR 3022	8.46**	-4.97	0.88*	0.68	8.50**	-19.45**	-16.18**	1.58**	-0.73
IR58025A x Taraori Basmati	-2.66	11.16**	0.16	2.06*	-7.17*	-9.32	-10.44*	0.71	-5.27**
IR58025 x M T U-7029	4.28	-2.57	1.59**	3.07**	-1.18	27.54**	25.64**	2.20**	1.05
IR58025A x BPT 5204	-3.30	6.26*	0.29	0.62	-2.97	-5.06	-1.43	0.12	0.18
IR58025A x Sarju-52	-5.03*	-4.98	-0.69	-0.78	2.84	2.92	1.29	-0.65	8.93**
IR58025A x Malviya-36	6.95**	-4.82	0.77	-1.78*	6.52*	-16.21**	-19.58**	-0.61	1.09
IR58025A x Badshahbhog	-1.22	-9.08**	-2.75**	-0.31	-1.06	-1.56	1.21	-0.52	8.90**
IR58025A x Pusa Sugandha-4	-1.05	8.76**	0.31	0.97	0.19	-1.19	-4.34	1.23*	1.27
IR68897A x CR 2340-1	4.26	-10.81**	0.93*	0.35	3.66	0.95	7.35	0.48	-1.30
IR68897A x Type-3	2.83	5.44	1.21**	2.39**	3.49	23.03**	15.60**	0.63	5.44**
IR68897A x Basmati-370	-1.80	7.75**	-0.44	-0.01	-1.71	1.99	9.87*	-0.48	1.01
IR68897A x Pant Dhan-11	2.05	-3.00	-1.83**	-0.21	2.11	-7.00	-9.42*	-0.58	0.74
IR68897A x Pusa Sugandha-3	-1.54	0.03	-0.49	-0.02	-0.57	-15.31**	-4.23	-0.87	-1.45
IR68897A x Krishna Hansa	-9.02**	3.34	-1.51**	-3.43**	-7.87*	-15.77**	-16.63**	-0.67	1.51
IR68897A x HUBR 2-1	3.94	-0.50	1.72**	1.62	3.55	24.24**	21.16**	1.44**	2.52
IR68897Ax Narendra-359	-0.10	-1.22	-1.04*	-0.08	-1.75	-3.08	-9.47*	0.63	-3.88**
IR68897A x HUR 3022	-0.46	-1.30	-0.28	-1.01	-0.88	-3.33	-3.45	0.37	-1.15
IR68897A x Taraori Basmati	-2.13	-4.27	0.24	0.70	0.14	-9.28	-5.09	0.70	4.30**
IR68897A x M T U-7029	2.30	1.00	0.23	-1.73*	4.48	-1.31	5.69	-1.34*	-0.26
IR68897A x BPT 5204	1.90	-5.05	0.13	0.00*	2.16	-8.00	-7.63	-0.50	-1.17
IR68897A x Sarju-52	-0.50	6.94*	-0.91*	1.12	-5.10	-10.68*	-10.47*	0.28	-6.49**
IR68897A x Malviya-36	1.87	0.04	0.94*	1.42	1.68	16.13**	23.06**	0.43	0.66
IR68897A x Badshahbhog	0.60	6.08*	1.50**	-0.36	0.00	15.09**	-6.53	-0.23	-0.63
IR68897A x Pusa Sugandha-4	-4.20	-4.47	-0.40	0.96	-3.40	-7.66	-9.81*	-0.31	0.14
Pusa6A x CR 2340-1	-2.59	2.41	-2.38**	-0.56	-2.99	2.39	-8.60	-0.14	-0.94
Pusa6A x Type-3	-4.37	-9.61**	1.21**	0.92	-5.57	8.78	17.56**	1.12*	3.09*
Pusa6A x Basmati-370	1.12	-9.83**	-0.88*	-0.56	1.65	-18.21**	-22.09**	0.98	1.45
Pusa6A x Pant Dhan-11	0.92	11.27**	1.89**	0.83	-0.57	-1.26	2.79	0.56	4.47**
Pusa6A x Pusa Sugandha-3	7.82**	-1.50	0.02	0.41	7.58*	-6.14	-14.58**	0.12	1.05
Pusa6A x Krishna Hansa	8.17**	0.95	2.03**	3.10**	8.15*	22.92**	21.27**	0.74	8.66**
Pusa6A x HUBR 2-1	2.52	2.67	-0.77	-0.09	2.81	-27.65**	-29.68**	-0.65	-6.32**
Pusa6A x Narendra-359	-7.78**	2.40	0.91*	-0.12	-6.29*	-12.19*	-4.72	0.71	-0.65
Pusa6A x HUR 3022	-8.00**	6.27*	-0.61	0.33	-7.63*	22.78**	19.63**	-1.95**	1.87
Pusa6A x Taraori Basmati	4.79	-6.89*	-0.40	-2.76**	7.02*	18.60**	15.52**	-1.41*	0.98
Pusa6A x M T U-7029	-6.58**	1.57	-1.82**	-1.34	-3.31	-26.23**	-31.32**	-0.86	-0.80
Pusa6A x BPT 5204	1.40	-1.21	-0.42	1.08	0.82	13.06*	9.07	0.38	1.00
Pusa6A x Sarju-52	5.53*	-1.96	1.60**	-0.34	2.26	7.76	9.18*	0.37	-2.44
Pusa6A x Malviya-36	-8.82**	4.78	-1.71**	0.36	-8.20*	0.07	-3.48	0.18	-1.75
Pusa6A x Badshahbhog	0.62	3.00	1.25**	0.67	1.06	-13.53**	5.32	0.75	-8.27**
Pusa6A x Pusa Sugandha-4	5.25*	-4.29	0.09	-1.94*	3.21	8.84	14.15**	-0.92	-1.41
	2.44	2.86	0.43	0.85	3.15	5.08	4.58	0.54	1.38

