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EXPLOITATION OF HETEROBELTIOSIS AND ECONOMIC HETEROSIS FOR YIELD AND ITS COMPONENT TRAITS IN RICE (*ORYZA SATIVA* L.)

Akhilesh Kumar Yadav[1*], R.P. Vyas[2], V. K. Yadav[2] and Vimilesh Kumar[3]

[1*]K.V.K., Kotwa, Azamgarh (Anduat, Ayodhya), (U.P.), India.
[2]Department of Genetics & Plant Breeding, CSAUA&T, Kanpur (U.P.), India.
[3]College of Agriculture, Azamgarh (Anduat, Ayodhya), (U.P.), India.

Abstract

A study was conducted with the aim to exploit the heterobeltiosis and economic heterosis for agrononomic, flowering and yield and its components. The experiment was comprised 19 parents along with two checks and their 48(F_1^S) hybrids developed with the using of line × tester design. The seeds were developed by the crossing of three testers (males) with sixteen genetically diverse aromatic and non-aromatic rice genotypes/ varieties as lines (females) parents in a line × tester mating fashion. The field experiment was conducted randomized block design with three replications during *kharif* 2010-11. The observations were recorded for sixteen traits of agronomic and yield. The study revealed that the in case of grain yield per plant heterobeltiosis range from -56.46% to 113.50% and standard heterosis varied from -57.62% to 40.26% over Sv_1 (NDR359) and from -11.55% to 131.99% over Sv_2 (PB-1). Thirty eight crosses showed positive and significant standard heterosis over SV_1 and only one cross combination viz; Sarjoo 52 × NDR 359 possessed significant and positive standard heterosis over SV_2 for grain yield per plant and some other contributing components traits. Besides yield, substantial heterosis over better parent and standard varieties was also observed in negative as well as positive direction for remaining characters. However, the number of crosses showing significant estimates and the range of heterosis varied from one character to another's. The study concluded that the most desirable crosses showing high mean performance along with high and significant heterosis of one or both types for grain yield per plant were Sarjoo 52 × NDR 359, CSR 13 × CSR 36, CSAR 839-3, Usar-3 × CSR 36, T-3 × Pusa Basmati, NDRK 5088 × NDR 359 and Ram Raj × CSR-36. the cross, Sarjoo 52 × NDR 359 showed highest mean performance (43.53 g), heterobeltiosis (11.16%), standard heterosis over SV_1 (11.16%) and SV_2 (131.99%) for grain yield per plant.

Introduction

Rice (*Oryza sativa* L.) occupies a pivotal place in Indian agriculture, as it forms the staple food for two-thirds of the population, provides 43 per cent calories requirement and 20-25 % agriculture income. More than 90 per cent of the world's rice is grown and consumed in Asia, known as rice bowl of the world, where 60 per cent of the earth's people and two third of world's poor live (Khush and Virk, 2000). To focus attention on the importance of rice in global food security and the necessity to increase rice production and productivity, United Nations General Assembly in 2002 declared to celebrate the year 2004 as "International Year of Rice (IYR 2004)" with the theme of "Rice is Life". Rice belongs to the genus *Oryza*, sub tribe Orygianeae of the family Gramineae. It is the plant species which enjoyed with remarkable genetic diversity. Rice is cultivated worldwide over an area of about 167.13 million hectares with an annual rice production of about 782.00 million tones with an average productivity of 4.68 tones per hectare. India has the largest area of 44.50 million hectare constituting 26.62% of the land under rice in the world. Annual production of rice in the country is more than 172.58 million tones, second largest in the world after China (Anonymous, 2018). More than 80 % of our countrymen depend fully or partially on rice as their main cereal food and staple diet. Uttar Pradesh is an important rice growing

***Author for correspondence :** E-mail: akyadavkvk@gmail.com

state in the country. Uttar Pradesh is contributing about 13 percent rice to the total national production. The area and production of rice in this state is about 6.0 million hectares and 13.27 million tones, respectively, with the productivity of 2.49 tones per hectare (Anonymous, 2018a).

The exploitation of heterosis for improving yield potential of crop plants has emerged as one of the most outstanding contributions of science of genetics to agriculture. The term heterosis, first coined by Shull (1914), denotes superiority of F_1 hybrids over both of its parents in terms of yield or any other character. The assessment of nature and magnitude of heterosis for different characters serves in the identification of potential hybrid combinations for exploitation as hybrid varieties or breeding materials for isolating transgressive segregants for developing high yielding pure line varieties.

Materials and Methods

The present experiment was laid out at Crop Research Farm Nawabganj during *Kharif* 2010 and 2011 of C.S. Azad University of Agriculture & Technology, Kanpur. The crosses were made during *Kharif* 2010 and hybrids along with parental lines and check varieties were evaluated in randomized complete block design with three replications during *Kharif* 2011. Three testers (males) viz., CSR-36, Pusa-Basmati-1, and NDR-359 were crossed with sixteen genetically diverse aromatic and non-aromatic rice genotypes/ varieties as lines (females) parents in a line × tester mating fashion. The sixteen female parents (lines) were Sarjoo 52, NDRK 5088, CSR 30, T-3, Pakistani Basmati, Ram Raj, CSAR 839-3, Pusa Sugandha-3, Pusa Sugandha 5, Narendra Usar 3, Pokkali, IR 79218-63-2-3-1, IR 79495-9-3-2-2, FL- 478, IR 82571-544-2-3 and CSR-13. A total of 48 F_1's were made during *kharif* 2010 in line×tester fashion. During *Kharif,* 2011, a total of 48 F_1's along with their 19 parents were evaluated in randomized complete block design with three replications. The seeds of each entry were sown on 26th June, 2011 in separate plots and 35 days old seedlings were transplanted (31st July 2010) as single seedling per hill in five row plots of 1.0 m length with inter- and intra-row spacing of 20 cm and 15 cm, respectively. All the recommended cultural practices were followed to raise a good crop. The fertilizers were applied @ 120 kg nitrogen, 60 kg phosphorus and 60 kg potash per hectare through urea, DAP and murate of potash, respectively. The full dose of phosphorus and potash and half dose of nitrogen were applied as basal and rest of nitrogen was applied in two split doses as top dressing at tillering and panicle initiation stage of crop growth.

