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Heterosis for seed yield and its components in Indian mustard (*Brassica juncea* L. Czern & Coss.)

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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 Castor-Mustard research station, S. D. Agricultural University, Sardarkrushinagar during *Rabi* 2016-17 to determine heterosis of 45 crosses of Indian mustard. Parents and F_1 hybrids were evaluated in RBD with three replications. The heterosis was observed amongst the best crosses identified on the basis of SCA effects. Hybrids RS 1134 x GM 2, RH 119 x GM 2,RS 1 x GM 2, RH 119 x Urvashi and Urvashi x GM 2 exhibited highest magnitude of heterosis with higher per se performance for seed yield, respectively. 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.

Key words: Heterosis, Seed yield and Indian mustard

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. Czernand Coss), black mustard (*B. nigra*) and taramira (*Eruca sativa/vesicara* Mill.) species. These species have been grown traditionally since about 3,500 BC along with non-traditional species like gobhi saraon (*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 after soyabean at national level and contributes nearly 27% of edible oil pool of the country. There is wider yield gap when productivity of India is compared with countries like Germany (4.3 tons/ha), France (3.8 tons/ha) and UK (3.4 ton/ha). 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). Exploitation of heterosis may play a very significant role in boosting up the production and productivity of Indian mustard and 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). Availability

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of effective means of hybrid seed production led to the development of few commercial hybrids in India during last decade (Kumar *et al*., 2012); however, the level of yield gain achieved from these hybrids is marginal.

MATERIALS AND METHODS

The study was conducted at Castor-Mustard Research Station, S. D. Agricultural University, Sardarkrushinagar (Gujarat) during *Rabi* 2016-17. The experimental material consisted of 45 F_1's hybrids of Indian mustard (*B. juncea*) involving 10 parents and one check GDM 4. The ten parental genotypes were crossed in half diallel fashion to generate 45 F_1's hybrids (crosses). The crosses along with their parents were planted in randomized block design with three replications. The treatments were raised in rows of 3 m length with a distance of 45 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. Observations were recorded on randomly selected five competitive plants for ten quantitative traits, *viz*., days to flowering, days to maturity, plant height (cm), length of main branch (cm), branches per plant, number of siliquae on main branch, number siliquae per plant, length of siliquae (cm), seeds per siliquae and seed yield per plant (g).

RESULTS AND DISCUSSION

The variation due to parents *vs.* crosses was highly significant for all the characters under study except plant height (cm), number of siliquae on main branch and length of siliquae 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 mid parent, better parent and standard heterosis for all the characters under study are presented in Table 2.Heterosis for days to 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 standard check ranged from -13.95 (Kranti x P.Vijay) to 6.98 (RH 1134 x Navgold) and for better parents ranged from -15.60 (RH 1134 x Kranti) to -2.13 (RH 1134 x Navgold) for days to flowering. The negative heterosis over better parent estimates was considered desirable for days to maturity. The heterosis for this character ranged from -6.06 (RH 119 x Kranti) to 2.20 (RH 1134 x GM 2) over standard check and for better parent heterosis ranged from -5.74 (Kranti x GM 2) to 1.69 (Urvashi x Kranti). From these consideration the cross Kranti x P.Vijay and RH 119 x Kranti were found earliest. There are twenty five crosses exhibited significant and negative heterosis over standard check as considered for early maturity. Standard heterosis for the plant height ranged from -11.66 (P.Vijay x Navgold) to 22.70 (RH 1134 x RS 1). Only one cross namely, P.Vijay x Navgold and P.Vijay xGM 2 revealed negative and significant heterosis over mid parent, better parent and standard check for dwarf type plant. The extent of heterosis over standard check for length of main branch ranged from -4.71 (P.Vijay x GM 2) to 15.88 (RH 119 x Urvashi). Eighteen crosses exhibited significant and positive heterosis over standard check as considered for length of main branch and none of the crosses exhibited negative significant heterosis over standard check for length of main branch. While for heterosis over better parent only three crosses exhibited significant and positive heterosis and range of this character from -13.16 (Navgold x RS 1) to 19.51 (Kranti x Navgold). The attribute branches per plant ranged from -14.50 (RH 1134 x RS 1) to 187.50 (RH 119 x GM 2) and the nineteen hybrids exhibited significant and positive heterosis over standard check. While none of the crosses expressed negative significant heterosis over standard check. For over better parent heterosis nine crosses expressed negative significant heterosis and sixteen crosses expressed positive and significant heterosis.

