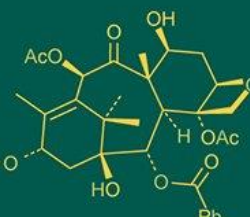


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Heterosis and inbreeding depression for seed yield and yield traits in Indian mustard (*Brassica juncea* L. Czern & Coss.)

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Abstract

The present investigation entitled “Heterosis and inbreeding depression for yield and yield traits in Indian mustard (*Brassica juncea* L. Czern & Coss.)” was conducted at the Nidharia Agriculture Farm of Shri Murali Manohar Town (P.G.) College, Ballia (U.P.) to estimate heterosis and inbreeding depression for yield and related traits in Indian mustard. Eight parental lines namely Maya, Aashirvaad, Azad-Mahak, Kranti, Basanti, Rohini, Varuna and Urvashi were crossed in an 8 × 8 full diallel mating design following Hayman’s approach. The parental lines were sown during November 2021 to produce 28 F₁s along with 28 reciprocal crosses. During November 2022, hybrids including reciprocal crosses were sown for maintenance and development of F₂ seed. During November 2023, parents, F₁s including reciprocals and F₂ populations were evaluated in a Randomized Block Design with three replications. Observations were recorded on days to flowering, plant height, number of primary branches per plant, number of secondary branches per plant, number of siliques per plant on main raceme, days to maturity, biological yield, number of seeds per silique, test weight, harvest index, oil content and seed yield per plant. Considerable heterosis was observed for seed yield and related traits. The highest better parent heterosis for seed yield per plant was recorded in Maya × Basanti followed by Aashirvaad × Basanti and Basanti × Urvashi, while the highest mid parent heterosis was observed in Maya × Rohini followed by Maya × Azad-Mahak and Azad-Mahak × Urvashi. Moderate inbreeding depression was observed only in reciprocal crosses, particularly in Varuna × Maya followed by Urvashi × Maya and Urvashi × Kranti.

Keywords: Indian mustard, Heterosis, inbreeding depression, full diallel analysis, Hayman approach, seed yield, yield traits, reciprocal crosses

Introduction

Brassica juncea is one of the most important oilseed crops cultivated in India and several other countries of the world. The crop belongs to the family Brassicaceae and occupies a significant place among edible oilseed crops because of its adaptability under diverse climatic conditions. Rapeseed-mustard group ranks third among global oilseed crops after soybean and palm. Vegetable oils obtained from oilseed crops are essential for human nutrition and also serve as raw materials for industrial products such as biodiesel, lubricants and pharmaceuticals. Increasing population, urbanization and changing dietary habits have continuously increased the global demand for edible oils.

India is one of the major consumers and importers of edible oils. Countries like Indonesia and Malaysia dominate palm oil trade, whereas Argentina is well known for soybean oil export. During 2024-25, global oilseed production was estimated to exceed 690 million tonnes due to expansion in soybean, rapeseed and sunflower cultivation. In India, rapeseed-mustard is cultivated mainly during the Rabi season and contributes substantially to the national oilseed economy. The crop covers more than 9 million hectares with productivity around 1.4 tonnes per hectare. Rajasthan occupies the leading position in production followed by Madhya Pradesh, Uttar Pradesh and Haryana. In eastern Uttar Pradesh, Ballia district has emerged as an important mustard-growing region because of suitable agro-climatic conditions.

Mustard seed contains approximately 30-42 percent oil and the residual cake is rich in protein. Besides its nutritional importance, mustard possesses medicinal value due to the

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presence of vitamins, minerals and antioxidants. However, traditional Indian mustard genotypes often contain high levels of erucic acid and glucosinolates, which adversely affect oil quality and meal suitability. Therefore, improving seed quality along with enhancement of yield has become a major objective in mustard breeding programmes.

The yield potential of presently cultivated varieties remains comparatively low because of their susceptibility to diseases, insect pests and environmental stresses. Development of high-yielding and stable varieties with better oil quality is therefore essential for achieving self-sufficiency in edible oil production. Understanding the nature of gene action controlling yield and its components is necessary for effective crop improvement. The principles of quantitative inheritance proposed by Ronald A. Fisher, J. B. S. Haldane and Sewall Wright later provided the basis for combining ability and heterosis studies. Combining ability analysis helps in identifying desirable parents and superior cross combinations for breeding programmes. Therefore, the present investigation was undertaken to study combining ability and heterosis for yield and related traits in Indian mustard.