Results and Discussion

The heterosis breeding has been used extensively in improving yield potential through development of hybrid cultivars in most of the allogamous crops and some autogamous crops like rice as well. The exploitation of heterosis for developing high yielding commercial hybrids in rice has been found highly fruitful inspite of its autogamous nature because significant heterosis is encountered in F_1 hybrids and successful and economical technology for commercial hybrid seed production is available the presence of high heterosis for economically important characters is not only useful for developing hybrids, synthetic and composites segregants for development of superior homozygous lines. In present study, the estimates of heterosis over better parent and standard variety, SV_1 (NDR 359) and SV_2 (Pusa Basmati-1) were calculated for F_1s to assess their genetic potential as breeding materials.

A wide range of variation in the estimates of heterobeltiosis and standard heterosis in positive and negative direction was observed for grain yield per plant (Table 1). In case of grain yield per plant, heterobeltiosis ranged from 56.46 per cent to 113.5 per cent and standard heterosis varied from -57.62% to 40.26% over sv_1 and from -115.55% to 131.99 over sv_2.

Out of 48 crosses there crosses showed positive and significant over SV1, SV_2, 40.26% (IR79495-9-3-2-2×(PB-1), 33.59% (Pakistan Basmati×PB-1) AND 11.16% (SARJOO 52×NDR 359). White 30 crosses showed positive and significant heterosis over SV_2. The best five crosses are 131.99 per cent (Sarjoo 52×NDR 359) followed by 125.04 per cent (CSR 13×CSR 36), 121.71% (CSAR 839-3×PB-1), 119.09 per cent (Usar-3×CSR 36), 113.20 per cent (NDRK 5088×NDR 359) and 113.50 per cent (T-3×PB-1).

Out of 48 hybrids eighteen crosses showed positive and significant heterosis over BP. The best five crosses are T-3×PB-1 (113.50%) followed by CSAR 839-3×PB-1 (100.84%), Ram Raj×CSR 36 (94.61%), FL 478×PB-1 (81.71%) and CSR 13×CSR-36 (79.13).

In general, some crosses showed appreciable and high heterosis for most of the characters under study. The existence of wide spectrum of heterosis in either direction with expression of high degree of desirable heterosis by some crosses for all the characters observed in present study is in conformity with the earlier reports reporting presence of high heterosis for such characters in rice (Janardanan *et al.,* 2001; Bhanumathi *et al.,* 2003, Punitha *et al.,* 2004; Singh *et al.,* 2007; Roy *et al.,*2009).

It was noted that higher heterosis over better parent

Table 1: Extent of per cent heterosis and better period (BP) and two standard varieties (SV_1 and SV_2) for 16 characters except grain chalkiness in rice.

S. No.	Crosses	Days to 50% flowering			Plant height (cm)			Panicle bearing tiller/plant		
		BP	SV_1	SV_2	BP	SV_1	SV_2	BP	SV_1	SV_2
1.	IR82571×CSR 36	-9.90**	-6.31*	2.55	-8.70	-12.50	-11.89	13.33	-35.85**	30.77*
2.	IR 82571×Pusa Basmati-1	-0.70	-6.31*	2.55	0.70	0.00	0.70	33.33**	-24.53**	53.85**
3.	IR82571×NDR 359	-13.62**	-13.62**	-5.45	-3.47	-3.47	-2.80	47.17**	-47.17**	7.69
4.	NDRK5O88×CSR36	-6.71**	-2.99	6.18*	4.92	11.11	11.89	5.41	-26.42**	50.00**
5.	NDRK 5088x Pusa Basmati-1	17.99**	13.29**	24.00**	9.84	16.32	17.13*	-35.14**	-54.72**	-7.69
6.	NDRK 5088x NDR-359	-17.61**	-17.61**	-9.82**	-4.10	1.56	2.27**	-3.77	-3.77	96.15**
7.	Pokkali×CSR 36	5.75*	9.97**	20.36**	19.55*	19.79*	20.63 *	0.00	-49.06**	3.85
8.	Pokkali×Pusa Basmati-1	-21.82**	-28.57**	-21.82**	-4.54	-4.34	-3.67	30.77*	-35.85**	30.77*