Heterosis response over better parent for number of siliquae on main branch ranged from -40.74 (Urvashi x Navgold) to 16.92 (Kranti x Navgold) and over standard check ranged from -35.85 (Urvashi x Navgold) to 26.13 (Urvashi x P.Vijay). Positive and significant standard heterosis for number of siliquae on main branch was recorded in the twenty nine crosses combinations and only one cross showed significant negative heterosis. While five crosses expressed significant and negative heterosis and only three crosses expressed significant and positive heterosis over better parents for number of siliquae on main branch. The best heterotic response for number of siliquae per plant was noted in hybrids (RH 119 x Urvashi, RH 119 x Kranti, RH 119 x Navgold, RH 119 x GM 1, RH 119 x GM 2, Urvashi x P.Vijay, Urvashi x Navgold, Urvashi x GM 2, RH 1134 x P.Vijay, Kranti x P.Vijay, Kranti x Navgold, Kranti x GM 2, P.Vijay x Navgold, P.Vijay x GM 1 and RH 749 x Navgold) respectively, over their respective standard check. While, none of the parent was found negative and significant for this trait over MP, BP and SH. Standard heterosis for length of siliquae ranged from -1.22 (RS 1 x GM 1) to 41.87 (Navgold x RS 1). The sixteen crosses exhibited significant positive heterosis over standard check GDM 4 for the character length of siliquae. While none of the parent was found negative and significant for this trait over better parent and standard check. Out of forty five cross combinations, only fifteen crosses were found significant and positive heterosis over standard check (GDM 4) for number of seeds per siliquae. While two crosses revealed significant and negative heterosis over standard check (GDM 4) for number of seeds per siliquae.For the traits seed yield per plant, standard heterosis ranged from 9.37 (Navgold x RS 1) to 181.25 (RH 1134 x GM 2) and better parent ranged from -51.78 (P.Vijay x GM 1)to 147.71 (RH 1134 x GM 2) and out of forty five cross combination there was thirty nine crosses show significant and positive standard heterosis over check GDM 4. While none of the crosses show significant negative standard heterosis for seed yield per plant. On the basis of overall study of heterosis the best crosses were Kranti x P. Vijay for days to flowering, RH 119 x Kranti for days to maturity, P. Vijay x Navgold for plant height, RH 119 x Urvashi for length of main branch, RH 119 x GM 2 for number of branches per plant and number of siliquae per plant, Urvashi x P. Vijay for number of siliquae on main branch,Navgold x RS 1 for length of siliquae, RH 119 x RH 1134 for seeds per siliquae and RH 1134 x GM 2 for seed yield per plant. A wide range of positive heterosis for length of siliquae and seed yield per plant was reported by Rawat (1975). Similarly, significant positive heterosis for seed yield and component traits in Indian mustard were reported by many workers (Banga and Labana, 1984; Hirve and Tiwari, 1992; Aher *et al*., 2009; Verma *et al*., 2011) using different sets of materials. 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 Chauhan *et al*., (2000), Kumar *et al*., (2002), Singh *et al*., (2003), Singh *et al*., (2007), Singh *et al*., (2009), Gupta *et al*., (2010), Verma *et al*., (2011), Saeed *et al*., (2013). It clearly demonstrates the scope of improving the productivity of Indian mustard through genetic manipulations.

CONCLUSION

The best heterotic response for yield and other yield contributing traits exhibited a reasonable and significantly increase over mid, better and standard parents. These cross combinations in order of merit were RS 1134 x GM 2, RH 119 x GM 2, RS 1 x GM 2, RH 119 x Urvashi and Urvashi x GM 2 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 mating 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.

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Table 1 Analysis of variance (mean squares) for various characters in Indian mustard

Source of variation	d.f.	Days to flowering	Days to maturity	Plant height (cm)	Length of main branch (cm)	Branches per plant
Replications	2	0.17	143.77**	483.75*	8.41	203.01**
Genotypes (G)	54	14.71**	17.71**	338.79**	78.51**	158.03**
Parents (P)	9	18.8**	10.23*	480.30**	122.37**	252.69**
Hybrids (H)	44	11.69**	18.16**	316.96**	64.38**	118.33**
Parents vs. Hybrids	1	110.94**	65.19**	26.21	305.16**	1052.93**
Error	108	1.75	3.99	139.18	23.73	16.71
Total :-	164	5.99	10.21	209.11	41.58	65.50

