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Meetika Singh
Department of Genetics and Plant Breeding, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, UP, India

SK Singh
Department of Genetics and Plant Breeding, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, UP (India), India

Pooran Chand
Department of Genetics and Plant Breeding, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, UP, India

SA Kerkhi
Department of Genetics and Plant Breeding, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, UP, India

Navneet Kumar
Department of Genetics and Plant Breeding, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, UP, India

Correspondence
Meetika Singh
Department of Genetics and Plant Breeding, Sardar Vallabhbhai Patel University of Agri culture and Technology, Meerut, UP, India

Heterosis for Seed Yield and Its Components in Indian mustard (*Brassica juncea* L.)

Meetika Singh, SK Singh, Pooran Chand, SA Kerkhi and Navneet Kumar

Abstract
Brassica juncea L. is an important oilseed crop which occupies premier position in Indian agriculture. Developing high yielding genotypes has been a major breeding objective in Indian mustard. Present study was conducted at Crop Research Centre (Chirodi) of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.) during *rabi* 2014-15. to determineheterosis of 60 crosses of Indian mustard. Parents and F1 hybrids were evaluated in RCBD with 3 replications heterosis was observed amongst the best hybrids identified on the basis of SCA effects. Hybrids R5 x Kranti, Krishna x Ashirvad, Vardan x Kranti and Pusa Jagannath x Kranti exhibited highest magnitude of better parent heterosis with higher per se performance for seed yield. The high yielding crosses may be exploited for developing superior genotypes and the parents involved may be converted to well adapted cytoplasmic male sterile or restorer lines.

Keywords: Mustard, Heterosis

Introduction

Oilseed *Brassicas*, also known as rapeseed mustard, have a significant role in Indian agriculture since almost each part of the plant is consumed either by human beings or animals depending upon the crop and its growth stage. Rapeseed-mustard crops in India include toria (*Brassica campestris* L. var. toria), brown sarson (*B. campestris* L. brown sarson), yellow sarson (*B. campestris* L. var. yellow sarson), Indian mustard (*B. juncea* L. Czernj and cosson), black mustard (*B. nigra*) and taramira (*Eruca sativa/vesicara* Mill.) species. These species have been grown traditionally since about 3,500 BC along withnon-traditional species like gobhisaraon (*B.napus* L.) and karan rai (*B. carinata* A. Braun). Among them, Indian mustard is an important oilseed crop of the Indian subcontinent and contributes more than 80% of the total rapeseed-mustard production of the country. It is the second important oilseed crop at national level and contributes nearly 27% of edible oil pool of the country. There is wider yield gaps when productivity of India is compared with countries like Germany (4.3 tons ha-1), France (3.8 tons ha-1) and UK (3.4 tons ha-1). There is compelling need to increase and stabilize the productivity of Indian mustard. This can be achieved through effective utilization of germplasm resources and integration of genomic tools to impart efficiency and pace of breeding processes (Banga, 2012) [3]. Exploitation of heterosis may play a very significant role in boosting up the production and productivity of Indian mustard Heterosis breeding can be one of the most viable options for breaking the present yield barrier. Comprehensive analysis of the combining ability involved in the inheritance of quantitative traits and in the phenomenon of heterosis is necessary for evaluation of various breeding procedures (Allard, 1960) [2]. Availability of effective means of hybrid seed production led to the development of few commercial hybrids in India during last decade (Kumar *et al.*, 2012) [6]; however, them level of yield gain achieved from these hybrids is marginal.

Materials and Methods

The study was conducted at Crop Research Centre (Chirodi) of SardarVallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.) during *rabi* 2014-15. The experimental material consisted of 60 F1 hybrids of Indian mustard (*B. juncea*) involving 15 advanced breeding lines and 4 released high yielding varieties that were utilized as lines and testers, respectively. The parental genotypes were crossed in line×tester fashion to generate 60 F1 hybrids (crosses). The crosses along with their parents were planted in randomized complete block design with three replications The treatments were raised in rows of 3 m length with a distance of 30 cm between rows and 15 cm between plants, where each treatment was represented by a single row. Standard agronomic practices were followed to raise the good crop. Recommended doses of fertilizers *viz.*, 80:40:40:40 kg ha-1 of N:P:K:S, respectively, were applied and irrigated thrice including pre-sowing irrigation. Observations were recorded on randomly selected five competitive plants for twelve quantitative traits, *viz.*, seed yield/plant (g), plant height (cm), point to first branch (cm), number of primary branches, main shoot length (cm), point to first siliqua (cm), number of siliquae on main shoot, siliqua length (cm), number of seeds per siliqua, 1,000-seed weight (g), oil content (%) and days to maturity.