9.	Pokali×NDR 359	-8.97**	-8.97**	-0.36	-13.55	-13.37	-12.76	-24.53**	-24.53**	53.85**
10.	CSR 13×CSR 36	4.79	8.97**	19.27**	-12.02	4.69	5.42	23.53*	-20.75**	61.54**
11.	CSR 13×Pusa Basmati-1	-14.92**	-16.61**	-8.73**	-4.29	13.89	14.69	-8.82	-41.51**	19.23
12.	CSR 13×NDR 359	-12.62**	-12.62**	-4.36	-37.85**	-26.04**	-25.52	-47.17**	-47.17**	7.69
13.	T-3×CSR 36	17.75**	-2.99	6.18*	-38.49**	-22.22**	-21.68	100.00**	1.89	107.69**
14.	T-3×Pusa Basmati-1	-28.45**	-15.61**	-7.64**	-25.86**	-6.25	-5.59	119.23**	7.55	119.23**
15.	T-3×NDR 359	-24.23**	10.63**	-2.18	-9.93	13.89	14.69	-43.40**	-43.40**	15.38
16.	IR79218-6×Pusa Basmati-1	-2.56	1.33	10.91**	2.82	7.64	8.39	-4.76	-24.53**	53.85**
17	IR 79218×Basmati-1	-2.55	-10.96**	-2.55	-12.44	-8.33	-7.69	-21.43*	-37.74**	26.92
18.	IR79218×NDR 359	-9.63**	-9.63**	-1.09	-5.80	-1.39	-0.70	-28.30**	-28.30**	46.15**
19.	PakistanBasmati×CSR36	-25.22**	-15.28**	-7.27*	-26.19**	-5.21	-4.55	7.41	-45.28**	11.54
20.	Pakistan Basmati×Pusa Basmati-1	-19.65**	-8.97 *	-0.36	-17.80**	5.56	629	50.00**	-26.42**	50.00**
21.	Pakistan Basmati×*NDR359	-11.14**	0.66	10.18**	-15.91*	7.99	8.74	49.06**	-49.06**	3.85
22.	Ramraj×CSR36	-23.00**	-19.93**	-12.36**	-1.78	-2.43	-1.75	77.78**	-9.43	84.62**
23.	Ramraj×Pusa Basmati-1	13.09**	3.32	13.09**	9.41	8.68	9.44	15.38	-43.40**	15.38
24.	Ramraj×NDR.359	-23.26**	-23.26**	-16.00**	-2.08	-2.08	-1,10	-35.85**	-35.85**	30.77*
25.	CSAR 839×CSR 36	-14.06**	-10.63**	-2.18	0.15	-10.07	-9,44	14.71	-26.42**	50.00**
26.	CSAR 839×Pusa Basmati-1	10.87**	1.66	11.27*	3.15	2.43	3.15	35.29**	-13.21	76.92**
27.	CSAR839×NDR 359	-17.61**	-17.61**	-9.82*	4.17	4.17	4.90	-39.62**	-39.62**	23.08
28.	IR79495-9-3-2-2×CSR36	-24.58**	-10.30**	-1.82	-6.02	-18.75*	-18.18*	-20.00*	-39.62**	23.08
29.	IR79495-9-3-2-2×Pusa Basmati-1	-21.51**	-6,64*	2.18	-16.08	-16.67*	-16.08	27.50**	-3.77	96.15**
30.	IR79495-9-3-2-2×NDR 359	-26.82**	-12.96**	-4.73	-2.43	-2.43	-1.75	5.66	5.66	115.38**
31.	Pusa Sugandha-3dha×CSR36	-13.42 **	-9.97**	-1.45	-10.48	9.72	10.49	10.71	-41.51**	1923
32.	Pusa Sugandha-3dha ×Pusa Basmati-1	6.55*	-2.66	6.55**	-13.88*	5.56	6.29	35.71**	-28.30**	46.15**
33.	Pusa Sugandha-3dha ×NDR 359	-6.3 *	-6.31*	2.55	-25.21**	-8.33	-7.69	-30.19**	-30.19**	42.31**
34.	PS 5×CSR 36	-8.95**	-5.32*	3.64	16.87	1.04	1.75	48.15**	-24.53**	53.85**
35.	PS 5×Pusa Basmati-1	-5.82*	-13.95**	-5.82**	-2.80	-3.47	-2.80	15.38	-43.40**	15.38
36.	PS 5×NDR 359	-3.65	-3.65	5.45	-29.17**	-29.17 **	-28.67**	-24.53**	-24.53**	53.56**
37.	FL 478×Pusa Basmati-1	4.47	8.64**	18.91**	26.91**	9.72	10.49	-50.94**	-50.94**	0.00
38.	FL 478×Pusa Basmati-1	-15.61**	-15.61**	-7.64**	-1.05	-1.74	-1.05	-11.32	-11.32	80.77**
39.	FL 478×NDR 359	8.31**	8.31**	18.55**	6.94	6.94	7.69	-45.28**	-45.28**	11 54
40.	Sarjoo 52×CSR 36	-28.12 **	-25.25**	-18 18**	-1.84	-1.56	-0.87	-31.37**	-33.96**	34.62**
41.	Sarjoo 52×Pusa Basmati-1	1.45	-7.31**	1.45	-9.46	-9.20	-8.57	-23.53**	-26.42**	50.00**
42.	Sarjoo 52×NDR 359	6.31*	6.31*	16.36**	-0.63	-0.35	0.35	-13.21	-13.21	76.92" *
43.	CSR 30×CSR36	-16.61**	-13.29**	-5.09	-14.11*	3.82	4.55	18.52	-39.62**	23.08
44.	CSR 30×Pusa Basmati-1	-4.00	-12.29**	-4.00	-30.77 **	-16.32	-15.73	7.69	-47.17**	7.69
45.	CSR 30×NDR 359	-5.32**	5.32*	3.64	-27.90 **	-12.85	-12.24	-5.66	-5.66	92.31**
46.	Usar 3×CSR 36	-15.97**	-12.62**	-4.36	-19.71 **	-5.56	-4.90	80.65**	5.66	115.3**8
47.	Usar 3×Pusa Basmati-1	-14.38**	-10.96**	-2.55	-12.03	3.47	4.20	0.00	-41.51**	19.23
48.	Usar 3×NDR 359	-4.15**	-0.33	9.09**	-12.33	3.13	3.85	-28.30**	-28.30**	46.15" **

