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Heterosis Studies in Indian Mustard [Brassica Juncea]

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Abstract **– Heterosis breeding approach is one of the most successful technological options being employed for the improvement of brassica variety for quality and quantity of seed yield and other yield related parameter. The present investigation was undertaken to study the heterosis in Indian mustard. Ten lines and five testers and their 50 F_1s were grown in randomized block design with three replications. Data on quantitative characters were recorded and Heterobeltosis and heterosis were determined. The crosses GM-3 x RGN-145, RGN-48 x Kranti and Gm-3 x Kranti took lesser days to flowering, as they had highest negative and significant heterosis and heterobeltiosis Five hybrids expressed negative and significant heterosis and heterobeltiosis, in which RGN-48 x RGN-145 and RGN-48 x Geeta were earliest in maturity. The most heterotic cross was RGN-48 x Kranti for days to 50% flowering, days to maturity, plant height, number of primary branches per plant and biological yield per plant.**

Keywords **– Heterosis, Indian Mustard, Yield, Better Parents**

I. INTRODUCTION

Indian mustard [*Brassica juncea* (L.) Czern & Coss] is an important oil seed crop of the world. It plays a major role in catering to edible oil demand of the country. The genus *Brassica*, belongs to cruciferae or brassicaceae family. Indian mustard is a natural amphidiploid (2n=36) of *Brassica campestris* (2n=20) and *Brassica nigra* (2n=16) (Nagaheru, 1935). It was introduced in India from China and from where it spread to Afghanistan and other countries. It is largely a self-pollinated crop (85-90 %). However, owing to insects, especially the honeybees, the extent of cross-pollination varies from 4.0 to 16.6 %. It covers an area of 6.70 million hectares with 8.00 million tonnes production and 1194 kg/ha productivity in India[1]. Rajasthan is the largest producer of rapeseed-mustard followed by Uttar Pradesh, Haryana, Madhya Pradesh, West Bengal, Gujarat and Assam. In Rajasthan mustard is cultivated on about 2.78 million hectares with 3.62 MT production and 1301 Kg/ha. Productivity [2]. Heterosis breeding could be a potential alternative for achieving quantum jumps in production and productivity. Since, commercial exploitation of heterosis in several crop plants has caused a major breakthrough in yield levels. The magnitude of heterosis particularly for yield is of paramount importance and if the heterosis is partially and economically feasible it can help to reach high yield levels and there by higher output of oil in mustard.

II. MATERIALS AND METHODS

The present investigation was undertaken to study the combining ability and heterosis in Indian mustard. Ten lines (Bio-902, GM-3, Rohini, RGN-13, RGN-48, RGN-73, RGN-229, RGN-236, RGN-298 and RGN-303) and five testers (RL-1359 Geeta Kranti RB-50 and RGN-145) along with their 50 F1s were grown in randomized block design with three replications during rabi-2015-16 at Research Farm, College of Agriculture, Bikaner. Each genotype was sown in single row plot of 3 m row length. Row to row and plant-to-plant distances were maintained at 45 cm and 20 cm, respectively in each replication. The observations were recorded on randomly selected five competitive plants for each genotype in each replication for eleven character *vz* Plant height (cm), Number of primary branches per plant, Number of secondary branches per plant, Number of siliquae per plant, Number of seeds per siliqua, Test weight (g), Biological yield per plant, Harvest index and Seed yield per plant (g) except days to 50% flowering and days to maturity which were recorded on whole plot basis. Heterosis expressed as per cent increase or decrease in hybrid (F_1) over better parent (BP) and mid-parent (Heterosis) value in desired direction was calculated using the following formula [3].

$$\text{Average heterosis} = \frac{\text{F1-MP}}{\text{MP}}$$

Where, F_1 is the mean over replications of a hybrid between i^{th} and j^{th} parents.

MP is the mean over the replications of the mid-parents. Percentage heterobeltiosis of a cross was calculated by the following formula,

$$\text{Heterobeltiosis (\%)} = \frac{\text{F1-BP}}{\text{BP}}$$

Where, F_1 is the mean over replications of a hybrid i^{th} and j^{th} parents

BP is the mean over replications of the better parent among i^{th} and j^{th} parents of a cross.