Results and Discussion

The variation due to parents vs. crosses was highly significant for seed yield/plant (g), plant height (cm), point to first branch (cm), number of primary branches, main shoot length (cm), point to first siliqua (cm), siliqua length (cm), number of seeds per siliqua, oil content (%) and days to maturity, suggesting the presence of heterosis for these traits in the series of crosses. Similarly, highly significant variance due to crosses revealed that the sufficient amount of genetic variability was generated in the hybrids The estimates of better parent heterosis for seed yield are presented in Table 6.Heterosis over better parent for days to 50% flowering was estimated over earlier flowering parent of the hybrids. Hence crosses with negative heterosis were considered as desirable. Manifestation of heterosis was found in both positive and negative directions. The extent of heterosis over better parent ranged from -22.64 (Vardan x Kranti) to 16.56 (Pusa Basant x Kranti). Seven hybrids showed negative and significant heterosis over better parent for early flowering in order of merit. Crosses R3 x Ashirvad, R1 x Varuna, Pusa Basant x Kranti, Pusa and Bold x Ashirvad revealed positive and significant heterosis over better parent for late flowering in order of merit. The negative heterosis over better parent estimates was considered desirable for days to maturity. The heterosis for this character ranged from -22.20 (Krishna x Ashirvad) to 15.69 (Mathura Rai x Kranti). only four hybrids namely, R5 x Kranti, R3 x Ashirvad, Krishna x Ashirvad and R8 x Ashirvad exhibited significant and negative heterosis over better parent as considered for early maturity. Five F_1 (hybrids) showed significant and positive heterosis over better parent and considered for late maturity Heterobeltiosis for the trait plant height ranged from -16.52 (Maya x Ashirvad) to 20.44 (Vardan x Kranti). nine hybrids were found to be taller for plant height over better parent. Two crosses, Maya x Ashirvad and Chamatkar x Kranti revealed negative and significant heterosis over better parent for dwarf type plant heightThe extent of heterosis over better parent for number of primary branches per plant ranged from -13.68 (Maya x Ashirvad) to 20.48 (Vardan x Vaibhav). Hybrids viz; R5 x Vaibhav, R5 x Varuna, Chamatkar x Kranti, Chamatkar x Ashirvad, R1 x Vaibhav, R4 x Varuna, Krishna x Varuna, Krishna x Kranti, Krishna x Ashirvad, Vardan x Vaibhav, Pusa Jagannath x Kranti, E38509 x Ashirvad and Mathura Rai x Varuna possessed positive significant heterosis over better parent and two crosses exhibited negative significant heterosis over better parent Heterobeltiosis for the attribute number of secondary branches per plant ranged from -14.10 (Pusa Basant x Vaibhav) to 20.85 (Pusa Jagannath x Kranti). Significant and positive heterosis over better parent was observed by hybrids namely, R5 x Varuna, Maya x Ashirvad, Chamatkar x Vaibhav, Chamatkar x Ashirvad, R4 x Kranti, Krishna x Vaibhav, Krishna x Kranti, Krishna x Ashirvad, Pusa Bold x Ashirvad, Vardan x Varuna, Vardan x Kranti, Pusa Jagannath x Kranti, Pusa Jagannath x Ashirvad, Aravali x Ashirvad, E38509 x Vaibhav, E38509 x Kranti, Mathura Rai x Vaibhav and Mathura Rai x Kranti. Only five crosses expressed negative significant heterosis over better parent.