Source of variation	d.f.	Number of silique on main branch	Number silique per plant	Length of silique	Seeds per silique	Yield per plant (g)
Replications	2	74.50**	53165.09**	0.69	4.32**	370.72**
Genotypes (G)	54	46.51**	11671.22**	1.47**	1.85**	467.96**
Parents (P)	9	56.35**	3190.92	0.12	1.39**	779.07**
Hybrids (H)	44	44.32**	6673.81**	1.73815**	1.84941**	295.74**
Parents vs. Hybrids	1	54.35	307879.8**	1.86	5.95**	5245.39**
Error	108	13.33	3042.91	0.51	0.37	59.53
Total :-	164	25.00	6495.19	0.83	0.91	197.81

Table 2: Estimates of per cent heterosis over mid parent (MP), better parent (BP) and check variety (GDM 4) for the characters under study

Sr. No.	Name of Cross	Days to lowering			Days to maturity		
		MP	BP	SH	MP	BP	SH
1	RH 119 x Urvashi	-10.87 **	-10.87 **	-4.65*	-2.11	-2.52	-4.13**
2	RH 119 x RH 1134	-5.38 **	-6.38 **	2.33	-2.1	-2.24	-3.86*
3	RH 119 x Kranti	-7.39 **	-13.77 **	-7.75**	-3.67 **	-4.48 **	-6.06**
4	RH 119 x P.Vijay	2.33	-4.35	2.33	-2.09	-2.5	-3.31*
5	RH 119 x RH 749	-2.22	-4.35	2.33	-2.26	-3.08 *	-4.68**
6	RH 119 x Navgold	-7.35 **	-8.70 **	-2.33	-2.77 *	-3.84 **	-3.31*
7	RH 119 x RS 1	-1.5	-5.07 *	1.55	1.39	0.55	0.55
8	RH 119 x GM 1	-9.09 **	-13.04 **	-6.98**	0.14	-0.28	-1.93
9	RH 119 x GM 2	-5.19 *	-7.25 **	-0.78	-0.69	-1.91	-1.10
10	Urvashi x RH 1134	-3.23	-4.26	4.65	-1.13	-1.4	-3.31*
11	Urvashi x Kranti	-5.84 **	-12.32 **	-6.20**	2.13	1.69	-0.83
12	Urvashi x P.Vijay	-2.33	-8.70 **	-2.33	2.52 *	1.67	0.83
13	Urvashi x RH 749	-5.19 *	-7.25 **	-0.78	0.71	0.28	-2.20
14	Urvashi x Navgold	-7.35 **	-8.70 **	-2.33	-2.36	-3.84 **	-3.31*
15	Urvashi x RS 1	-6.02 **	-9.42 **	-3.10	-3.77 **	-4.96 **	-4.96**
16	Urvashi x GM 1	-4.55 *	-8.70 **	-2.33	-3.39 **	-3.39 *	-5.79**
17	Urvashi x GM 2	-10.37 **	-12.32 **	-6.20**	-2.78 *	-4.37 **	-3.58*
18	RH 1134 x Kranti	-8.46 **	-15.60 **	-7.75**	-3.25 **	-3.93 **	-5.79**
19	RH 1134 x P.Vijay	-3.45	-10.64 **	-2.33	-1.96	-2.5	-3.31*
20	RH 1134 x RH 749	-7.69 **	-10.64 **	-2.33	0.42	-0.28	-2.20
21	RH 1134 x Navgold	0.36	-2.13	6.98*	2.36	1.1	1.65
22	RH 1134 x RS 1	1.86	-2.84	6.20*	0.14	-0.83	-0.83
23	RH 1134 x GM 1	-4.87 *	-9.93 **	-1.55	1.41	1.12	-0.83
24	RH 1134 x GM 2	-2.56	-5.67 *	3.10	2.77 *	1.37	2.20
25	Kranti x P.Vijay	-7.11 **	-7.50 **	-13.95**	-1.27	-2.5	-3.31*
26	Kranti x RH 749	0.4	-4.55	-2.33	0	0	-3.31*
27	Kranti x Navgold	-2.77	-8.21 **	-4.65*	-1.96	-3.84 **	-3.31*
28	Kranti x RS 1	-3.64	-7.03 **	-7.75**	-3.64 **	-5.23 **	-5.23**
29	Kranti x GM 1	-5.31 *	-7.94 **	-10.08**	-2.98 *	-3.39 *	-5.79**