III. RESULT AND DISCUSSION

The mean performance (Table 1) and magnitude of heterosis (Table 2) over better parent for earliness and other yield parameter are depicted. The crosses with negative significant heterosis for days to 50% flowering and days to maturity were considered as desirable for these traits. Out of 50 F_1 crosses, 12 F_1 depicted negative and significant heterosis over mid-parent and better parent value. The crosses GM-3 x RGN-145, RGN-48 x Kranti

and Gm-3 x Kranti took lesser days to flowering, as they had highest negative and significant heterosis and heterobeltiosis. These findings are in line with [4] and [5]. Five hybrids expressed negative and significant heterosis and heterobeltiosis, in which RGN-48 x RGN-145 and RGN-48 x Geeta were earliest in maturity. The results are in conformity with [6].

In respect of plant height, three hybrids exhibited positive and significant heterosis, the cross RGN-48 x Kranti was tallest as it had highest positive and significant heterosis and heterobeltiosis. These results were also founded by [4] and Choudhary and Sharma [7]. Ten hybrids showed significant and positive heterosis and heterobeltiosis for number of primary branches per plant. The hybrids RGN-73 x RB-50, RGN-73 x RGN-145 and RGN-48 x RGN-145 manifested maximum significant positive heterosis (63.87, 54.17 and 57.35) and heterobeltiosis (61.34, 51.02 and 40.80) respectively. These findings agreed with the results of [8] and [9].The highest heterosis (29.05) and heterobeltiosis (29.67) was registered in cross combination RGN-303 x RL-1359 for number of secondary branches per plant. Positive and significant heterosis was showed by six cross combinations. Similar inclinations were observed by [10].Three F_1 crosses namely RGN-229 x Kranti, RGN-229 x RL-1359 and GM-3 x RL-1359 depicted postive and significant heterosis over mid-parent and better parent value for number of silliquae per plant. This is compliance with earlier findings of [11] and [12]. Out of 50 F_1 eleven cross combination were registered for positive and significant heterosis and heterobeltiosis for test weight in which crosses RGN-303 x RL-1359 (52.31), Rohini x RB-50 (48.03) and RGN-303 x Kranti (40.82) depicted highest heterosis and heterobeltiosis. The 21 crosses showed positive and significant heterosis over mid-parent and better parent for biological yield per plant. The finding are in accordance with that of [10] and [13].Maximum heterosis and heterobeltiosis for harvest index was showed by Bio-902 x RB-50. One cross showed positive and significant heterosis over better parent and two crosses were positive and significant for seed yield per plant. These were supported by [11] and [14].

IV. Conclusion

The superior crosses identified on overall basis of *per se performance*, specific combining ability and heterosis were RGN-303 x RGN-145 for plant height, RGN-73 x Geeta for number of primary branches per plant; RGN-303 x RL-1359 for number of secondary branches per plant; RGN-229 x RL-1359 and RGN-229 x Kranti for number of siliquae per plant; RGN-298 x RGN-145 and RGN-303 x RB-50 for number of seeds per siliqua; RGN-303 x Kranti for test weight; Bio-902 x RB-50 for harvest index and RGN-298 x Kranti for seed yield per plant.

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Table 1: Mean performance of crosses in mustard for Heterobeltiosis and Heterosis