Heterosis response over better parent for the character number of siliqua per plant ranged from -19.89 (R3 x Vaibhav) to 22.97 (Vardan x Kranti). Maximum heterosis was recorded in the cross combinations viz; R5 x Varuna, R5 x Kranti, Maya x Varuna, Chamatkar x Vaibhav, Chamatkar x Varuna, Chamatkar x Kranti, R1 x Kranti, Kranti, R4 x Kranti, Pusa Basant x Varuna, Krishna x Varuna, Krishna x Kranti, Vardan x Kranti, Pusa Jagannath x Kranti, Aravali x Varuna, Aravali x Kranti, R8 x Varuna, R8 x Kranti, E38509 x Varuna, E38509 x Kranti, Mathura Rai x Varuna and Mathura Rai x Kranti and minimum heterosis were found in five hybrids.The best heterotic response for number of seeds per siliqua was noted in hybrids *i.e.* R5 x Vaibhav, R5 x Kranti, Maya x Kranti, Chamatkar x Vaibhav, Chamatkar x Kranti, R3 x Ashirvad, R4 x Varuna, Pusa Basant x Varuna, Krishna x Vaibhav, Krishna x Ashirvad, Pusa Bold x Vaibhav, Pusa Jagannath x Kranti, Aravali x Kranti, R8 x Varuna, E38509 x Varuna and Mathura Rai x Kranti over their respective better parent. Only one parent was found negative and significant for this trait.Heterobeltiosis for biological yield per plant ranged from -16.19 (Vardan x Ashirvad) to 23.21 (Krishna x Ashirvad). The maximum significant positive heterosis over better parent was denoted by the crosses namely, R5 x Vaibhav, R5 x Kranti, R1 x Vaibhav, Pusa Basant x Ashirvad, Krishna x Ashirvad, Vardan x Kranti, Pusa Jagannath x Kranti, Aravali x Vaibhav and Mathura Rai x Varuna. Three hybrids expressed significant negative heterosis over better parent.Eleven cross combinations possessed significant positive heterosis over better parent for harvest index. The highest positive estimate was recorded in the crosses. Two F_1 emerged positive and significant heterosis over better parent. The extent of heterosis over better parent for 1000 seed weight ranged from -25.76 (R1 x Ashirvad) to 28.65 (Pusa Jagannath x Vaibhav). The cross combinations viz; R5 x Kranti, Maya x Varuna, Maya x Kranti, Chamatkar x Varuna, R3 x Ashirvad, R1 x Varuna, R1 x Kranti, R4 x Varuna, R4 x Kranti, Pusa Basant x Ashirvad, Krishna x Kranti, Krishna x Ashirvad, Vardan x Kranti, Pusa Jagannath x Vaibhav, Pusa Jagannath x Kranti and Aravali x Ashirvad showed significant and positive heterosis over better parent whereas two hybrids had significant negative heterosis over better parent for 1000 seed weight. Out of sixty cross combinations, only nine were found significant and positive heterosis over better parent for high oil content while three crosses revealed significant and negative heterosis over better parent for low oil content.Maximum magnitude of heterosis and *per se* performance was exhibited highly significant and positive desirable heterosis over mid and better parent manifested in cross combinations *i.e.* R5 x Kranti, R3 x Vaibhav, Pusa Basant x Kranti, Pusa Basant xAshirvad, Krishna x Ashirvad, Vardan x Kranti, Vardan x Ashirvad, Pusa Jagannath x Kranti, R8 x Vaibhav, E38509 x Vaibhav and Mathura Rai x Varuna. On the basis of overall study of heterosis the best four crosses namely, R5 x Kranti for days to 50% flowering, days to maturity, plant height, number of siliqua per plant, number of seeds per siliqua, biological yield per plant, harvest index, oil content and seed yield per plant; Krishna x Ashirvad for days to maturity, plant height, number of primary branches per plant, number of secondary branches per plant, number of seeds per siliqua, biological yield per plant, harvest index, 1000 seed weight, oil content and seed yield per plant; Vardan x Kranti for days to 50% flowering, plant height, number of secondary branches per plant, number of siliqua per plant, harvest index, 1000 seed weight, oil content