30	Kranti x GM 2	-8.37 **	-12.88 **	-10.85**	-3.77 **	-5.74 **	-4.96**
31	P.Vijay x RH 749	-4.76 *	-9.09 **	-6.98**	-0.42	-1.67	-2.48
32	P.Vijay x Navgold	-5.51 *	-10.45 **	-6.98**	-4.83 **	-5.48 **	-4.96**
33	P.Vijay x RS 1	-4.03	-7.03 **	-7.75**	-2.90 *	-3.31 *	-3.31**
34	P.Vijay x GM 1	0	-2.38	-4.65*	0	-0.83	-1.65
35	P.Vijay x GM 2	-4.76 *	-9.09 **	-6.98**	-1.1	-1.91	-1.10
36	RH 749 x Navgold	-9.77 **	-10.45 **	-6.98**	-3.35 **	-5.21 **	-4.68**
37	RH 749 x RS 1	-9.23 **	-10.61 **	-8.53**	-3.36 **	-4.96 **	-4.96**
38	RH 749 x GM 1	-9.30 **	-11.36 **	-9.30**	-1.7	-2.12	-4.55**
39	RH 749 x GM 2	-5.30 *	-5.30 *	-3.10	-2.09	-4.10 **	-3.31*
40	Navgold x RS 1	-1.53	-3.73	0.00	-1.37	-1.64	-1.10
41	Navgold x GM 1	-0.77	-3.73	0.00	-2.36	-3.84 **	-3.31*
42	Navgold x GM 2	-9.77 **	-10.45 **	-6.98**	-1.5	-1.64	-0.83
43	RS 1 x GM 1	-3.15	-3.91	-4.65*	-0.98	-2.2	-2.20
44	RS 1 x GM 2	-3.08	-4.55	-2.33	-1.51	-1.91	-1.10
45	GM 1 x GM 2	-4.65 *	-6.82 **	-4.65*	0	-1.64	-0.83
	Max	2.33	-2.13	6.98	2.77	1.69	2.20
	Min	-10.87	-15.60	-13.95	-4.83	-5.74	-6.06

Table 2: Continued…

Sr. No.	Name of Cross	Plant height(cm)			Length of main branch (cm)		
		MP	BP	SH	MP	BP	SH
1	RH 119 x Urvashi	-6.29	-9.88 *	11.96*	10.67 **	5.91	15.88**
2	RH 119 x RH 1134	-4.46	-7.41	15.03**	0.55	-2.15	7.06*
3	RH 119 x Kranti	-6.37	-12.84 **	8.28	6.02	-5.38	3.53
4	RH 119 x P.Vijay	-3.34	-7.16	15.34**	-2.02	-8.6	0.00
5	RH 119 x RH 749	2.84	-1.48	22.39**	-1.09	-2.69	6.47
6	RH 119 x Navgold	-2.93	-10.12 *	11.66*	-1.14	-6.99	1.76
7	RH 119 x RS 1	-6.65	-8.15	14.11**	-6.38	-7.37	3.53
8	RH 119 x GM 1	-4.43	-9.38	12.58**	-1.69	-5.91	2.94
9	RH 119 x GM 2	-1.53	-12.35 *	8.90	-8.08 *	-11.29 **	-2.94
10	Urvashi x RH 1134	4.77	3.95	21.17**	6.36	4.55	8.24*
11	Urvashi x Kranti	-4.84	-8.02	5.52	4.43	-2.94	-2.94
12	Urvashi x P.Vijay	0.67	0.53	15.34**	10.57 *	7.65	7.65*
13	Urvashi x RH 749	3.62	3.21	18.40**	4	1.11	7.06*
14	Urvashi x Navgold	5.98	1.87	16.87**	12.57 **	10.59 *	10.59**
15	Urvashi x RS 1	-5.48	-7.65	11.04*	6.67	1.05	12.94**
16	Urvashi x GM 1	-11.26 *	-12.57 *	0.31	4.12	4.12	4.12
17	Urvashi x GM 2	4.64	-3.48	10.74	4.96	4.05	5.88
18	RH 1134 x Kranti	-6.45	-10.26 *	4.60	6.21	-2.84	0.59
19	RH 1134 x P.Vijay	-1.46	-2.37	13.80**	5.64	1.14	4.71
20	RH 1134 x RH 749	0.67	-0.53	15.95**	-5.06	-6.11	-0.59
21	RH 1134 x Navgold	2.34	-2.37	13.80**	2.94	-0.57	2.94
22	RH 1134 x RS 1	3.63	2.04	22.70**	3.28	-0.53	11.18**
23	RH 1134 x GM 1	1.21	-1.05	15.34**	-4.43	-6.06	-2.75
24	RH 1134 x GM 2	8.05	-1.05	15.34**	6.02	5.11	8.82*
25	Kranti x P.Vijay	-0.83	-4.02	9.82	16.61 **	11.18 *	5.29
26	Kranti x RH 749	2.78	-0.27	13.50**	14.11 **	3.33	9.41*
27	Kranti x Navgold	5.48	4.87	12.27**	26.45 **	19.51 **	15.29**
28	Kranti x RS 1	-9.58 *	-14.54 **	2.76	16.07 **	2.63	14.71**
29	Kranti x GM 1	-1.69	-3.58	7.36	12.66 **	4.71	4.71
30	Kranti x GM 2	13.08 *	7.74	15.34**	15.36 **	6.36	8.24*