Table 4. Ranking of five desirable parent on the basis of *per se* performance and gca effects for in rice

Characters	Desirable parent based on *per se* performance	Best general combiners	Best parent based on *per se* performance and gca effect
Days to 50% flowering	IR68897A CR 2340-1 Narandra-359 Krishna Hansa Pant Dhan-11	CR 2340-1 Krishna Hansa Narandra-359 Pant Dhan-11 Pusa Sugandha-3	CR 2340-1 Narandra-359 Krishna Hansa Pant Dhan-11
Plant height (cm)	IR68897A Taraori Basmati Pusa6A BPT5204 IR58025A	MTU-7029 BPT 5204 Krishuna Hansa Taraori Basmati HUBR2-1	Taraori Basmati BPT 5204
Number of effective tillers plant^{-1}	IR58025A Pusa6A Badshahbhog Basmati-370 Pant Dhan-11	Badshahbhog Type-3 Krishna Hansa HUR 3022 Basmati-370	Badshahbhog Basmati-370
Panicle length (cm)	Pusa Sugandha-3 Narendra-359 Krishna Hansa Type-3 Pusa Sugandha-4	Narendra-359 Type-3 HUR 3022 Pusa Sugandha-4 Krishna Hansa	Narendra-359 Krishna Hansa Type-3 Pusa Sugandh-4
Days to maturity	Type-3 IR68897A Narendra-359 CR 2340-1 Krishna Hansa	CR 2340-1 Krishna Hansa Pant Dhan-11 Pusa Sugandha-3 IR68897A	IR68897A CR 2340-1 Krishna Hansa
Number of spikelets panicle^{-1}	Malviya-36 Badshahbhog IR58025A Pusa Sugandha-4 BPT 5204	Malviya-36 BPT 5204 Pusa Sugandha-4 Badshahbhog HUR 3022	Malviya-36 Badshahbhog Pusa Sugandha-4 BPT 5204
Number of grains panicle^{-1}	Malviya-36 Badshahbhog IR58025A HUR 3022 BPT 5204	Pusa Sugandha-4 Malviya-36 BPT 5204 HUR 3022 CR 2340-1	Malviya-36 HUR 3022 BPT 5204
1000-grain weight (g)	IR58025A Narendra-359 IR68897A Pusa Sugandha-4 Type-3	Taraori Basmati Narendra-359 HUR 3022 Type-3 HUBR 2-1	Narendra-359 Type-3
Grain yield plant^{-1} (g)	IR58025A MTU-7029 BPT 5204 IR68897A Sarju-52	BPT 5204 Taraori Basmati HUR 3022 Type-3 HUBR 2-1	BPT 5204

genes for different component of yield (Table 4). The *per se* performance of the parent and their gca effects for all the characters were almost in close correspondence, which indicated that the per se performance of the parent for these traits could possibly be taken as a criterion for selection of parent.

In general, specific combining ability is associated with interaction effects, which may be due to dominance and epistatic component of variation that are non-fixable in nature. Hence, it can be utilized in F_1 generation only for development of hybrid varieties. In the present investigation, none of the cross combination showed high SCA effect for all the characters. Ghosh (1993) also observed that none of the cross exhibited significant sca effect for all the traits. The present finding revealed that cross combination IR58025 x Sarju-52, IR58025A x Badshahbhog, Pusa6A x Krishna Hansa, IR68897A x Type-3, IR58025A x Narendra-359, Pusa6A x Pant Dhan-11, IR68897A x Taraori Basmati, IR58025A x HUBR 2-1 and Pusa6A x Type-3 exhibited high sca effects for grain yield plant^{-1} (Table 3). The desirable sca effect of IR58025A x Sarju-52 for grain yield plant^{-1} was accompanied by desirable sca effects for days to 50% flowering. Similarly desirable sca effect of IR58025A x Badshahbhog was found to be related with desirable sca effect for plant height. Desirable sca effect of Pusa6A x Krishna Hansa for grain yield plant^{-1} was found to be related with number of effective tillers plant^{-1}, panicle length, number of spikelets panicle^{-1} and number of grains panicle^{-1}. Similar pattern of association between sca effects for grain yield plant^{-1} with other yield attributing traits were reported by Anand Kumar and Rangasumai (1984) and Singh (2002). The most desirable hybrids based on *per se* performance and higher significant positive sca effect for grain yield were IR58025A x Sarju-52 and Pusa6A x Krishna Hansa (Table 5). These combinations proved to be good hybrids on cms system in rice.