Materials and Methods

The present investigation was conducted during Rabi seasons of 2021-22 to 2023-24 at the Nidharia Agricultural Farm of Shri Murli Manohar Town Post Graduate College. The experimental material comprised eight diverse parents of *Brassica juncea* namely Maya, Aashirvaad, Azad-Mahak, Kranti, Basanti, Rohini, Varuna and Urvashi collected from the Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture and Technology. These genotypes differed for flowering, maturity, plant height, branching pattern, silique formation, oil content and seed yield.

The crossing programme was carried out in a full diallel design including reciprocal crosses following the method of Singh and Chaudhary (1985) based on Hayman's approach. The parents were sown on 17 November and 24 November 2021 to synchronize flowering and to obtain 28 F₁s along with 28 reciprocal crosses. During 2022-23, parents and hybrids were again planted for maintenance and development of F₂ populations through selfing.

The final experimental material consisting of eight parents, 56 F₁s including reciprocals and their corresponding 56 F₂s was evaluated during Rabi 2023-24 in a Randomized Block Design with three replications. Sowing was done on 18 November 2023 in two rows of four metre length with spacing of 50 cm × 25 cm. Recommended agronomic practices were followed throughout the experiment.

Observations were recorded on days to flowering, plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of siliques per plant on main raceme, days to maturity, biological yield per plant (g), number of seeds per silique, test weight (g), harvest index (%), oil content (%) and seed yield per plant (g).

Heterobeltiosis was estimated as the superiority of F₁ over the better parent using the following formula:

$$HB(\%) = \frac{F_1 - BP}{BP} \times 100$$

The significance of heterosis was tested using standard error and critical difference values calculated as:

$$S.E. = \sqrt{\frac{2M_e}{r}}$$

$$C.D. = S.E. \times t$$

Inbreeding depression was estimated by comparing F₂ performance with F₁ using the formula:

$$\text{Inbreeding Depression}(\%) = \frac{F_1 - F_2}{F_1} \times 100$$

The genetic components of heterobeltiosis were partitioned according to Jinks and Jones (1958) as:

$$\text{Heterobeltiosis} = F_1 - P_0 = (h - i) - (d - \frac{1}{2}j)$$

The variance associated with heterobeltiosis was estimated as:

$$V(\text{Heterobeltiosis}) = V_h + V_i + V_d + \frac{1}{2}V_j$$

Results and Discussion

The present investigation was conducted at the Nidharia Farm of Shri Murli Manohar Town Post Graduate College using eight diverse genotypes of *Brassica juncea* in a full diallel mating design including direct and reciprocal crosses. The parents along with their F₁ hybrids were evaluated in a Randomized Block Design with replications under field conditions. Observations were recorded on twelve important agronomic traits related to flowering, maturity, yield and oil content.

The study revealed considerable heterosis and inbreeding depression for all the characters, indicating the involvement of both additive and non-additive gene actions. For days to 50% flowering and maturity, crosses such as Varuna × Aashirvaad and Azad-Mahak × Kranti exhibited desirable negative heterosis indicating earliness. Plant height showed both positive and negative heterosis, where Kranti × Maya exhibited maximum positive heterosis while Aashirvaad × Basanti showed desirable negative heterosis for lodging resistance.

High positive heterosis for primary and secondary branches was observed in Basanti × Maya and Aashirvaad × Basanti, respectively, indicating strong hybrid vigour. For siliques per plant and biological yield, Azad-Mahak × Kranti and Maya × Basanti were identified as superior crosses. Rohini × Azad-Mahak and Aashirvaad × Varuna exhibited desirable heterosis for seeds per silique and test weight, respectively. Similarly, Azad-Mahak × Varuna showed maximum heterosis for harvest index, while Aashirvaad × Basanti was superior for oil content.

Seed yield per plant exhibited high positive heterosis in Maya × Basanti followed by Aashirvaad × Basanti and Basanti × Urvashi, indicating their potential for heterosis breeding. Inbreeding depression varied widely among crosses, suggesting differential stability of hybrids in F₂ generation. Crosses showing high heterosis along with low or negative inbreeding depression may be useful for future breeding programmes aimed at developing high yielding mustard varieties.