31	P.Vijay x RH 749	2.42	2.14	16.87**	10.85 **	5	11.18**
32	P.Vijay x Navgold	-19.78 **	-22.79 **	-11.66*	7.08	6.1	2.35
33	P.Vijay x RS 1	-5.36	-7.65	11.04*	-0.28	-7.89	2.94
34	P.Vijay x GM 1	-1.36	-2.68	11.35*	2.11	-0.59	-0.59
35	P.Vijay x GM 2	-7.4	-14.48 **	-2.15	-2.99	-6.36	-4.71
36	RH 749 x Navgold	5.59	1.89	15.95**	4.07	-0.56	5.29
37	RH 749 x RS 1	-3.54	-6.12	12.88**	4.32	1.58	13.53**
38	RH 749 x GM 1	0	-1.08	12.58**	5.14	2.22	8.24*
39	RH 749 x GM 2	10.63 *	2.43	16.56**	6.52	4.44	10.59**
40	Navgold x RS 1	-3.66	-9.44	8.90	-6.78	-13.16 **	-2.94
41	Navgold x GM 1	5.65	3.03	14.72**	-0.6	-2.35	-2.35
42	Navgold x GM 2	8.32	3.77	9.82	-2.08	-4.62	-2.94
43	RS 1 x GM 1	-8.87	-12.24 *	5.52	-2.22	-7.37	3.53
44	RS 1 x GM 2	7.91	-2.55	17.18**	1.93	-2.63	8.82*
45	GM 1 x GM 2	8.39	1.38	12.88**	0.87	0	1.76
	Max	13.08	7.74	22.70	26.45	19.51	15.88
	Min	-19.78	-22.79	-11.66	-8.08	-13.16	-4.71

Table 2: Continued…

Sr. No.	Name of Cross	Branches per plant			Number of silique on main branch		
		MP	BP	SH	MP	BP	SH
1	RH 119 x Urvashi	83.51 **	76.82 **	33.50**	3.26	-2.46	18.75**
2	RH 119 x RH 1134	96.94 **	77.37 **	-0.25	-18.46 **	-20.64 **	-3.38
3	RH 119 x Kranti	-25.00 *	-49.54 **	10.25	7.42	-7.8	12.25**
4	RH 119 x P.Vijay	51.16 **	50.66 *	14.50	3.17	-6.37	14.00**
5	RH 119 x RH 749	37.34 *	31.52	8.50	-2.61	-8.01	12.00**
6	RH 119 x Navgold	38.18 *	27.37	14.00	-1.25	-11.09	8.25
7	RH 119 x RS 1	41.77 *	31.36	16.25	-1.66	-2.67	18.50**
8	RH 119 x GM 1	65.59 **	32.21 *	67.25	0.57	-9.03	10.75*
9	RH 119 x GM 2	243.28 **	212.50 **	187.50**	3.67	-1.44	20.00**
10	Urvashi x RH 1134	80.84 **	68.57 **	18.00	5.82	2.6	18.25**
11	Urvashi x Kranti	17.74	-22.27 **	69.50**	6.65	-3.7	4.25
12	Urvashi x P.Vijay	74.32 **	67.43 **	27.25	21.57 **	16.51 *	26.13**
13	Urvashi x RH 749	72.46 **	59.39 **	31.50**	3.46	3.46	12.00**
14	Urvashi x Navgold	30.41	16.2	4.00	-37.64 **	-40.74 **	-35.85**
15	Urvashi x RS 1	29.97	16.38	3.00	1.32	-3.35	15.25**
16	Urvashi x GM 1	-2.29	-24.11	-4.00	5.44	0.69	9.00
17	Urvashi x GM 2	38.27 *	21.74	12.00	6.65	5.92	16.25**
18	RH 1134 x Kranti	-20.43	-49.20 **	11.00	1.48	-10.85	2.75
19	RH 1134 x P.Vijay	109.16 **	87.83 **	42.75**	7.58	0.11	15.38**
20	RH 1134 x RH 749	42.66 *	23.64	2.00	-2.91	-5.86	8.50
21	RH 1134 x Navgold	112.00 **	77.65 **	59.00**	4	-4.01	10.63*
22	RH 1134 x RS 1	14.77	-3.39	-14.50	-3.41	-5.03	13.25**
23	RH 1134 x GM 1	75.22 **	29.51 *	63.83**	-6.82	-13.59 *	-0.42
24	RH 1134 x GM 2	51.80 **	25.82	15.75	-6.07	-8.32	5.67
25	Kranti x P.Vijay	-7.08	-37.38 **	36.83**	20.91 **	13.6	12.75**
26	Kranti x RH 749	-22.92 *	-46.91 **	16.00	22.76 **	10.85	20.00**
27	Kranti x Navgold	6.49	-24.94 **	64.00**	23.41 **	16.92 *	14.00**
28	Kranti x RS 1	-16.45	-41.30 **	28.25	6.66	-7.65	10.13*
29	Kranti x GM 1	-24.35 **	-40.27 **	30.50*	23.82 **	16.75 *	15.00**