Table 1 Contd....

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S. No.	Crosses	Particle length (cm)			Spikelet/panicle			Spikelet fertility (%)		
		BP	SV_1	SV_2	BP	SV_1	SV_2	BP	SV_1	SV_2
1.	lR82571×CSR36	-0.54	-9.18	-10.31	9.52	1.10	16.95	0.39	-7.89 **	0.39
2.	IR 82571×Pusa Basmati-1	-5.64	-4.46	-5.64	5.30	-8.97	5.30	8.98**	0.00	8.98 **
3.	lR82571×NDR359	-6.66	-6.66	-7.82	-3.85	-3.85	11,23	-0.86	-0.86	8.05**
4.	NDRK5O88×CSR36	14.29	4.36	3.07	-8.13	-15.20 *	-1.91	1.47	-5.26 *	3.25
5.	NDRK 5088x Pusa Basmati-1	6.79	8.13	6.79	-6.14	-18.86 **	-6.14	2.69	-4.12	4.49
6.	NDRK5088x NDR-359	6.05	6.05	4.74	4.40	4.40	20.76**	-1.67	-1.67	7.16**
7.	Pokkali×CSR36	44.90**	32.31 **	30.67**	-14.88*	-21.43 **	-9.11	1.85	5.34 *	3.16
8.	Pokkali×Pusa Basmati-1	4.91	6.22	4.91	1.06	-12.64	1.06	7.64**	0.04	9.02**
9.	PokaIi×NDR 359	-1.98	-1.98	-3.19	-3.11	-3.11	12.08	-2.75	-2.75	5.99**
10.	CSR13×CSR36	6.26	-2.97	-4.17	5.36	-2.75	12 .50	5,30*	-3.15	5.55 *
11.	CSR 13×Pusa Basmati-1	38.28**	40.02 **	38.28**	12.92	-2.38	12.92	3.27	-5.02*	3.52
12.	CSR13×NDR359	14.83	14.83	13.41	-5.68	-5.68	9.11	-0.72	-0.72	8.20**
13.	T-3×CSR36	-13.92	-8.56	-9.69	-15.48*	-21.98**	-9.75	2.34	-6.09 **	2 34
14.	T-3×Pusa Basmati-1	3.74	10.20	8.83	15.47*	-0.18	15.47*	7.15**	-1.68	7.15**
15.	T-3×NDR359	7.84	14.55	13.13	-7.14	-7.14	7.42	-4.21	-4.2 1	4.39
16.	IR79218-6×Pusa Basmati-1	12.79	7.34	6.01	5.36	-2.75	12.50	3.58	-2.54	6.21*
17	IR 79218×Basmati-1	-6.64	-5.47	-6.64	14.31	2.38	18.43*	-0.95	-6.81 **	1.56
18.	lR79218×NDR359	-5.55	-5.55	-6.72	-8.42	-8.42	5.93	-1.79	-1.79	7.03**
19.	PakistanBasmati×CSR36	-10.35	7.58	6.25	5.16	-2.93	12.29	7.42**	-1.43	7.42**
20.	Pakistan Basmati×Pusa Basmati-1	-11.33	6.41	5.09	-0.21	-13.74 *	-0.21	3.91	-4.66 *	3.91
21.	Pakistan Basmati×*NDR359	-9.63	8.45	7.10	-18.50 **	-18.50 **	-5.72	-3.94	-3,94	4.69
22.	Ramraj×CSR36	16.71	6.57	5.25	11.31	2.75	18.86*	7.42**	-1.43	7.42**
23.	Ramraj×Pusa Basmati-1	29.33 **	30.95 **	29.33**	-7.63	-20.15 **	-7.63	1.17	-7.17 **	1.17
24.	Ramraj×NDR.359	3.32	3.32	2.04	-41.76**	-41.76 **	-32..63**	-1.43	-1.43	7.42**
25.	CSAR 839×CSR36	6.68	-1.65	-2.87	5.56	-2.56	12.71	2.59	-2.51	6.25*
26.	CSAR 839×Pusa Basmati-1	6.66	8.00	6.66	19.28*	3.11	19.28*	6.36**	1.08	10 16**
27.	CSAR839×NDR359	36.43 **	36.43 **	34.74**	-2.01	-2.01	13.35	-3.58	-3.58	5.08*
28.	IR79495-9-3-2-2×CSR36	14.16	15.17	13.74	0.39	-5,49	9.32	4.44	-2.51	6 25*
29.	IR79495-9-3-2-2×Pusa Basmati-1	-9.12	-7.98	-9.12	-14.01 *	-19.05 **	-6.36	-2.47	-8.96 **	-0.78
30.	IR79495-9-3-2-2×NDR359	7.59	8.54	7.19	0.18	0.18	15.89*	-1.79	-1.79	7.03**
31.	Pusa Sugandha-3dha×CSR36	-24.73 **	10.86	9.48	1.39	-6.4	8.26	-0.61	-6.45 **	1.95
32.	Pusa Sugandha-3dha ×Pusa Basmati-1	-26.32 **	8.52	718	11.86	-3.30	11.86	0.15	5.73*	2.73
33.	Pusa Sugandha-3dha ×NDR 359	-35.24 **	-4.62	-5.80	3.11	3.11	19.28*	4.66*	-4.66*	3.91
34.	PS 5×CSR36	-13.02	-5.31	-6.48	-0.99	-8.61	5.72	8.98**	0.00	8.98**
35.	PS 5×Pusa Basmati-1	-15.30 *	-7.79	-8.93	12.29	-2.93	12.29	7.42**	-1.43	7.42**
36.	PS 5×NDR359	-4.54	3.93	2.64	-15.02 *	-15.02*	-1.69	-4.66*	4.66*	3.91
37.	FL478×Pusa Basmati-1	17.61 *	7.39	6.06	-12.10	-18.86**	-6.14	7.03**	-1.79	7 03**
38.	FL478×Pusa Basmati-1	-0.04	1.22	-004	18.43 *	2.38	18.43*	6.64**	-2.15	6.64**
39.	FL478×NDR359	28.39 **	28.39 **	26 80**	-20.88 **	-20.88**	-8.47	-6.45 **	-6.45**	1 95
40.	Sarjoo 52×CSR36	-5.03	3.01	1.73	-6.35	-13.55*	0.00	3.32	-2.15	6.64 -
41.	Sarjoo 52×Pusa Basmati-1	-10.93	-3.39	-4 59	13.14	-2.20	13.14	0.67	-4.66*	3.91
42.	Sarjoo 52×NDR359	0.23	8.71	7.36	4.40	4.40	20 76**	-3.94	-3,94	4.69
43.	CSR30×CSR36	39.85 **	37.78 **	36.07**	16.87 *	7.88	24.79**	0.32	-3.23	5.47*
44.	CSR 30×Pusa Basmati-1	11.56	12.96	11.56	9.96	-4.95	9.96	2.18	-1.43	7.42**
45.	CSR30×NDR359	-13.47	-13.47	-14.54	-22.34 **	-22.34*	-10.17	-6,45 **	-6.45**	1.95
46.	Usar 3×CSR36	15.44	8.57	7.23	8.53	0.18	15.89*	-0.22	-3.94	4.69
47.	Usar 3×Pusa Basmati-1	9.83	11.21	9.83	8.26	-6.41	8.26	-4.32	-7.89**	0.39
48.	Usar 3×NDR359	6.40	6.40	5.08	-2.38	-2.38	12.92	-7.17 **	-7.17**	1.17

Table 1 Contd....

Table 1 Contd....