and seed yield per plant; Vardan x Kranti for days to 50% flowering, plant height, number of secondary branches per plant, number of siliqua per plant, harvest index, 1000 seed weight, oil content and seed yield per plant and Pusa Jagannath x Kranti for days to maturity, number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, number of seeds per siliqua, biological yield per plant, harvest index, 1000 seed weight, oil content and seed yield per plant had manifested the heterosis for yield and more than eight desirable traits. A wide range of positive heterosis for number of primary branches and secondary branches per plant, plant height, and number of seeds per siliqua was reported by Rawat (1975) [8]. Similarly, significant positive heterosis for seed yield and component traits in Indian mustard were reported by many workers (Ram *et al.*, 1976; Banga and Labana, 1984; Hirve and Tiwari, 1992; Verma, 2000; Aher *et al*., 2009; Verma *et al.*, 2011) [7, 4, 10, 5, 18, 1, 11] using different sets of materials. It clearly demonstrates the scope of improving the productivity of Indian mustard through genetic manipulations. Keeping these points in view, the present investigation was undertaken to determine better parent heterosis of different cross combinations in *B. juncea*.

All the hybrids may prove to be the best sources for tracking down the better recombinants for yield and important contributing traits. The high yielding cross combination can further be exploited for their commercial utilization and the parents involved in developing heterotic hybrids in the present study shall be converted to well adapted cytoplasmic male sterile or restorer lines. These results are similar in agreement with earlier reported by Verma *et al*. (1989) [12], Kumar *et al*. (1990) [14], Rai (1993) [15], Rai and Singh (1994) [16], Agarwal and Badwal (1998) [17], Chauhan *et al.* (2000) [9], Kumar *et al*. (2002) [13], Singh *et al*. (2003) [21], Singh *et al.* (2007) [20], Singh *et al.* (2009) [19], Gupta *et al.* (2010) [22], Verma *et al.* (2011) [11], Saeed *et al.* (2013) [23], Tomar *et al.* (2015).

Conclusion

The best heterotic response for yield and other yield contributing traits exhibited (more than 17%) a reasonable and significantly increase over both better and mid parents. These cross combinations in order of merit were R5 x Kranti, Krishna x Ashirvad, Vardan x Kranti and Pusa Jagannath x Kranti suggested that these individual hybrids may be used in heterosis breeding programme for improvement in seed yield. On the basis of computed genetic parameters simple selection or pedigree method of breeding with inter matting in early segregating generation has been suggested for the exploitation of additive genetic variance for the simultaneous exploitation of both additive and non-additive gene action and breeding method such as biparental mating was suggested.

Table 1: Estimates of heterosis over better parent and mid parent for twelve characters in mustard (*Brassica juncea*)