30	Kranti x GM 2	-1.29	-29.86 **	53.25**	16.75 *	4.78	15.00**
31	P.Vijay x RH 749	78.23 **	71.21 **	41.25**	5.3	0.92	9.25
32	P.Vijay x Navgold	68.28 **	55.59 **	39.25**	12.71	11.71	10.88**
33	P.Vijay x RS 1	43.16 *	33.05	17.75	-2.29	-10.48	6.75
34	P. Vijay x GM 1	35.80 *	8.7	37.50**	1.39	1.01	0.25
35	P. Vijay x GM 2	26.19	15.22	6.00	5.26	0.23	10.00*
36	RH 749 x Navgold	83.72 **	76.54 **	58.00**	10.57	5.08	13.75**
37	RH 749 x RS 1	26.9	22.6	8.50	7.47	2.52	22.25**
38	RH 749 x GM 1	28.23 *	5.93	34.00**	11.25	6.24	15.00**
39	RH 749 x GM 2	30.66	23.91	14.00	10.44	9.68	20.38**
40	Navgold x RS 1	27.25	26.54	13.25	-6.81	-15.30 *	1.00
41	Navgold x GM 1	22.45	4.55	32.25**	14.41 *	13.83	12.13*
42	Navgold x GM 2	57.02 **	54.89 **	42.50**	-4.22	-9.57	-0.75
43	RS 1 x GM 1	1.4	-13.83	9.00	2.18	-6.71	11.25*
44	RS 1 x GM 2	41.83 *	39.13 *	28.00	-10.59	-14.15 *	2.38
45	GM 1 x GM 2	32.04 *	14.03	44.25**	2.16	-3.08	6.37
	Max	243.28	212.50	187.50	23.82	16.92	26.13
	Min	-25.00	-49.54	-14.50	-37.64	-40.74	-35.85