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Table 5. Ranking of five desirable hybrids on the basis of *per se* performance and sca effects in rice

Characters	Desirable hybrids based on *per se* performance	Best specific combiners	Best hybrids based on *per se* performance and sca effect
Days to 50% flowering	IR 68897A x Krishna Hansa IR 58025A x CR 2340-1 IR 68897A x CR 2340-1 Pusa 6A x CR 2340-1 IR 58025A x Pant Dhan-11	IR 68897A x Krishna Hansa Pusa 6A x Malviya-36 Pusa 6A x HUR 3022 Pusa 6A x Narendra-359 Pusa 6A x MTU-7029	IR 68897A x Krishna Hansa
Plant height (cm)	Pusa 6A x MTU-7029 IR 68897A x MTU-7029 IR 58025A x MTU-7029 IR 68897A x BPT5204 Pusa 6A x BPT5204	IR 68897A x CR 2340-1 Pusa 6A x Basmati-370 Pusa 6A x Type-3 IR 58025A x Badshahbhog IR 58025A x Pant Dhan-11	
Number of effective tillers $plant^{-1}$	Pusa 6A x Krishna Hansa Pusa 6A x Badshahbhog IR 68897A x Badshahbhog Pusa 6A x Type-3 Pusa 6A x Pant Dhan-11	Pusa 6A x Krishna Hansa Pusa 6A x Pant Dhan-11 IR 68897A x HUBR2-1 Pusa 6A x Sarju-52 IR 58025A x MTU-7029	Pusa 6A x Krishna Hansa Pusa 6A x Pant Dhan-11
Panicle length (cm)	IR 68897A x Type-3 IR 58025A x Taraori Basmati Pusa 6A x Krishna Hansa IR 68897A x HUBR2-1 IR 58025A x Pusa Sugandha-4	Pusa 6A x Krishna Hansa IR 58025A x MTU-7029 IR 68897A x Type-3 IR 58025A x Taraori Basmati	IR 68897A x Type-3 IR 58025A x Taraori Basmati Pusa 6A x Krishna Hansa
Days to maturity	IR 68897A x Krishna Hansa IR 58025A x CR 2340-1 IR 58025A x Pusa Sugandha-3 IR 58025A x Krishna Hansa IR 58025A x Pusa Sugandha-4	Pusa 6A x Malviya-36 IR 68897A x Krishna Hansa Pusa 6A x HUR 3022 IR58025 x Taraori Basmati IR58025 x Pusa Sugandha-3	IR 68897A x Krishna Hansa IR58025 x Pusa Sugandha-3
Number of spikelets $panicle^{-1}$	IR68897A x Malviya -36 IR58025A x BPT 5204 Pusa 6A x Pusa Sugandha-4 Pusa 6A x Malviya-36 IR68897A x BPT 5204	IR58025A x MTU-7029 IR68897A x HUBR 2-1 IR 68897A x Type-3 Pusa 6A x Krishna Hansa Pusa 6A x HUR 3022	
Number of grains $panicle^{-1}$	IR68897A x Malviya -36 Pusa 6A x Pusa Sugandha-4 Pusa 6A x HUR 3022 Pusa 6A x BPT 5204 IR 58025A x Pusa Sugandha-4	IR58025A x MTU-7029 IR68897A x Malviya -36 Pusa 6A x Krishna Hansa IR68897A x HUBR 2-1 Pusa 6A x HUR 3022	IR68897A x Malviya -36 Pusa 6A x HUR 3022
1000-grain weight (g)	IR68897A x Taraori Basmati IR 58025A x Pusa Sugandha-4 IR58025A x Taraori Basmati IR68897A x Narendra-359 IR58025A x HUR 3022	IR58025A x MTU-7029 IR58025A x HUR 3022 IR68897A x HUBR 2-1 IR 58025A x Pusa Sugandha-4 Pusa 6A x Type-3	IR 58025A x Pusa Sugandha-4 IR58025A x HUR 3022
Grain yield $plant^{-1}$ (g)	IR58025A x Sarju-52 IR58025A x BPT 5204 Pusa6A x BPT5204 IR68897A x BPT 5204 Pusa6A x Krishna Hansa	IR58025A x Sarju-52 IR58025A x Badshahbhog Pusa 6A x Krishna Hansa IR 68897A x Type-3 IR58025A x Narendra-359	IR58025A x Sarju-52 Pusa6A x Krishna Hansa

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