Sl. No.	Genotypes	Days to 50% flowering		Days to maturity		Plant height (cm)		Number of primary branchesper plant		Number of secondary branches per plant		Number of siliqua per plant	
		BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP
1	R5 × Vaibhav	-2.01	-2.62	1.14	1.74	-3.31	-0.78	19.05**	19.76**	0.65	0.76	-0.68	-0.68
2	R5 × Varuna	-0.67	-0.59	-2.27	-1.27	-0.04	-2.67	14.29**	14.97**	12.88**	12.64**	17.46**	16.51**
3	R5 × Kranti	-18.79**	-17.64**	-19.17**	-18.96**	16.51**	15.32**	-1.14	-1.34	2.12	3.33	13.56**	12.57**
4	R5 ×Ashirvad	1.48	1.96	1.89	1.00	1.52	1.16	-1.84	-1.47	0.40	0.60	7.24	6.58
5	Maya × Vaibhav	1.77	1.66	1.10	1.76	-1.02	-1.49	-11.63**	-11.60**	-14.08**	-13.08**	-0.38	-0.19
6	Maya × Varuna	-1.41	-1.97	-2.29	-1.78	1.46	1.78	2.33	2.09	-1.63	-1.13	12.79**	11.23**
7	Maya × Kranti	-6.17**	-5.64**	1.39	3.64	10.51**	10.21**	-4.20	-4.35	3.45	4.51	2.64	3.18
8	Maya ×Ashirvad	-0.14	-1.30	-1.54	-1.85	-16.52**	-15.40**	-13.68**	-13.39**	16.05**	14.40**	-12.94**	-12.43**
9	Chamatkar × Vaibhav	-1.34	-1.65	1.50	1.05	-3.62	-2.94	1.96	1.11	12.99**	11.37**	14.97**	13.45*
10	Chamatkar × Varuna	-1.41	-1.34	-2.40	-2.03	0.33	0.89	3.88	3.78	-1.65	-1.21	13.42*	16.33*
11	Chamatkar × Kranti	-0.86	-0.96	10.25**	9.46**	-11.74**	-11.60**	17.65**	16.34**	1.70	1.13	17.61**	16.59**
12	Chamatkar ×Ashirvad	-1.48	-1.31	2.35	2.76	4.62	6.39	13.73**	10.36**	14.44**	14.66**	-0.40	-0.48
13	R3× Vaibhav	-9.95**	-9.36**	3.09	3.29	-3.62	-2.49	-1.38	-1.40	0.65	0.53	-19.89**	-18.46**
14	R3× Varuna	-0.74	-0.37	0.05	0.25	-2.11	-3.15	-3.38	-2.79	-4.94	-4.94	18.97**	15.84**
15	R3× Kranti	-0.68	-0.07	0.25	1.27	1.13	2.55	-2.16	-2.22	0.24	0.21	0.79	0.63
16	R3×Ashirvad	13.94**	12.84**	-16.85**	-15.33**	1.29	2.51	-5.21	-4.71	-13.63**	-12.65**	-16.06**	-15.66**
17	R1× Vaibhav	-1.74	-1.19	1.25	1.93	-4.13	-3.81	18.43**	11.11**	2.55	3.10	-8.92	-5.52
18	R1× Varuna	14.27**	14.09**	0.90	0.72	2.52	2.70	4.23	4.88	-0.82	0.84	7.38	12.22*
19	R1× Kranti	-0.91	0.68	1.46	0.07	2.34	2.87	-0.20	-0.57	-0.42	-0.21	11.49**	11.53**
20	R1×Ashirvad	-0.27	0.46	2.57	2.05	2.92	2.71	1.39	1.15	-1.61	-1.04	-5.33	-4.09
21	R4× Vaibhav	2.15	2.27	-2.68	-2.57	-1.97	-1.23	-3.19	-2.83	0.22	0.76	-1.59	-1.40
22	R4× Varuna	-1.36	-1.19	1.13	1.85	1.14	1.68	17.45**	14.12**	0.41	3.17	13.35**	11.14**
23	R4× Kranti	-1.71	-0.74	1.73	1.27	2.81	1.81	-1.35	-1.63	13.39**	12.15**	19.22**	15.43**
24	R4×Ashirvad	-1.48	-0.27	0.57	0.33	3.27	3.70	-1.58	-1.11	0.82	0.84	0.42	1.17
25	Pusa Basant × Vaibhav	-14.49**	-13.78**	1.90	1.03	-0.12	-0.96	-1.08	1.55	-14.10**	-13.78**	-0.68	-1.27
26	Pusa Basant × Varun	0.74	0.25	3.26	3.57	1.10	2.68	-3.60	-3.41	-0.82	-0.62	13.08**	12.00**
27	Pusa Basant × Kranti	16.56**	14.88**	1.30	1.43	4.73	3.71	-1.08	-1.57	2.05	3.75	0.43	0.23
28	Pusa Basant ×Ashirvad	0.54	0.49	2.71	3.04	2.52	0.08	-0.32	-0.32	4.44	-3.66	4.73	6.27
29	Krishna × Vaibhav	1.88	2.67	2.90	2.94	-3.47	-2.42	-1.70	-1.27	19.66**	18.19**	-6.16	-6.08
30	Krishna × Varuna	-2.36	-1.93	3.48	2.57	0.20	0.80	16.75**	15.20**	-3.70	-2.63	18.43**	19.44**
31	Krishna × Kranti	-0.50	-0.41	-1.16	-2.94	1.93	1.12	17.70**	15.06**	12.97**	11.24**	21.15**	21.19**
32	Krishna ×Ashirvad	0.54	0.99	-	-	10.48**	10.11**	14.83**	10.78**	14.84**	12.39**	-0.79	-0.05