Table 2: Continued…

Sr. No.	Name of Cross	Number of siliquae per plant			Length of siliqua (cm)		
		MP	BP	SH	MP	BP	SH
1	RH 119 x Urvashi	98.09 **	94.50 **	55.78**	-1.75	-4.55	2.44
2	RH 119 x RH 1134	26.73	26.7	-2.20	8.57	7.95	15.85**
3	RH 119 x Kranti	58.46 **	48.83 **	30.78*	4.65	2.27	9.76*
4	RH 119 x P.Vijay	55.83 **	47.64 **	27.34	12.79	10.23	18.29**
5	RH 119 x RH 749	38.31 **	22.69	22.34	20.66	16.81	33.90**
6	RH 119 x Navgold	53.11 **	35.91 *	35.31*	8.57	7.95	15.85*
7	RH 119 x RS 1	36.61 **	20.62	21.56	0	-2.27	4.88
8	RH 119 x GM 1	57.26 **	37.99 **	41.09**	1.73	0	7.32
9	RH 119 x GM 2	99.17 **	79.24 **	72.97**	13.12	6.82	14.63*
10	Urvashi x RH 1134	58.59 **	55.68 **	24.69	10.59	8.05	14.63*
11	Urvashi x Kranti	50.33 **	43.67 **	26.25	1.8	1.19	3.66
12	Urvashi x P.Vijay	57.86 **	52.23 **	31.30*	8.98	8.33	10.98*
13	Urvashi x RH 749	42.68 **	28.64 *	28.28	16.38	9.57	25.61**
14	Urvashi x Navgold	45.42 **	31.20 *	30.63*	5.88	3.45	9.76*
15	Urvashi x RS 1	35.18 *	21.3	22.25	-0.6	-1.19	1.22
16	Urvashi x GM 1	21.23	8.1	10.53	2.38	1.18	4.88
17	Urvashi x GM 2	49.00 **	36.33 *	31.56*	6.7	3.61	4.88
18	RH 1134 x Kranti	52.05 **	42.78 **	25.47	5.26	3.45	9.76*
19	RH 1134 x P.Vijay	71.03 **	62.01 **	39.73*	10.29	8.39	15.00*
20	RH 1134 x RH 749	24.91	10.78	10.47	-4.97	-8.51	4.88
21	RH 1134 x Navgold	42.18 **	26.18	25.63	-4.6	-4.6	1.22
22	RH 1134 x RS 1	17.67	3.88	4.69	-1.75	-3.45	2.44
23	RH 1134 x GM 1	26.46	10.94	13.44	-4.65	-5.75	0.00
24	RH 1134 x GM 2	23.99	11.56	7.66	0.48	-4.6	1.22
25	Kranti x P.Vijay	57.57 **	56.12 **	37.19*	1.19	1.19	3.66
26	Kranti x RH 749	29.27 *	21.59	21.25	6.74	1.06	15.85*
27	Kranti x Navgold	72.56 **	62.43 **	61.72**	-1.17	-2.87	3.05
28	Kranti x RS 1	24.23	16.28	17.19	11.9	11.9	14.63*
29	Kranti x GM 1	27.88 *	18.89	21.56	8.88	8.24	12.208
30	Kranti x GM 2	43.29 **	36.88 *	32.09*	14.43	10.48	13.178

31	P.Vijay x RH 749	26.37	17.83	17.50	5.62	0	14.638
32	P.Vijay x Navgold	42.62 **	33.08 *	32.50*	5.26	3.45	9.76*
33	P.Vijay x RS 1	21.14	12.4	13.28	1.19	1.19	3.66
34	P. Vijay x GM 1	56.00 **	43.80 **	47.03**	-2.96	-3.53	0.00
35	P.Vijay x GM 2	25.86	19.17	15.00	10.23	6.43	9.02*
36	RH 749 x Navgold	41.04 **	40.93 **	40.53**	-2.76	-6.38	7.32
37	RH 749 x RS 1	18.61	17.98	18.91	-1.12	-6.38	7.32
38	RH 749 x GM 1	11.56	10.18	12.66	-3.91	-8.51	4.88
39	RH 749 x GM 2	24.91	22.89	22.55	3.37	-5.32	8.54
40	Navgold x RS 1	11.95	11.27	12.14	114.04 **	110.34 **	41.87**
41	Navgold x GM 1	19.7	18.12	20.78	-2.33	-3.45	2.44
42	Navgold x GM 2	28.47 *	26.49	25.94	-0.73	-5.75	0.00
43	RS 1 x GM 1	5.28	4.52	6.88	-4.14	-4.71	-1.22
44	RS 1 x GM 2	15.95	13.49	14.38	1.11	-2.38	0.00
45	GM 1 x GM 2	30.35 *	26.68	29.53	5.39	1.18	4.88
	Max	99.17	94.50	72.97	114.04 **	110.34 **	41.87**
	Min	5.28	3.88	-2.20	4.97	-8.51	-1.22