Genotypes	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of primary branches per plant	No. of secondary branches per plant	No. of siliquae per plant	No. of Seeds per siliqua	Test weight (g)	Biological yield per plant (g)	Harvest index (%)	Seed yield per plant (g)
Crosses											
RGN-13 x RGN-145	53.00	136.33	157.20	9.93	13.87	464.16	12.73	4.97	137.00	32.09	43.95
RGN-13 x Kranti	51.33	135.33	168.27	9.33	13.57	435.08	10.47	4.87	142.53	32.41	45.99
RGN-13 x RL-1359	54.67	137.33	154.47	8.07	10.87	311.08	10.00	4.87	249.53	18.81	46.85
RGN-13 x Geeta	52.67	135.33	159.40	9.00	17.40	540.67	15.73	4.87	164.00	25.09	41.10
RGN-13 x RB-50	46.00	134.33	172.57	7.60	16.33	463.89	14.33	4.93	142.00	32.41	45.95
RGN-73 x RGN-145	46.00	136.33	176.67	9.87	12.37	538.65	11.33	4.87	152.80	30.82	46.81
RGN-73 x Kranti	44.67	142.00	167.27	9.13	14.33	919.43	14.20	5.67	214.27	20.71	44.34
RGN-73 x RL- 1359	45.67	145.00	155.87	10.40	12.13	641.17	15.33	5.83	178.00	25.79	45.59
RGN-73 x Geeta	51.00	142.33	158.80	11.40	12.60	802.17	14.80	4.57	164.67	25.27	41.49
RGN-73 x RB-50	42.67	141.00	160.53	10.43	14.67	547.68	12.13	4.43	147.40	30.26	44.28
RGN-48 x RGN-145	48.00	131.67	172.73	11.73	12.27	455.19	15.87	5.50	160.27	30.06	48.04
RGN-48 x Kranti	43.00	133.00	193.90	11.10	13.27	504.95	14.40	5.50	161.67	27.60	44.63
RGN-48 x RL-1359	40.00	132.33	163.93	8.93	10.67	330.19	12.00	5.67	158.00	29.25	45.51
RGN-48 x Geeta	43.00	131.00	173.93	8.90	10.60	735.29	14.90	5.30	150.13	33.44	50.11
RGN-48 xRB-50	49.33	133.33	193.80	11.20	10.07	753.67	15.33	5.23	136.80	33.53	45.51
RGN-229 x RGN-145	52.33	131.00	162.73	10.70	9.90	450.66	14.40	5.57	116.40	38.18	44.26
RGN-229 x Kranti	53.33	134.33	164.93	10.10	13.07	1111.71	13.47	5.13	187.33	24.74	46.00
RGN-229 x RL-1359	45.67	136.00	190.87	8.97	16.00	1055.00	17.33	5.73	202.67	21.98	44.55
RGN-229 x Geeta	52.00	135.00	183.07	8.13	12.60	313.11	17.33	4.53	173.07	26.76	47.60
RGN-229 x RB-50	52.67	137.67	187.40	8.13	15.53	845.11	15.47	4.63	189.27	24.29	45.81
RGN-298 x RGN-145	52.67	140.33	179.80	11.27	14.60	630.09	19.60	5.70	164.93	30.62	50.00
RGN-298 x Kranti	51.00	141.33	172.20	8.53	10.20	500.39	12.53	5.33	199.33	26.91	53.053
RGN-298 x RL-1359	48.67	146.67	184.40	9.20	10.57	441.82	13.20	5.73	177.87	26.55	47.08