S. No.	Crosses	1000-grain weight (g)			Biological yield/plant (g)			Harvest index (%)		
		BP	SV_1	SV_2	BP	SV_1	SV_2	BP	SV_1	SV_2
1.	IR82571×CSR 36	-7.15	-16.52	26.80	6.65	-20.22 **	25.67**	-1.18	-23.36**	1.54
2.	IR 82571 ×Pusa Basmati-1	4.40	-6.14	42.57	5.62	-32.94 **	5.62	10,00	-14.69*	13.03
3.	IR82571×NDR 359	-11.59	-11.59	34.28	-30.19**	-30.19 **	9.97	-0.06	-0.06	32.41**
4.	NDRK5O88×CSR36	11.06	4.64	58.94	10.70	-17.19 **	30.45**	14.45	-20.26**	5.65
5.	NDRK 5088x Pusa Basmati-1	-13.62	-18.60	23.63	-13.48	-45.07 **	-13.48	4,50	-21.13**	4.50
6.	NDRK 5088x NDR	-6.94	-6.94	41.35	-3.15	-3.15	52.55" **	5.13	5.13	39.28**
7.	Pokkali×CSR 36	-27.83	-38.52	-6.61	5.41	21.15**	24.20"	-36.23**	-40.86**	-21.64*
8.	Pokkali×Pusa Basmati-1	1.47	-17.78	24.88	-13.99	39.95 **	-5.41	11.06	3.00	36.46**
9.	PokaIi×NDR 359	245.42**	245.42**	424.65**	-9.42	-9.42	42.68**	-0.55	-0.55	31.76**
10.	CSR 13×CSR 36	-8.29	-8.32	39.25	50.00**	12.21*	70.75**	-0,21	-4,74	26.21**
11.	CSR 13×Pusa Basmati-1	-21.99	-22.02	18.44	39.56**	-10.63 *	40.76**	-11.12	-15.15*	12.42
12.	CSR 13×NDR 359	-9.05	-9.05	38.15	-8.61	-8.61	43.95**	-19.27**	-19.27**	6.96
13.	T-3×CSR 36	28.40	9.39	66.14	-4.86	-28.83**	12.10	-20.17**	-24.02**	0.66
14.	T-3×Pusa Basmati-1	25.18	-3.59	46.44	86.1 **	18.16**	86.11**	-9.18	-13.57*	14.52
15.	T-3×NDR 359	-18.75	-18.75	23.41	-31.66**	-31,66**	7.6	-11.29	-11.29	17.54*
16.	IR79218-6×Pusa Basmati-1	-6.10	-9.65	37.23	41 .82**	6,75	68.15**	-29.76	-27.38**	-3.78
17	IR 79218×Basmati-1	-5.67	-9.24	37.85	8.68	-18.20 **	28.85'**	-26.20**	-23.70**	1.10
18.	IR79218×NDR 359	-8.16	-8.16	39.49	-32.94**	-32.94 **	5.62	-17.82**	-15.03*	12.57
19.	PakistanBasmati×CSR36	3.59	-11.75	34.04.	-6.68	-30.19**	9.97	24.09**	0.67	33.38**
20.	Pakistan Basmati×Pusa Basmati-1	23.89	1.58	54.28	30.45**	-17.19**	30.45 **	-0.29	-19.10 **	7.18
21.	Pakistan Basmati×*NDR359	-17.39	-17.39	25.47	-45.07 **	-45.07 **	-13.48	-19.02"	19.02**	7.30
22.	Ramraj×CSR36	12.09	-4.51	45.04	31.89**	-1.33	55.41	19.39*	1.08	33.92**
23.	Ramraj×Pusa Basmati-1	17.13	-15.57	28.24	24.20**	-21.15**	24.20**	-30.45"	-41.11**	-21.98*
24.	Ramraj×NDR.359	-18.43	-18.43	23.89	42.58**	-42.58**	-9.95	3.34	3.34	36.91**
25.	CSAR 839×CSR 36	-3.22	-13.49	31.41	12.54	-15.81 **	32.61**	31.68**	6,64	41.28**
26.	CSAR 839×Pusa Basmati-1	7.72	-3.71	46.25	78.67 **	17.47 **	85.03**	12.67	-8.75	20.89**
27.	CSAR839×NDR 359	-17.80	-17.80	24.85	-9.02	-9.02	43.31**	-9.73	-9,73	19.60**
28.	IR79495-9-3-2-2×CSR36	-5.44	-9.18	37.94	12.66	-8.61	43.95**	-21.58**	-21.80**	3.61
29.	IR79495-9-3-2-2×Pusa Basmati-1	8.33	4.05	58.04	-12.26	-28.83**	12.10	-23.71**	23.93**	0.78
30.	IR79495-9-3-2-2×NDR 359	-0.97	-0.97	50.41	18.16 **	18.16**	86.11**	-16.01*	-16.0 *	11.28
31.	Pusa Sugandha-3dha×CSR36	-4.17	-18.36	24.00	-8.65	-31.66 **	7.64	-3.78	-958	19.80 *
32.	Pusa Sugandha-3dha ×Pusa Basmati-1	13.64	-10.59	35.81	68.15	6.75	68.15**	-25.74**	-30.22**	-7.55
33.	Pusa Sugandha-3dha ×NDR 359	-10.14	-10.14	36.49	-18,20 **	-18.20 **	28.85**	-19.53**	-19.53**	6.62
34.	PS 5×CSR 36	5.49	-6.34	42.25	-10.36	-32.94 **	5.62	-19.32**	-12.02	16.57
35.	PS 5×Pusa Basmati-1	-0.75	-11.88	33,8a	9.97	-30.19 **	9.97	-7.22	1.18	34.05**
36.	PS 5×NDR 359	5.80	5.80	60.69	-17.19 **	-17.19 **	30.45**	-23.23**	-16.27	10.93
37.	FL 478×Pusa Basmati-1	-22.54	-18.88	23.21	-26.58 **	-45.07 **	-13.48	2.27	-15.52*	11.93
38.	FL 478×Pusa Basmati-1	-11.21	-7.02	41.22	46.62 **	-6.91	46.62**	14.34	-5.54	25.15**
39.	FL 478×NDR 359	-17.70	-13.81	30.91	-21.15 **	-21.15 **	24.20**	-38.26**	-38.26	-18.20*
40.	Sarjoo 52×CSR 36	-9.89	-17.17	25.81	-26.41 **	-42.58 **	-9.55	23.35**	5.90	40.31**
41.	Sarjoo 52×Pusa Basmati-1	-7.27	-14.76	29.47	7.90	-15.81 **	32.61**	24.42**	6.82	41.52**
42.	Sarjoo 52×NDR 359	-4.90	-4.90 ‘	44.45	17,47**	17.47**	85.03**	4.52**	-4.52	26.51**
43.	CSR 30×CSR36	-2.19	-16.67	26.56.	21.62 **	-9.02	43.31**	0.51	-7.44	22.63**
44.	CSR 30×Pusa Basmati-1	36.31	-9.59	37.32	43 95 **	-8.61	43.95**	-19.95**	-26.28**	-2.33
45.	CSR 30×NDR 359	9.58	9.58	66.44	-28,83 **	-28.83 **	12.10	-25.98**	-25.98**	-1.92
46.	Usar 3×CSR 36	8.20	-3.36	46.79	56.76 **	17.27 **	84.71**	8.89	-10.44	18.66*
47.	Usar 3×Pusa Basmati-1	-8.31	-18.11	24.39	-7.14	-31.66 **	7.64	13.11	-6.97	23.26**
48.	Usar 3×NDR 359	-9.33	-9.33	37.72	6.75	6.75	68.15**	27.03**	-27.03	-3.32

Table 1 Contd....

Table 1 Contd....