				22.20**	18.57**								
33	Pusa Bold × Vaibhav	-1.88	-2.95	1.04	0.47	-1.02	-1.43	0.84	1.85	-0.41	1.99	-12.40**	-11.94**
34	Pusa Bold × Varuna	-1.59	-1.16	3.96	3.19	4.71	4.72	1.66	1.72	-12.46**	-12.26**	1.58	1.10
35	Pusa Bold × Kranti	-1.59	-1.11	2.66	2.58	4.55	4.15	0.16	0.28	-1.64	-1.78	0.96	0.50
36	Pusa Bold ×Ashirvad	13.27**	12.66**	-3.86	4.69	3.06	3.25	-1.37	-0.28	13.63**	12.34**	4.56	4.87
37	Vardan × Vaibhav	-0.65	-0.77	3.40	3.55	-0.95	-1.21	20.48**	25.39**	5.33	7.76	-16.95**	-12.04**
38	Vardan × Varuna	1.55	1.11	0.10	0.55	1.10	1.76	1.87	2.63	16.51**	14.53**	1.04	2.06
39	Vardan × Kranti	-22.64**	-22.90**	-1.15	-0.88	20.44**	20.02**	-2.04	1.03	13.30**	12.98**	22.97**	21.94**
40	Vardan ×Ashirvad	-2.02	-0.41	-1.40	-0.93	16.96**	15.21**	-0.53	-0.88	-6.51	-5.48	-4.13	-3.31
41	Pusa Jagannath× Vaibhav	-10.11**	-9.75**	-1.25	-1.17	-2.01	-2.11	0.99	1.05	7.95	8.08	-9.93	-5.24
42	Pusa Jagannath× Varuna	1.40	0.77	1.50	2.01	-0.33	0.15	-3.78	-4.05	0.24	0.49	0.24	0.23
43	Pusa Jagannath× Kranti	4.20	3.57	15.24**	15.08**	0.26	0.09	20.12**	18.13**	20.85**	19.86**	19.81**	17.40**
44	Pusa Jaganath ×Ashirvad	1.57	1.03	1.49	1.05	1.82	1.36	0.53	0.11	14.40**	15.78**	-1.89	-1.74
45	Aravali× Vaibhav	1.97	1.28	14.59**	13.24**	0.39	9.70	-1.16	1.47	2.80	2.91	-3.36	-3.69
46	Aravali× Varuna	-2.63	-2.13	0.54	1.60	1.79	0.79**	3.19	3.40	-12.06**	-11.25**	12.38**	13.70**
47	Aravali× Kranti	-3.38	-3.67	-1.63	-0.77	1.12	1.97	-1.25	1.47	0.85	0.72	19.85**	14.08**
48	Aravali×Ashirvad	-0.48	-0.98	2.52	3.62	4.32	3.89	-0.31	0.38	12.82**	10.49**	-2.33	-1.27
49	R8× Vaibhav	-2.83	-2.67	15.32**	14.56**	1.14	1.04	0.48	2.70	0.43	0.52	-1.63	-1.71
50	R8× Varuna	-2.57	-1.62	1.88	1.56	1.06	5.42	0.84	1.88	-0.22	-0.41	14.66**	19.06*
51	R8× Kranti	2.33	1.15	1.15	1.62	19.56**	18.66**	-3.27	-4.49	-2.83	-1.62	13.95**	17.31**
52	R8×Ashirvad	1.67	1.77	-11.10**	-10.27**	10.97**	10.53**	1.32	1.71	-3.63	-3.43	0.37	0.44
53	E38509× Vaibhav	3.50	3.36	-2.00	3.15	0.88	0.97	2.62	3.23	14.40**	14.93**	-1.83	-1.68
54	E38509× Varuna	1.15	3.20	0.44	0.99	-0.33	-0.04	3.74	1.08	-0.20	-0.61	19.28**	15.27**
55	E38509× Kranti	-2.91	-2.78	2.20	1.20	17.69**	15.43**	-1.56	-1.44	15.20**	14.23**	1.46	1.26
56	E38509×Ashirvad	1.54	1.51	2.15	2.91	5.38	3.31	15.53**	12.12**	-5.60	-5.22	-1.99	-1.66
57	Mathura Rai × Vaibhav	-16.37**	-15.02**	-1.75	-2.71	-0.83	0.40	0.52	0.18	16.94**	15.45**	-3.11	-4.68
58	Mathura Rai × Varuna	1.15	1.14	2.44	2.28	1.22	1.80	14.99**	14.97**	2.06	3.48	15.11**	11.04**
59	Mathura Rai × Kranti	-1.12	-1.99	15.69**	15.93**	3.91	3.71	-1.27	-1.59	16.78**	13.26**	17.43**	15.55**
60	Mathura Rai ×Ashirvad	-1.84	-1.79	2.20	2.83	15.99**	15.14**	3.68	2.38	-0.81	-0.71	-5.31	-5.14