RGN-298 x Geeta	53.67	139.67	192.80	8.67	9.33	651.35	16.67	5.87	154.53	33.10	50.65
RGN-298 x RB-50	52.33	142.00	209.20	9.67	15.47	586.30	15.33	6.23	219.53	22.55	49.40
RGN-303 x RGN-145	54.00	142.00	217.13	9.60	16.17	553.10	14.27	4.67	302.53	16.46	49.82
RGN-303 x Kranti	53.33	131.67	185.13	8.90	20.67	775.89	12.40	6.90	188.07	27.98	52.53
RGN-303 x RL-1359	53.67	132.33	186.27	8.47	24.43	923.92	14.40	6.60	141.33	37.67	52.74
RGN-303 x Geeta	52.67	137.67	203.73	8.80	17.33	704.49	16.27	5.40	204.73	25.95	52.74
RGN-303 x RB-50	54.33	138.00	178.40	9.27	19.13	652.33	18.40	6.27	116.47	38.61	43.97
Bio-902 x RGN-145	53.00	137.67	178.60	10.73	13.27	722.55	16.53	5.37	146.67	30.26	44.39
Bio-902 x Kranti	51.00	139.00	159.80	11.13	13.00	874.78	12.33	4.80	151.33	29.53	44.60
Bio-902 x RL-1359	53.00	140.67	160.80	11.67	13.93	730.20	15.20	4.60	178.00	25.19	44.80
Bio-902 x Geeta	52.67	141.67	169.47	9.87	14.87	621.77	11.33	5.40	181.47	25.18	45.64
Bio-902 x RB-50	52.67	148.33	166.93	10.13	14.83	632.67	14.60	5.83	83.20	55.18	45.85
RGN-236 x RGN-145	49.33	151.33	170.80	11.70	14.87	710.81	17.33	4.30	191.93	25.75	49.41
RGN-236 x Kranti	51.00	152.33	155.93	9.60	14.80	749.81	17.60	5.53	176.80	28.39	50.10
RGN-236 x RL-1359	44.00	153.00	159.00	9.50	16.80	577.75	17.33	5.60	175.87	28.90	50.48
RGN-236 x Geeta	54.67	152.33	153.20	9.67	14.67	561.94	14.53	5.37	179.33	28.34	50.52
RGN-236 x RB-50	53.00	151.67	161.47	8.30	17.43	554.43	17.60	5.30	145.93	33.24	48.37
Rohini x RGN-145	53.00	140.33	165.80	9.60	13.40	542.07	18.00	5.43	141.27	39.39	55.12
Rohini x Kranti	44.33	140.33	171.13	10.93	15.20	785.75	18.33	5.47	138.33	33.37	46.06
Rohini x RL-1359	42.00	141.67	163.20	9.40	13.53	741.35	17.87	5.73	149.53	30.58	45.64
Rohini x Geeta	43.00	144.67	156.27	9.97	15.33	392.90	14.80	5.73	166.17	29.46	45.84
Rohini x RB-50	45.67	146.67	161.80	10.23	13.07	499.95	17.73	6.27	173.73	26.32	45.72
GM-3 x RGN-145	41.33	146.67	164.53	8.43	15.33	544.20	14.93	6.20	168.80	23.04	45.78
GM-3 x Kranti	43.67	141.00	165.00	8.97	15.47	832.61	15.77	6.37	167.20	28.46	47.24
GM-3 x RL-1359	47.00	141.67	168.83	11.07	18.13	579.04	14.27	5.03	173.87	25.22	43.84
GM-3 x Geeta	56.33	143.00	171.93	9.40	16.13	567.68	15.87	5.63	186.93	24.60	45.93
GM-3 x RB-50	54.00	141.67	152.27	7.97	11.73	680.20	14.67	5.67	136.33	33.82	44.68