S. No.	Crosses	Grain yield/plant (g)			Kernel length (mm)			Kernel breadth (mm)		
		BP	SV_1	SV_2	BP	SV_1	SV_2	BP	SV_1	SV_2
1.	lR82571×CSR 36	21.65*	-37.02**	31.44**	-1.95	-7.52*	-5.20	6.82	-4.78	10.22*
2.	IR 82571×Pusa Basmati-1	17.76	-43.57**	17.76	-2.45	-4.83	-2.45	23.38**	9.99*	27.30*
3.	lR82571×NDR 359	-30.81**	-30.81**	44.40**	1.59	1.59	4.13	-5.07	-5.07	9.88*
4.	NDRK5O88×CSR36	26.42**	-34.55**	35.59**	13.56**	7.12	9.80**	-19.39**	-11.58**	2.35
5.	NDRK 5088x Pusa Basmati-1	-11.55	-57.62**	-11.55	15.51**	12.69**	15.51	-21.90**	-14.33**	-0.84
6.	NDRK 5088x NDR-359	2.15	2.15	113.20**	3.68	3.68	6.28	-9.89	-1.16	14.41**
7.	Pokkali×CSR 36	-28.14**	-53.19**	-2.31	38.58**	30.71**	33.98**	-19.17**	-23.73**	-11.73*
8.	Pokkali×Pusa Basmati-1	-7.37	-39.66**	25.93*	4.23	1.69	4.23	-15.34**	-20.12**	-7.54
9.	PokaIi×NDR 359	-10,34*	-10.34*	87.12**	18.52**	18.52**	21.48**	-23.01	-23.01**	-10.89*
10.	CSR 13×CSR 36	79.13**	7.83	125.04**	0.42	-5.28	-2.91	4.57	-7.24	7.37
11.	CSR 13×Pusa Basmati-1	33.47**	-19.66**	67.67**	7.24	4.63	7.24	7.11	-6.22	8.54
12.	CSR 13×NDR 359	-25.40**	-25.40**	55.70**	40.02**	40.02**	43.52**	-19.25**	-19.25**	-6.53
13.	T-3×CSR 36	15.73	-40.09**	25.04*	-0.05	-3.09	-0.66	4.73	-7.09	7.54
14.	T-3×Pusa Basmati-1	113.50**	2.30	113.50**	20.05**	17.12**	20.05**	22.61**	5.93	22.61**
15.	T-3×NDR 359	-43.40**	-43.40**	18.12	14.83**	14.83**	17.70**	1.30	1.30	17.25**
16.	IR79218-6×Pusa Basmati-1	-0.72	-22.82**	61.08**	5.91	-0.10	2.40	-31.95**	-33.43**	-22.95**
17	IR 79218×Basmati-1	-18.35**	-36.52**	32.49**	4.29	-1.84	4.39	-2.66	-4.78	10.22*
18.	lR79218×NDR 359	-43.80**	-43.80**	17.30	-4.78	-4.78	-2.40	10.13*	10.13*	27.47**
19.	PakistanBasmati×CSR36	34.62**	-30.31**	45.45**	-0.50	-0.50	1.99	7.34	-4.78	10.21*
20.	Pakistan Basmati×Pusa Basmati-1	38.60**	33.59**	38.60**	7.22**	7.22**	-9.90**	2.01	-11.87**	2.01
21.	Pakistan Basmati×*NDR359	56.46**	5.48**	-9.13	-2.02	13.54**	16.38*	-14.76**	14.76**	-1.34
22.	Ramraj×CSR36	94.61**	0.75	110..27**	9.71*	3.48	6.07	11.75*	-0.87	14.74**
23.	Ramraj×Pusa Basmati-1	-2.65	-53.35**	-2.65	31.07**	27.87**	31.07**	-12.23*	-24.17**	-12.23**
24.	Ramraj×NDR.359	-41.45**	-41.45**	22.20*	-1.24	-1.24	1.22	-19.10**	-19.10**	6.37
25.	CSAR 839×CSR 36	70.68**	-9.72	88.42**	8.75*	18.22**	21.17**	-13.21**	-23.01**	-10.89*
26.	CSAR 839×Pusa Basmati-1	100.84**	6.23	121.71**	-13.37**	-5.82	3.47	8.38	-6.37	8.38
27.	CSAR839×NDR 359	17.00**	-17.00**	73.21**	0.09	8.81*	11.53**	-5,21	-5.21	9.72*
28.	IR79495-9-3-2-2×CSR36	-1.84	-27.74	50.82**	49.39**	40.92**	44.44*	-12.11**	-19.10**	-6.37
29.	IR79495-9-3-2-2×Pusa Basmati-1	18.84**	40.26**	24.69**	-0.61	-3.04	-0.61	1.73	-6.37	8.38
30.	IR79495-9-3-2-2×NDR 359	-0.60	-0.60	107.46**	16.87**	16.87**	19.80**	5.21	5.21	21.78**
31.	Pusa Sugandha-3dha×CSR36	11.23	-42.42**	20.18	20.17**	13.59	16.43	8.15	1.74	17.76**
32.	Pusa Sugandha-3dha ×Pusa Basmati-1	44.55**	-25.77**	54.92**	1.63	-0.85	1 6.43**	-29.23**	-33.43**	-22.95**
33.	Pusa Sugandha-3dha ×NDR 359	-33.06**	-33.06**	39.72	-0.40	-0.40	2.09	-2.89	-2.89	12.40*
34.	PS 5×CSR 36	5.72	-41.81**	21.44	-24.63**	-0.25	2.24	24.80**	10.71*	28.14**
35.	PS 5×Pusa Basmati-1	27.26**	-29.96**	46 18	-24.48**	-0.05	2.45	15.41**	-0.29	15.41**
36.	PS 5×NDR 359	-31.27**	-31.27**	43.45	-16.66**	10.30**	13.6**	-11.00**	-11.00**	3.02
37.	FL 478×Pusa Basmati-1	-12.28	-54.59**	-5.22	19.74**	12.94**	15.77**	-6.60	-14.04**	-0.50
38.	FL 478×Pusa Basmati-1	81.71**	-12.94**	81.71	12.04**	9.31*	12.04**	7.86	-0.72	14.91**
39.	FL 478×NDR 359	-51.17**	-51.17**	1.92	28.97**	28.97**	32.19**	-23.44**	-23.44**	-11.39*
40.	Sarjoo 52×CSR 36	-9.50	-39.95**	25.33	-1.18	0.35	2.86	-21.70**	-17.51**	-4.52
41.	Sarjoo 52×Pusa Basmati-1	36.31**	-9.55	88.77**	18.82**	20.66**	23.67**	-32.83**	-29.23**	-18.09**
42.	Sarjoo 52×NDR 359	11.16*	11.16*	131.99**	-6.91	-5.48	-3.11	-11.13**	-6.37	8.38
43.	CSR 30×CSR36	64.44**	-14.87**	77.67**	12.96**	13.64**	16.48**	-5.17	-4.49	10.55*
44.	CSR 30×Pusa Basmati-1	41.65**	-32.13**	41 65**	42.21**	43.06**	46.63**	-5.17	-4.49	10.55*
45.	CSR 30×NDR 359	-41.23**	-41.23**	22.65*	0.30	0.90	3.42	-5.03	-4.34	10.72*
46.	Usar 3×CSR 36	76.74**	4.98	119.09**	23.38**	16.38**	19.29**	30.67**	15.92**	34.17*
47.	Usar 3×Pusa Basmati-1	-0.16	-40.70**	23.77*	15.92**	13.09**	15.92**	23.62**	6.80	23.62**
48.	Usar 3×NDR 359	-22.3Z**	-22.31**	62.13**	-3.29	-3.29	-0.87	-32.27**	-32.27**	-21.61**