Table 1: Combined analysis of variance for parent and hybrids (F₁s)

Sourced of variation	df	Days to 50% flowering	Plant height (cm)	No of primary branches	No of secondary branches	No of siliquae/plant on main raceme	Days to maturity	Biological yield per plant (g)	No of seeds per siliqua	Test weight (gm)	Harvest index (%)	Oil content (%)	Seed yield per plant (gm)
REP	2	3.66	63.12	3.92	6.92	29.36	4.57	6.01	1.65	0.002	8.68	5.05	1.75
Treatment	63	24.21**	149.98**	3.67**	16.42**	197.36**	16.17**	674.19**	9.33**	1.225**	50.73**	4.98**	38.66**
PAR	7	11.61**	70.51**	3.75**	19.28**	226.53**	11.98**	385.40**	14.35**	1.02**	44.02**	2.73**	9.89**
F1	55	25.88**	155.38**	3.73**	15.32**	133.81**	15.09**	688.77**	8.84**	1.27**	51.42**	5.23**	38.79**
PVF1	1	20.25**	409.22**	0.03	57.46**	3488.18**	105.18**	1893.90**	1.29	0.20	59.47**	6.85**	232.58**
EROR	126	1.09	4.97	0.21	0.40	2.88	1.28	2.30	0.42	0.11	0.96	0.04	0.46
Total	191	8.90	53.40	1.39	5.75	67.31	6.23	223.95	3.37	0.480	17.46	1.72	13.07

*, ** significant at 5% and 1% level, respectively

Table 2: Analysis of variance (F₂s)

Sourced of variation	df	Days to 50% flowering	Plant height (cm)	No of primary branches	No of secondary branches	No of siliquae/plant on main raceme	Days to maturity	Biological yield per plant (g)	No of seeds per siliqua	Test weight (gm)	Harvest index (%)	Oil content (%)	Seed yield per plant (gm)
Replication	2	1.90	5.96	3.22	4.66	13.77	0.64	3.56	5.11	0.34	11.37	0.83	3.91
Treatment	55	31.64**	337.21**	12.19**	27.02**	217.25**	23.22**	428.20**	7.56**	1.46**	142.08**	4.80**	36.51**
Error	110	1.60	4.49	0.33	0.73	1.74	0.92	2.47	0.64	0.09	1.67	0.08	0.50
Total	167	11.66	114.69	4.27	9.43	72.86	8.26	142.69	2.97	0.54	48.03	1.64	12.40