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Table 2: Heterobeltiosis and Heterosis for earliness and other yield parameter

Crosses	Day to 50 % flowering		Days to maturity		Plant height (cm)		No. of primary branch per plant		No. of secondary branch per plant		No. of silliqua per plant	
	BP	Heterosis	BP	Heterosis	BP	Heterosis	BP	Heterosis	BP	Heterosis	BP	Heterosis
RGN-13 x RGN-145	10.42*	12.37**	-0.73	0.99	-11.19**	-9.64**	22.13	35.45**	-36.78**	-22.24**	-62.47**	-50.54**
RGN-13 x Kranti	-8.33*	0.33	-1.46	0.25	-1.56	2.79	3.32	8.74	-46.02**	-42.35**	-64.83**	-56.88**
RGN-13 x RL-1359	17.99**	19.71**	3.52**	3.65**	-14.09**	-11.92**	-16.55	-9.36	-50.46**	-46.82**	-74.85**	-69.74**
RGN-13 x Geeta	-3.07	4.64	2.01	2.53*	-6.75*	-5.31	5.06	7.78	-22.78**	-21.74**	-56.29**	-50.46**
RGN-13 x RB-50	-9.80*	-5.48	1	1.13	-14.17**	-7.22**	-6.56	4.11	-32.51**	-29.19**	-62.50**	-62.01**
RGN-73 x RGN-145	-4.17	-3.5	-0.73	1.74	-7.34*	3.9	51.02**	54.17**	-52.56**	-37.86**	-61.19**	-46.87**
RGN-73 x Kranti	-20.24**	-13.55**	3.40**	5.97**	-12.27**	-3.63	1.11	19.39	-45.01**	-44.01**	-33.75**	-15.21*
RGN-73 x RL-1359	-3.52	-1.08	9.57**	10.27**	-18.25**	-15.85**	7.59	30.54**	-53.45**	-46.07**	-53.80**	-41.90**
RGN-73 x Geeta	-6.13	0.33	8.38**	8.65**	-16.71**	-10.89**	33.07**	53.71**	-51.66**	-48.15**	-42.20**	-31.24**
RGN-73 x RB-50	-16.34**	-13.22**	6.02**	6.95**	-20.16**	-18.04**	61.34**	63.87**	-43.73**	-41.64**	-60.53**	-57.76**
RGN-48 x RGN-145	-10.00**	-5.26	-10.63**	-7.49**	-2.41	-0.92	40.80**	57.85**	-39.87**	-28.13**	-43.11**	-36.78**
RGN-48 x Kranti	-23.21**	-21.34**	-9.73**	-6.56**	12.95**	18.18**	22.88*	27.83**	-47.21**	-41.73**	-36.89**	-36.13**
RGN-48 x RL-1359	-25.00**	-18.64	-10.18**	-5.36**	-8.82**	-6.71*	-7.59	-0.74	-47.71**	-45.76**	-59.70**	-59.22**
RGN-48 x Geeta	-20.86*	-20.12**	-11.09**	-5.98**	1.32	3.1	3.89	5.33	-52.96**	-50.62**	-22.24*	-15.76
RGN-48 x RB-50	-7.50*	-5.43	-9.50**	-4.88**	-3.61	3.99	34.40**	51.35**	-58.40**	-54.86**	-37.47**	-24.83**
RGN-229x RGN-145	9.03*	13.36**	-4.61**	-2.60*	-10.98**	-9.54**	27.89*	43.62**	-39.14**	-34	-29.58*	-24.24
RGN-229 x Kranti	-4.76	6.31	-2.18	-0.12	-9.77**	-2.77	11.81	16.09	-48.01**	-36.88**	42.34**	67.07**
RGN-229 x RL-1359	1.48	2.24	2.77**	3.03**	4.41	5.28	-7.24	-0.55	-15.49	-9.09	28.79*	54.14**
RGN-229 x Geeta	-4.29	5.41	2.53*	2.66*	0.15	5.05	-5.06	-3.94	-44.08**	-35.05**	-66.89**	-58.13**
RGN-229 x RB-50	3.27	10.49**	3.51**	4.03**	-6.80*	-2.36	-2.79	9.66	-35.81**	-23.23**	-29.88**	-3.69
RGN-298x RGN-145	9.72*	14.91**	2.18	4.21**	-10.70**	-4.95	5.63	31.01**	6.31	11.33	-18.38	-10.75
RGN-298 x Kranti	-8.93*	2.34	2.91*	4.95**	-14.47**	-3.75	-20.00*	-13.37	-59.42**	-45.79**	-35.93**	-35.56**
RGN-298 x RL-1359	8.15	9.77*	10.83**	10.97**	-8.41**	-3.24	-13.75	-9.51	-44.19**	-32.77**	-46.08**	-44.47**
RGN-298 x Geeta	-1.23	9.52**	5.81**	6.08**	-4.24	5.05	-18.75*	-9.88	-58.58**	-46.72**	-31.12**	-24.16*
RGN-298 x RB-50	2.61	10.56**	6.77**	7.17**	3.91	3.98	-9.38	12.84	-36.09**	-15.71*	-51.36**	-40.70**