Table 1 Contd....

Table 1 Contd....

S. No.	Crosses	L:B ratio			Kernel length after cooking (KLAC)			Kernel elongation ratio		
		BP	SV_1	SV_2	BP	SV_1	SV_2	BP	SV_1	SV_2
1.	IR82571×CSR 36	-14.53*	-9.94	-20.24**	-9.90**	-14.91**	-27.74**	-12.02**	-8.35*	-23.96**
2.	IR 82571×Pusa Basmati-1	-28.95**	-19.77**	-28.95**	-24.48**	-11.07**	-24.48**	-24:44**	-6.51	-22.44**
3.	IR82571×NDR 359	-2.86	-2.86	-13.97*	-15.36**	-15.36**	-28.12**	-20.03**	-16.69**	-30.89**
4.	NDRK5O88×CSR36	0.65	6.06	-6.07	-1.58	-7.06**	-21.07**	-23.68**	-13.36**	-26.12**
5.	NDRK 5088x Pusa Basmati-1	5.16	18.74**	5.16	-1.61	15.86**	-1.61	-14.82**	2.67	-14.82**
6.	NDRK 5088x NDR-359	-4.34	-4.34	-15.28**	-6.78*	-6.78*	-20.84**	-20.59	-9.85*	-25.21**
7.	Pokkali×CSR 36	49.57 **	57.60**	39.57**	30.45**	23.19**	4.62**	-5.99	-5.68	-21.75**
8.	Pokkali×Pusa Basmati-1	2.23	15.43*	2.23	-28.40**	-15.69**	-28.40**	-31.60**	-17.03**	-31.16**
9.	PokaIi×NDR 359	47.20**	47.20**	30.36**	15.46**	15.46**	-1.95	-2.50	-2.17	-18.84**
10.	CSR 13×CSR 36	-15.29**	-10.06	-20.34**	-4.32	-7.78**	-21.69**	-5.96	-2.50	-19.11**
11.	CSR 13×Pusa Basmati-1	-17.2 **	-6.51	-17.21**	6.57**	25.49**	6.57**	-4.99	14.52**	4. 99**
12.	CSR 13×NDR 359	57.37**	67.09**	47.98**	8.65**	8.65	-7.73**	-25.12**	-22.37**	-35.60**
13.	T-3×CSR 36	-21.31**	-10.51	-20.75**	-28.34**	-16.68**	-29.25**	-28.37**	-14.02**	-28.67**
14.	T-3×Pusa Basmati-1	13.17*	-1.26	-12.55**	-28.76**	-16.11**	-28.76**	-40.44**	-28.21**	-40.44**
15.	T-3×NDR 359	-10.15	2.17	-9.51	-5.92*	9.38**	-7.12**	-20.58**	-4.67	-20.91**
16.	IR79218-6×Pusa Basmati-1	16.05**	22.29**	8.30	-9.34**	-12.82**	-25.96**	-19.29**	-12.69**	-27.56**
17	IR 79218×Basmati-1	-10.63*	0.91	-10.63*	-26.94**	-13.97**	-26.94**	-29.78**	-15.36**	-29.78**
18.	IR79218×NDR 359	-19.54**	-19.54**	-28.74**	-11.07**	-11.07**	-24.48**	-13.58**	-6.51	-22.44**
19.	PakistanBasmati×CSR36	-36.57**	-3.09	-14.17**	-32.41**	-15.14**	-27.93**	-21.26**	-14.69**	-29.22**
20.	Pakistan Basmati×Pusa Basmati-1	-30.59**	6.06	-6.07	-25.90**	-6.96*	-20.99**	-27.98 **	-13.19**	-27.98**
21.	Pakistan Basmati×*NDR359	-22.06**	19.09**	5.47	-7.63**	15.99**	-1.50	-5.70	2.17	-15.24**
22.	Ramraj×CSR36	-13.40*	-4.69	-15.59**	-1.16	-6.66*	-20.73**	-9.83*	-9.68*	-25.07**
23.	Ramraj×Pusa Basmati-1	39.57**	57.60**	39.57**	5.21*	23.89**	5.21*	-19.53**	-3.01	-19.53**
24.	Ramraj×NDR.359	2.49	12.80*	-0.10	-15.61**	-15.61**	-28.34**	-14.69**	-14.69**	-29.22**
25.	CSAR 839×CSR 36	3.14	46.29**	29.55**	-0.60	15.56**	-1.85	-8.27*	-1.84	-18.56**
26.	CSAR 839×Pusa Basmati-1	-37.15**	-10.86	-21.05**	-21.58**	-7.66**	-21.58**	-18.70**	-2.00	-18.70**
27.	CSAR839×NDR 359	-27.07**	3.43	-8.40	12.57**	30.87**	11.14**	12.64**	20.53**	0.00
28.	IR79495-9-3-2-2×CSR36	56.29**	64.69**	45.85**	15.08**	8.68**	-7.71**	-31.00**	-22.70**	-35.87**
29.	IR79495-9-3-2-2×Pusa Basmati-1	.21.36**	-11.20	-21.36**	-29.16**	-16.58**	-29.16**	-28.53**	-13.86**	-28.53**
30.	IR79495-9-3-2-2×NDR 359	-0.91	-0.91	-12 25*	-16.01**	-16.01**	-28.67**	-35.92**	-28.21**	-40.44**
31.	Pusa Sugandha-3dha×CSR36	-3.58	1.60	-10.02	-15.81**	9.40 **	7.09*	-29.98**	-3.67	-20.08**
32.	Pusa Sugandha-3dha ×Pusa Basmati-1	7.59	21.49**	7.59	-32.80**	-12.67**	-25.84**	-35.92**	11.85*	-26.87**
33.	Pusa Sugandha-3dha ×NDR 359	-2.96	-2.74	-13.87*	-32.60**	-12.42**	-25.62**	-36.04**	-12.02**	-27.01**
34.	PS 5×CSR 36	-51.42**	-19.77**	-28.95**	-15.09**	-12.02**	-25.29**	-11.83**	-11.69**	-26.73**
35.	PS 5×Pusa Basmati-1	-45.33**	-9.71	-20.04**	-27.06**	-14.11**	-27.06**	-28.67**	-14.02**	-28.67**
36.	PS 5×NDR 359	-35.78**	6.06	-6.07	-9.29**	-6.01*	-20.18**	-14.86**	-14.86**	-29.36**
37.	FL 478×Pusa Basmati-1	12.36	18.40**	4.86	22.26**	15.46**	-1.95	-2.40	2.00	-15.37**
38.	FL 478×Pusa Basmati-1	-12.04*	-0.69	-12.04*	-21.07**	-7.06**	-21.07**	-29.09**	-14.52**	-29.09**
39.	FL 478×NDR 359	54.74**	54.74**	37.04**	24.11**	24.11**	5.40*	-7.67*	-3.51	-19.94**
40.	Sarjoo 52×CSR 36	6.94	12.69*	-0.20	-8.34**	-13.44**	-26.49**	-13.67**	-13.52**	-28.25**
41.	Sarjoo 52×Pusa Basmati-1	38.46**	56.34**	38.46**	-1.84	15.59**	-1.84	-20.08**	-3.67	-20.08**
42.	Sarjoo 52×NDR 359	11.77	-11.77	21.86**	-5.89*	-5.89*	-20.08**	-0.50	-0.50	-17.45**
43.	CSR 30×CSR36	1.63	7.09	-5.16	17.33**	31.67**	11.82**	3.74	15.86**	-3.88
44.	CSR 30×Pusa Basmati-1	47.67**	66.74**	47.67**	-11.80**	3.87	-11.80**	-45.98**	-34.89**	-45.98**
45.	CSR 30×NDR 359	-10.51	-10.51	-20.75**	-22.20**	-12.69**	-25.86**	-22.42**	-13.36**	-28.12**
46.	Usar 3×CSR 36	-19.39**	-6.86	-17.51**	-10.01**	-15.01**	-27.83**	-39.72**	-27.05**	-39.47**
47.	Usar 3×Pusa Basmati-1	-12.17*	1.49	-10.12	-6.16**	10.50**	-6.16*	-19.17**	-2.17	-18.84**
48.	Usar 3×NDR 359	6.13	22.63**	8.60	-13.19**	13.19**	-26.28**	-25.93**	-10.35*	-25.62**