Sl. No.	Genotype	Number of seeds per siliqua		Biological yield per plant (g)		Harvest inde×(%)		1000 seed weight (g)		Oil content (%)		Seed yield per plant (g)	
		BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP
1	R5 × Vaibhav	14.35**	13.09**	13.55**	12.18**	1.58	2.00	-1.96	-1.44	-1.57	-1.32	-11.29**	-10.94**
2	R5 × Varuna	3.07	4.06	-3.36	-2.34	-0.26	-0.22	-2.32	1.53	-3.67	-3.42	3.34	1.51
3	R5 × Kranti	16.26**	16.26**	21.21**	20.44**	14.76**	13.48**	21.00**	20.92**	-4.55	-3.87	26.32**	22.87**
4	R5 ×Ashirvad	1.99	1.49	-0.90	-0.62	-17.10**	-16.41*	-25.76**	-25.26**	-3.62	-2.46	-3.37	-3.82
5	Maya × Vaibhav	-20.11**	-21.43**	-3.79	-2.89	-0.49	-0.82	-3.98	-4.53	-5.19	-4.45	-1.32	-1.06
6	Maya × Varuna	5.56	6.97	-4.00	-2.68	2.36	2.88	17.07**	16.52**	-5.36	-4.62	-1.48	-0.90
7	Maya × Kranti	14.44**	16.38**	1.62	1.24	1.27	1.72	10.33**	11.62**	-5.54	-4.38	-0.14	-0.07
8	Maya ×Ashirvad	1.52	1.39	0.90	0.95	18.15**	11.30**	1.40	1.67	-4.67	-4.34	-0.40	-2.47
9	Chamatkar × Vaibhav	16.76**	15.66**	-3.23	-1.92	1.87	1.04	2.82	1.25	-4.17	-3.58	8.86	7.97
10	Chamatkar × Varuna	3.66	3.21	-4.00	-2.28	-1.94	-2.32	22.60**	22.14**	-15.04**	-14.45**	-18.44**	-14.02**
11	Chamatkar × Kranti	19.65**	20.03**	-14.97**	-12.57**	-2.42	-1.90	2.26	1.46	-5.90	-4.91	-10.41**	-10.18**
12	Chamatkar ×Ashirvad	1.37	1.76	-1.48	-1.03	0.11	0.45	3.20	2.05	13.65**	13.48**	-0.91	-0.71
13	R3× Vaibhav	6.09	3.70	-0.81	-0.08	-1.23	-2.21	1.71	3.59	-2.81	-2.47	21.17**	20.80**
14	R3× Varuna	2.40	2.50	-4.24	-3.12	-4.59	-3.44	1.06	2.09	-1.05	-0.71	-1.51	-1.44
15	R3× Kranti	2.75	2.75	2.98	5.25	1.66	1.42	3.96	2.18	-4.78	-4.69	2.34	2.63
16	R3×Ashirvad	16.88**	14.21**	1.44	1.61	4.98	5.13	18.49**	12.86**	-2.96	-2.20	0.12	1.57
17	R1× Vaibhav	2.07	3.46	14.18**	14.09**	-3.99	-3.77	2.42	3.65	0.35	0.71	0.96	0.39
18	R1× Varuna	2.57	2.86	2.40	2.65	0.32	-5.62	17.88**	16.86**	-5.10	-4.76	4.39	3.89
19	R1× Kranti	1.05	2.49	1.46	2.84	-12.42**	-11.42**	18.88**	17.79**	-2.12	-2.04	0.73	1.06
20	R1×Ashirvad	0.75	0.71	1.37	2.48	22.82**	10.87**	-2.27	-2.40	-3.66	-2.90	-1.15	-1.38
21	R4× Vaibhav	2.61	3.31	1.35	1.09	-1.47	-1.33	3.13	2.22	-2.29	-0.63	-2.20	-1.63
22	R4× Varuna	14.21**	14.86**	-5.28	-4.21	18.87**	17.71**	16.66**	16.36**	-0.70	0.98	-2.15	-0.89
23	R4× Kranti	0.23	1.74	2.51	2.81	-4.82	-5.31	16.06**	15.68**	-1.06	-0.18	-3.86	-3.14
24	R4×Ashirvad	1.67	1.56	1.80	2.01	-1.74	1.92	3.80	3.02	-6.79	-4.80	0.93	0.83
25	Pusa Basant × Vaibhav	2.35	3.33	-2.50	-0.94	-0.32	1.22	1.00	3.42	-2.46	-2.20	0.99	1.00
26	Pusa Basant × Varuna	27.00**	26.07**	-2.96	-0.98	-0.61	-0.39	1.12	2.45	-2.64	-2.38	-3.26	-3.54
27	Pusa Basant × Kranti	1.97	2.67	3.92	2.11	-3.86	-2.17	-2.61	-2.90	-0.88	-0.71	17.03**	10.86**
28	Pusa Basant ×Aahirvad	1.36	2.68	21.25**	11.99**	-1.29	-1.50	12.69**	11.60**	-2.96	-2.28	16.40**	15.55**
29	Krishna × Vaibhav	16.00**	15.72**	-4.28	-3.07	18.24**	17.08**	3.84	1.84	-1.92	-1.49	-1.17	-1.54
30	Krishna × Varuna	2.96	3.09	-1.72	-3.13	3.92	2.21	0.41	1.44	-0.70	-0.26	4.03	3.63
31	Krishna × Kranti	1.58	1.43	2.19	1.99	1.97	1.34	14.05**	14.00**	-15.40**	-14.57**	1.20	1.50
32	Krishna ×Ashirvad	20.97**	20.09**	23.21**	22.59**	20.37**	19.70**	11.20**	10.24**	23.31**	22.31**	27.46**	24.86**
33	Pusa Bold × Vaibhav	19.24**	13.56**	0.97	0.05	-0.10	-0.90	2.53	1.96	-0.35	0.18	-4.67	-4.78
34	Pusa Bold × Varuna	3.07	4.46	-1.84	-0.41	-2.28	-1.22	1.80	1.68	0.53	1.06	0.27	0.74
35	Pusa Bold × Kranti	3.67	3.07	-0.86	1.61	-0.33	-1.90	0.40	1.20	-14.61**	-14.53**	-2.32	-2.52