RGN-303 xRGN-145	12.50**	22.26**	3.40**	5.32**	1.37	11.01**	-21.74**	2.13	17.72	39.97**	-25.32	-19.87
RGN-303 x Kranti	-4.76	10.73**	-4.13**	-2.35*	-13.57**	-0.11	-27.45**	16.43*	-17.77**	19.81**	-0.66	1.98
RGN-303 x RL-1359	19.26**	25.78**	0	0	-13.04**	-5.45*	-30.98**	-22.80**	29.05**	72.67**	12.76	18.45
RGN-303 x Geeta	-3.07	11.27**	4.03**	4.42**	-3.49	8.83**	-28.26**	-15.52	-23.08**	8.67	-25.50*	-16.44
RGN-303 x RB-50	6.54	18.98**	3.76**	4.02**	-16.71**	-14.08**	-24.46**	-1.07	-20.94**	14	-45.87**	-32.95**
Bio-902 x RGN-145	10.42*	18.66**	0.24	1.47	-13.39	-6.78**	30.89*	45.70**	-3.4	23.6	12.9	26.24
Bio-902 x Kranti	-8.93*	4.79	1.21	2.46*	-22.50**	-11.87**	23.25*	29.21**	-48.28**	-20.89**	12	36.07**
Bio-902 x RL-1359	17.78**	22.78**	4.98**	5.63**	-22.11**	-16.79**	20.34	30.22**	-26.41**	4.5	-10.88	10.29
Bio-902 x Geeta	-3.07	10.10**	5.72**	6.78**	-17.81**	-8.87**	15.18	17.66	-34.02**	-1.76	-34.25**	-14.26
Bio-902 x RB-50	3.27	14.08**	10.70**	11.11**	-19.04**	-18.02**	23.58	38.18**	-38.71**	-7.1	-47.51**	-26.00**
RGN-236x RGN-145	-2.63	0	7.33**	8.74**	-9.63**	-6.67*	26.71*	48.41**	-30.53**	-15.37*	11.07	11.09
RGN-236 x Kranti	-8.93*	-4.38	8.04**	9.46**	-17.50**	-9.73**	3.97	5.11	-41.11**	-36.39**	-4	5.55
RGN-236 x RL-1359	-13.16**	-8.01*	8.51**	11.95**	-15.87**	-13.77**	-1.72	0.53	-21.50**	-16.69*	-29.49*	-20.8
RGN-236 x Geeta	0.61	4.13	8.04**	11.87**	-18.94**	-13.63**	4.69	8.61	-34.91**	-33.23**	-40.58**	-29.11**
RGN-236 x RB-50	3.92	4.26	7.57**	10.71**	-19.69**	-17.21**	-10.11	5.73	-27.96**	-23.54**	-54.00**	-39.90**
Rohini x RGN-145	-15.69**	-13.13**	-2.09	0	-12.80**	-9.68**	12.94	27.72*	-2.43	6.63	-15.3	-2.21
Rohini x Kranti	-20.83**	-17.13**	-2.09	0	-9.99**	-1.25	21.03	24.71*	-39.52**	-16.79*	0.6	25.74
Rohini x RL-1359	-17.65**	-12.50**	-1.16	2.78**	-14.17**	-11.77**	-2.76	3.49	-28.52**	-10.77	-9.52	15.11
Rohini x Geeta	-20.86**	-18.35**	0.93	5.34**	-17.81**	-12.18**	16.34	16.8	-31.95**	-9.63	-58.45**	-44.44**
Rohini x RB-50	-10.46**	-10.46**	2.33*	6.15**	-19.53**	-17.28**	20.39	36.75**	-46.01**	-25.69**	-58.52**	-40.27**
GM-3 x RGN-145	-23.93**	-19.22**	6.80**	7.45**	-10.51**	-8.81**	-24.70**	-4.89	11.65	31.81**	-14.96	-3.71
GM-3 x Kranti	-22.02**	-20.85**	2.67*	3.30**	-10.26**	-3.04	-19.94*	-11.37	-38.46**	-10.77	6.6	30.97*
GM-3 x RL-1359	-13.50**	-5.37	4.42**	5.72**	-8.18**	-7.15**	-1.19	6.07	-4.23	27.40**	31.70**	64.77**
GM-3 x Geeta	3.68	3.68	5.41**	7.12**	-6.49*	1.64	-16.07	-4.89	-28.40**	0.62	-39.97**	-20.94
GM-3 x RB-50	-0.61	2.53	4.42**	5.48**	-24.27**	-20.89**	-28.87**	-9.81	-51.52**	30.43**	-43.56**	-19.77*
S.E. diff.	**1.96**	**1.69**	**1.62**	**1.41**	**5.68**	**4.92**	**0.99**	**0.86**	**1.49**	**1.29**	**95.14**	**82.39**
CD at 5%	**3.89**	**3.37**	**3.23**	**2.8**	**11.27**	**9.76**	**1.98**	**1.71**	**2.97**	**2.57**	**188.8**	**163.5**
CD at 1%	**5.15**	**4.46**	**4.28**	**3.7**	**14.93**	**12.93**	**2.62**	**2.27**	**3.94**	**3.41**	**249.92**	**216.44**