Table 2: Continued…

Sr. No.	Name of Cross	Seeds per siliqua			Seed yield per plant (g)		
		MP	BP	SH	MP	BP	SH
1	RH 119 x Urvashi	-2.39	-5.92	2.14	95.10 **	73.04 **	107.29**
2	RH 119 x RH 1134	14.29 **	10.53 **	20.00**	74.75 **	58.72 **	80.21**
3	RH 119 x Kranti	1.97	1.97	10.71**	10.6	-6.25	25.00
4	RH 119 x P.Vijay	9.97 **	5.26	14.29**	54.59 **	35.59 *	66.67**
5	RH 119 x RH 749	8.36 **	6.58	15.71**	19.81	5.08	29.17
6	RH 119 x Navgold	1.37	-2.63	5.71	35.79 *	27.72	34.38*
7	RH 119 x RS 1	-1.05	-7.24 *	0.71	62.50 **	60.67 **	48.96**
8	RH 119 x GM 1	0.69	-3.95	4.29	-5.26	-35.97 **	68.75**
9	RH 119 x GM 2	1.75	-4.61	3.57	148.35 **	143.01 **	135.42**
10	Urvashi x RH 1134	6.01	5.63	7.14*	72.32 **	67.83 **	101.04**
11	Urvashi x Kranti	-5.8	-9.21 **	-1.43	25.93	19.53	59.38**
12	Urvashi x P.Vijay	4.64	3.9	4.64	63.95 **	61.86 **	98.96**
13	Urvashi x RH 749	-2.08	-4.08	0.71	47.64 **	45.76 **	79.17**
14	Urvashi x Navgold	-1.07	-1.42	-0.71	55.56 **	46.09 **	75.00**
15	Urvashi x RS 1	0.73	-2.13	-1.43	42.57 **	25.22	50.00**
16	Urvashi x GM 1	-4.66	-5.67	-5.00*	6.52	-22.53 **	104.17**
17	Urvashi x GM 2	2.19	-0.71	0.00	89.42 **	71.30 **	105.21**
18	RH 1134 x Kranti	6.12 *	2.63	11.43**	0.42	-7.03	23.96
19	RH 1134 x P.Vijay	9.82 **	8.66 *	10.21**	50.66 **	44.92 **	78.13**
20	RH 1134 x RH 749	-1.04	-2.72	2.14	35.68 *	30.51	60.42**
21	RH 1134 x Navgold	0.35	-0.35	1.07	64.76 **	58.72 **	80.21**
22	RH 1134 x RS 1	7.64 *	4.23	5.71	81.63 **	63.30 **	85.42**
23	RH 1134 x GM 1	-2.86	-4.23	-2.86	-10.5	-35.97 **	68.75**
24	RH 1134 x GM 2	8.00 *	4.58	6.07	167.33 **	147.71 **	181.25**
25	Kranti x P.Vijay	-0.34	-4.61	3.57	42.28 **	36.72 *	82.29**
26	Kranti x RH 749	5.69	3.95	12.86**	17.07	12.5	50.00*
27	Kranti x Navgold	6.16 *	1.97	10.71**	37.99 **	23.44	64.58**
28	Kranti x RS 1	6.67 *	0	8.57*	51.63 **	27.34	67.71**
29	Kranti x GM 1	7.24 *	2.3	11.07**	-20.73 *	-40.32 **	57.29**
30	Kranti x GM 2	7.72 *	0.99	9.64**	52.94 **	32.03 *	76.04**

31	P.Vijay x RH 749	6.64 *	3.74	8.93**	53.39 **	53.39 **	88.54**
32	P.Vijay x Navgold	5.02	4.64	4.64	20.55	11.86	37.50
33	P.Vijay x RS 1	7.17 *	4.86	4.11	59.02 **	38.14 *	69.79**
34	P.Vijay x GM 1	0.72	0.36	-0.36	-34.23 **	-51.78 **	27.08
35	P.Vijay x GM 2	11.03 **	8.63 *	7.86*	64.93 **	47.46 **	81.25**
36	RH 749 x Navgold	3.14	0.68	5.71	68.95 **	56.78 **	92.71**
37	RH 749 x RS 1	3.57	-1.36	3.57	46.34 **	27.12	56.25**
38	RH 749 x GM 1	1.05	-2.04	2.86	-15.36	-37.94 **	63.54**
39	RH 749 x GM 2	4.64	-0.34	4.64	48.82 **	33.05 *	63.54**
40	Navgold x RS 1	10.62 **	7.86 *	7.86*	11.7	3.96	9.37
41	Navgold x GM 1	-1.08	-1.79	-1.79	-8.47	-35.97 **	68.75**
42	Navgold x GM 2	4.03	1.43	1.43	89.69 **	82.18 **	91.67**
43	RS 1 x GM 1	-1.85	-3.62	-5.00*	-14.12	-42.29 **	52.08**
44	RS 1 x GM 2	2.63	2.63	-2.50	130.00 **	122.58 **	115.63**
45	GM 1 x GM 2	2.95	1.09	-0.36	-6.94	-36.36 **	67.71**
	Max	14.29 **	10.53 **	20.00	167.33	147.71	181.25
	Min	-5.80	-9.21	-5.00	-34.23	-51.78	9.37