36	Pusa Bold ×Ashirvad	1.37	2.67	-15.94**	-15.84**	2.21	3.84	2.60	1.60	15.05**	14.13**	-4.66	-4.66
37	Vardan × Vaibhav	2.54	2.54	1.61	2.69	3.65	2.59	- 24.96**	- 24.40**	17.38**	16.64**	-3.10	-2.81
38	Vardan × Varuna	3.23	3.23	-1.52	-0.04	-1.06	-1.79	-0.36	0.55	-4.92	-4.16	-1.79	-0.16
39	Vardan × Kranti	0.46	0.75	22.04**	21.62**	18.06**	17.17*	11.08**	10.90**	14.43**	14.09**	23.88**	22.90**
40	Vardan ×Ashirvad	0.89	1.89	-16.19**	-16.05**	21.09**	19.15**	-0.58	-0.85	19.93**	18.82**	15.93**	14.77**
41	Pusa Jagannath× Vaibha	2.37	2.37	-3.14	-1.79	1.65	0.44	32.65**	27.42**	0.53	1.60	-2.22	-2.24
42	Pusa Jagannath× Varuna	1.25	1.25	0.55	1.51	-0.59	-0.08	-0.01	-0.66	-2.99	-1.95	-1.87	_1.02
43	Pusa Jagannath× Kranti	23.88**	23.67**	23.17**	22.26**	21.96**	20.27**	21.43**	21.12**	22.66**	21.05**	18.53**	17.54**
44	Pusa Jagannath×Ashirvad	3.18	3.18	-0.79	-0.49	0.27	12.26	-3.94	-1.83	-4.01	-2.56	5.33	1.94
45	Aravali× Vaibhav	2.09	2.09	12.42**	11.15**	3.31	1.77	3.84	1.36	1.05	1.32	1.49	1.94
46	Aravali× Varuna	1.61	1.61	-3.84	-3.30	-4.22	-2.09	3.23	1.28	-3.67	-3.42	-1.88	-1.48
47	Aravali× Kranti	15.52**	14.54**	2.12	3.74	2.75	1.02	2.68	1.02	-4.72	-4.05	0.54	1.66
48	Aravali×Ashirvad	1.36	1.35	4.45	5.26	-1.18	-1.54	14.60**	14.06**	-1.74	-1.57	1.73	2.62
49	R8× Vaibhav	0.33	0.36	-4.04	-3.92	1.64	3.73	-3.27	-0.59	1.05	1.41	16.35**	15.22**
50	R8× Varuna	36.36**	35.88**	3.08	2.68	2.65	-4.16	4.51	3.59	21.23**	19.03**	1.61	1.46
51	R8× Kranti	1.48	1.74	-3.84	-2.31	-4.25	-1.94	3.26	1.24	-2.12	-2.04	1.70	2.21
52	R8×Ashirvad	1.74	2.91	0.73	0.04	2.80	3.69	2.26	5.43	-0.45	-0.71	4.53	4.28
53	E38509× Vaibhav	2.91	3.07	2.42	3.38	22.76**	19.24**	-5.88	-4.60	-1.93	-1.84	22.30**	18.87**
54	E38509× Varuna	35.75**	38.60**	0.32	1.70	-2.25	-4.45	-1.19	-1.29	-1.58	-1.49	-1.99	-1.11
55	E38509× Kranti	2.40	2.58	-2.74	-0.40	-2.33	-1.11	-1.65	-0.57	-0.70	-0.18	-4.38	-2.79
56	E38509×Ashirvad	2.58	1.22	-0.58	-0.53	-2.10	-1.35	1.04	2.35	23.00**	22.73**	-4.26	-4.93
57	Mathura Rai × Vaibhav	1.22	2.57	-4.18	-3.03	17.88**	16.12**	2.40	1.58	2.11	3.29	-2.47	-2.86
58	Mathura Rai × Varuna	2.57	3.43	14.57**	13.36**	-1.13	-1.05	0.76	0.50	1.41	2.58	14.96**	13.94**
59	Mathura Rai × Kranti	37.43**	39.05**	-0.63	-0.35	-2.01	-1.74	4.15	3.88	-2.31	-1.61	0.39	4.22
60	Mathura Rai ×Ashirvad	0.22	1.15	-4.81	-2.82	-2.73	-3.06	3.77	2.80	-2.61	-1.06	-2.89	-2.18

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