*and ** indicate significant at 5 and 1 percent levels, respectively, BP: Heterobeltiosis/Better parent Heterosis

Conti…..

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Crosses	No. of seeds per siliqua		Test weight (g)		Biological yield per plant		Harvest index		Seed yield per plant (g)	
	BP	Heterosis	BP	Heterosis	BP	Heterosis	BP	Heterosis	BP	Heterosis
RGN-13 x RGN-145	-35.91**	-33.68**	-3.25	2.05	4.85	16.04	-32.74**	-28.03**	-18.62**	-15.57**
RGN-13 x Kranti	-47.32**	-42.49**	-9.32	-2.34	11.82	22.38**	-32.07**	-24.19**	-8.21	-6.38
RGN-13 x RL-1359	-49.66**	-46.04**	5.8	10.19	95.46**	114.07**	-60.58**	-56.79**	-6.72	-6.6
RGN-13 x Geeta	-20.81*	-11.94	5.8	5.8	7.66	27.23**	-47.41**	-36.53**	-17.97**	-15.26**
RGN-13 x RB-50	-27.85**	-20.66**	7.25	8.42	13.6	23.23**	-32.06**	-26.54**	-8.90*	-8.60*
RGN-73 x RGN-145	-40.97**	-39.93**	-5.19	0	16.94*	27.12**	-26.61**	-26.14**	-13.31**	-5.91
RGN-73 x Kranti	-26.04**	-20.52**	5.59	13.71*	68.10**	80.66**	-50.69**	-48.09**	-7.9	-5.31
RGN-73 x RL-1359	-20.14*	-15.75*	26.81**	32.08**	39.43**	49.96**	-38.35**	-36.34**	-9.23*	-4.76
RGN-73 x Geeta	-22.92**	-15.59	-0.72	-0.72	8.1	25.67**	-39.83**	-31.10**	-11.53*	-10.21*
RGN-73 x RB-50	-36.81**	-31.58**	-3.62	-2.56	17.92*	25.59**	-27.95**	-26.68**	-12.21**	-7.7
RGN-48 x RGN-145	-14.39	-4.42	-1.2	2.8	22.65**	22.78**	-27.51**	-21.30**	-11.04**	-3.46
RGN-48 x Kranti	-12.9	-7.69	-1.2	0.61	23.98**	25.39**	-26.96**	-24.08**	-7.3	-4.7
RGN-48 x RL-1359	-30.23**	-24.69**	1.8	15.65**	21.17*	22.45**	-25.65**	-21.23**	-9.40*	-4.93
RGN-48 x Geeta	-6.09	-2.4	-4.79	4.26	-1.44	6.2	-4.25	0.92	6.85	8.45*
RGN-48 x RB-50	-5.74	-0.86	-5.99	3.97	4.91	7.13	-17.29**	-11.14	-9.77*	-5.14
RGN-229x RGN-145	-22.30*	-14.62	1.21	4.7	-24.81**	-18.45**	-7.93	7.42	-18.04**	-11.23**
RGN-229 x Kranti	-18.55	-15.13	-6.67	-5.52	21.02**	32.74**	-34.55**	-26.61**	-4.47	-2
RGN-229 x RL-1359	0.78	7	4.24	17.81**	30.92**	43.50**	-44.15**	-36.27**	-11.31*	-7.14
RGN-229 x Geeta	9.24	11.59	-17.58**	-10.23	11.8	12.70*	-14.66**	-12.23	-2.78	-1.54
RGN-229 x RB-50	-4.92	-1.69	-15.76*	-7.33	22.27**	35.29**	-40.09**	-30.76**	-9.18*	-4.73
RGN-298x RGN-145	5.76	7.69	6.88	8.92	26.22**	48.68**	-50.90**	-41.03**	-11.01**	-9.26**
RGN-298 x Kranti	-29.85**	-27.13**	-0.62	-0.31	56.38**	82.32**	-56.85**	-46.27**	-4.7	2.63
RGN-298 x RL-1359	-26.12**	-27.71**	7.5	19.86**	39.32**	62.53**	-57.42**	-47.79**	-16.19**	-11.51**
RGN-298 x Geeta	-6.72	-1.19	10	18.12**	1.44	26.91**	-46.93**	-29.37**	-9.84*	-1.72
RGN-298 x RB-50	-14.18	-10.16	16.88**	26.78**	75.63**	103.08**	-63.84**	-56.18**	-12.05**	-7.32*