Table 2: Relationship of positive and significant standard heterosis over SV_1 (NDR 359) and SV_2 (Pusa Basmati-1) for grain yield per plant with standard heterosis for other characters.

SV_1

Characters / Crosses	Grain yield/ plant	Days of 50% flowering	Plant height (cm)	Panicle bearing tillers/ plant	Panicle length (cm)	Spikelets/ panicle	Spikelet fertility (%)	1000 grain weight (g)	Biological yield/ plant (g)	Harvest index (%)
Sarjoo-52 ×NDR-359	11.16	+	-	-	0	0	-	-	+	-

Characters / Crosses	Kenrnel length (mm)	Kernel breadth (mm)	L::B ratio	Kernel length after cooking (KLAC)	Kernel elongation ratio
Sarjoo-52 ×NDR-359	-	-	-	-	-

Table 3: Most promising crosses based on mean performance, heterobeltiosis and standard heterosis (SV_1 and SV_2) for grain yield/ plant.

S.No.	Crosses	*Per se* performance	Heterosis over BP	Heterosis over SV_1	Heterosis over SV_2
1.	Sarjoo-52 ×NDR 359	43.53	11.16	11.15	131.99
2.	CSR 13 ×CSR 36	42.23	79.13	7.83	125.04
3.	CSAR 839-3 ×PB-1	41.60	100.84	6.23	121.71
4.	Usare-3 ×CSR-36	41.11	76.74	4.98	119.09
5.	T-3 ×PB-1	40.06	113.50	2.30	113.50
6.	NDRK 5088 ×NDR 359	40.01	2.15	2.15	113.20
7.	Ram Raj ×CSR 36	39.46	94.61	0.75	110.27
8.	IR 79495-9-3-2-2 ×NDR 359	38.9	-0.60	-0.60	107.60
9.	Sarjoo 52 ×PB-1	35.43	36.31	-9.55	88.77
10.	CSAR 839-3 ×CSR 36	35.36	70.68	-9.72	88.42

was found in some lower yielding crosses other compared to other crosses which have displayed high yield. This suggested that white selecting the best hybrid besides the heterotic response over parent, the mean performance of the crosses showed also be given due to consideration since, heterosis estimate results from F_1-BP and depends more or less on the mean of the parents in question, there is every possibility of getting a cross with lower mean performance but high heterotic responses. In case of parental performance it's very poor. On the contrary, there can be a cross with high mean performance being the realized value and the heterotic response being an estimate, the farmer should be given due to consideration while making selection of cross combinations especially when objective is to identify a hybrid for commercial cultivation as in present case. In this context the most desirable crosses showing high mean performance and high and significant heterosis of one or both types for grain yield per plant were Sarjoo 52 ×NDR 359, CSR 13 ×CSR 36, CSAR 839-3 ×PB-1, Usar-3 ×CSR-36, T-3 ×PB-1, NDRK 5088 ×NDR 359, Ram raj ×CSR 36, IR 79495-9-3-2-2 ×NDR 359, Sarjoo 52 ×PB-1 and CSAR 839-3 ×CSR 36 as listed in table 5.8. the cross Sarjoo 52 ×NDR 359 showed highest mean performance (43.53 q), standard heterosis over SV_1 (11.16%) and SV2 (131.99) for grain yield per plant while highest yielding parent, NDR 359 (39.16 g).

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