RGN-303 xRGN-145	-27.70**	-25.44**	-9.09	-2.44	131.53**	172.72**	-72.98**	-67.85**	-9.82*	-8.79*
RGN-303 x Kranti	-37.16**	-31.62**	28.57**	40.82**	47.54**	72.01**	-54.07**	-43.31**	-4.92	1.62
RGN-303 x RL-1359	-27.03**	-22.02**	48.87**	52.31**	10.7	29.15**	-38.24**	-24.95**	-4.54	0
RGN-303 x Geeta	-17.57**	-8.61	17.39*	19.56**	34.40**	68.14*	-57.41**	-43.76**	-4.54	3.27
RGN-303 x RB-50	-6.76	2.22	39.26**	40.30**	-6.83	7.74	-36.62**	-23.88**	-20.42**	-16.80**
Bio-902 x RGN-145	-12.68	-11.74	-22.22**	-10.80*	-7.37	1.5	-27.023**	-22.26**	-22.58**	-20.26**
Bio-902 x Kranti	-34.86**	-30.45**	-30.43**	-21.74**	-4.42	5.9	-21.86**	-20.37**	-22.22**	-15.44**
Bio-902 x RL-1359	-19.72*	-15.87*	-33.33**	-17.37**	12.42	24.48**	-35.99**	-33.48**	-21.86**	-16.69**
Bio-902 x Geeta	-40.14**	-34.87**	-21.74**	-6.09	14.61*	16.82**	-30.79**	-25.66**	-20.39**	-12.42**
Bio-902 x RB-50	-22.89**	-17.05*	-15.46**	2.34	-47.45**	-41.27**	36.11**	43.48**	-20.02**	-14.91**
RGN-236x RGN-145	-15.03	-10.96	-22.75**	-19.63**	16.37*	29.86**	-37.90**	-24.91**	-8.50*	0.22
RGN-236 x Kranti	-13.73	-4.69	-0.6	1.22	7.19	20.93**	-24.87**	-12.52	4.07	8.04
RGN-236 x RL-1359	-15.03	-7.8	0.6	14.29*	6.63	20.21**	-26.54**	-13.03	0.49	6.45
RGN-236 x Geeta	-28.76**	-19.85*	-3.59	5.57	8.73	13.05*	-9.62	-3.08	7.73	10.43*
RGN-236 x RB-50	-13.73	-4	-4.79	5.3	-11.52	0.67	-18.00*	-1.74	-4.11	1.78
Rohini x RGN-145	-12.34	-7.85	5.84	19.41**	-10.76	-2.23	-5.02	6.11	2.07	4.55
Rohini x Kranti	-10.71	1.08	1.86	17.14**	-12.61	-3.18	-11.7	-5.41	-10.46*	-7.5
Rohini x RL-1359	-12.99	-5.3	35.43**	39.84**	-5.54	4.58	-22.27**	-15.18*	-11.28**	-10.22**
Rohini x Geeta	-27.92**	-18.68*	24.64**	33.85**	4.97	6.99	-10.1	8.12	-5.05	-0.66
Rohini x RB-50	-13.64	-3.62	39.26**	48.03**	9.75	22.65**	-35.08**	-28.20**	-11.12*	-10.24**
GM-3 x RGN-145	-19.42*	-11.11	19.23**	20.00**	13.82*	30.22**	-44.43**	-34.38**	-15.22**	-12.08**
GM-3 x Kranti	-4.64	-0.21	18.63**	20.50**	-4.27	10.68	-24.70**	-14.48*	-5.8	-3.88
GM-3 x RL-1359	-17.05	-11.57	-3.21	6.71	-0.46	15.02*	-35.90**	-25.95**	-12.72**	-12.65**
GM-3 x Geeta	0	2.59	8.33	14.97*	7.02	14.33*	-21.55*	-18.17*	-8.41	-5.34
GM-3 x RB-50	-9.84	-6.38	8.97	16.84**	-21.95**	-9.01	-16.57*	-2.4	-11.42*	-11.17*
S.E. diff.	**1.6**	**1.38**	**0.33**	**0.29**	**11.09**	**9.6**	**2.6**	**2.25**	**2.2**	**1.91**
CD at 5%	**3.17**	**2.75**	**0.66**	**0.57**	**22.01**	**19.06**	**5.16**	**4.47**	**4.38**	**3.79**
CD at 1%	**4.2**	**3.64**	**0.88**	**0.76**	**29.13**	**25.23**	**6.83**	**5.91**	**5.79**	**5.02**

*and ** indicate significant at 5 and 1 percent levels, respectively, BP: Heterobeltiosis/Better parent Heterosis