*, ** significant at 5% and 1% level, respectively

Table 3: Mean performance of parents F₁ hybrids and reciprocals

S.N	Parent/Hybrids	Days to 50% flowering	Plant height (cm)	No of primary branches	No of secondary branches	No of siliquae/plant on main raceme	Days to maturity	Biological yield per plant (g)	No of seeds per siliqua	Test weight (gm)	Harvest index (%)	Oil content (%)	Seed yield per plant (gm)
	Parents												
P1	Maya	72.00	190.91	4.67	10.33	70.17	129.33	60.93	14.60	4.38	33.04	38.14	20.13
P2	Aashirvaad	73.33	196.97	4.67	9.07	76.40	130.67	71.67	10.99	3.99	28.18	39.06	20.18
P3	Azad-Mahak	69.00	197.63	5.40	10.67	69.67	132.33	72.21	12.75	3.83	28.36	37.36	20.47
p4	Kranti	71.33	194.69	5.87	11.27	67.13	126.00	69.02	12.57	5.00	25.01	40.67	17.27
p5	Basanti	69.67	194.27	4.27	9.33	69.87	124.67	69.20	10.72	4.96	17.97	38.49	12.44
p6	Rohini	68.00	191.60	4.53	10.80	77.80	126.33	78.03	14.01	4.77	23.21	36.95	18.11
p7	Varuna	71.67	205.05	5.53	11.33	82.07	130.00	77.67	17.48	4.63	23.63	39.96	18.32
p8	Urvashi	66.33	190.00	4.53	11.13	77.60	130.00	70.13	12.72	4.53	25.36	38.38	17.76
	Mean	70.17	195.14	4.93	10.49	73.84	128.67	71.11	13.23	4.51	25.60	38.63	18.09
	Min	66.33	190.00	4.27	9.07	67.13	124.67	60.93	10.72	3.83	17.97	36.95	12.44
	Max	73.33	205.05	5.87	11.33	82.07	132.33	78.03	17.48	5.00	33.04	40.67	20.47
	F1 Hybrids (Direct)												
p1p2	Maya X Aashirvaad	71.00	186.13	6.73	15.60	45.80	125.33	72.67	12.71	5.36	24.19	39.45	17.58
p1p3	Maya X Azad-Mahak	70.67	196.09	4.73	10.87	61.93	124.67	78.27	9.90	5.13	24.13	38.29	18.88
p1p4	Maya X Kranti	69.00	199.33	4.67	10.85	59.47	124.33	62.75	14.16	4.34	24.51	38.74	15.39
p1p5	Maya X Basanti	69.33	197.05	6.67	13.98	71.07	124.33	97.24	8.19	6.02	20.60	37.33	20.03
p1p6	Maya X Rohini	72.00	200.57	7.47	16.97	71.13	123.00	81.17	13.09	5.31	23.44	36.70	19.02
p1p7	Maya X Varuna	73.67	195.37	5.27	10.65	66.44	127.00	73.54	11.09	4.59	21.57	36.87	15.86
p1p8	Maya X Urvashi	74.67	199.07	6.40	12.47	69.40	126.67	76.30	12.77	5.36	22.22	37.41	16.96
p2p3	Aashirvaad X Azad-Mahak	68.67	201.42	7.07	14.20	70.89	125.00	96.51	12.25	4.90	21.08	40.27	20.34
p2p4	Aashirvaad X Kranti	71.00	202.89	6.80	14.73	82.29	126.33	93.03	10.28	5.24	20.12	38.76	18.72
p2p5	Aashirvaad X Basanti	71.67	185.21	7.40	15.93	76.97	129.33	83.53	12.39	4.65	23.59	41.38	19.70
p2p6	Aashirvaad X Rohini	72.33	187.22	6.60	14.27	84.00	126.00	104.50	13.32	5.52	16.57	40.48	17.30
p2p7	Aashirvaad X Varuna	71.00	197.37	6.40	13.33	77.13	128.67	78.69	10.99	6.23	19.92	38.99	15.87
p2p8	Aashirvaad X Urvashi	77.00	189.79	6.53	14.40	84.72	130.33	69.53	12.08	5.02	23.49	38.38	16.34
p3p4	Azad-Mahak X Kranti	71.67	201.76	5.73	12.60	86.46	123.67	75.40	12.64	5.11	20.72	37.19	15.61
p3p5	Azad-Mahak X Basanti	73.33	197.19	5.40	11.60	82.86	126.00	60.00	13.68	5.51	12.53	36.92	7.53
p3p6	Azad-Mahak X Rohini	75.00	198.60	4.80	9.73	78.80	125.33	46.10	12.32	5.25	24.21	39.51	11.16
p3p7	Azad-Mahak X Varuna	73.00	204.80	4.67	10.17	87.17	126.33	42.61	14.19	5.25	23.09	37.49	9.84
p3p8	Azad-Mahak X Urvashi	72.33	205.36	5.67	12.98	81.13	127.33	57.64	12.92	5.30	22.94	38.55	13.23
p4p5	Kranti X Basanti	69.67	204.36	5.47	10.45	80.20	126.67	49.50	12.89	5.86	23.15	37.23	11.46
p4p6	Kranti X Rohini	68.33	214.87	4.80	9.87	66.53	125.33	53.47	10.44	6.29	20.74	36.84	11.09
p4p7	Kranti X Varuna	69.00	193.29	6.13	9.80	65.80	125.33	45.49	11.75	4.93	26.62	37.46	12.11
p4p8	Kranti X Urvashi	68.67	185.43	4.60	9.27	74.06	126.67	51.85	12.59	5.25	22.31	38.20	11.57
p5p6	Basanti X Rohini	72.33	200.10	6.13	12.03	78.97	127.67	78.85	12.67	5.25	23.77	38.28	18.72
p5p7	Basanti X Varuna	77.33	192.84	5.93	14.05	88.07	129.00	96.46	13.19	4.75	18.80	41.65	18.12
p5p8	Basanti X Urvashi	72.33	195.56	6.20	13.73	77.38	128.33	77.52	11.89	4.93	24.44	35.76	18.95
p6p7	Rohini X Varuna	72.33	197.90	6.80	16.48	81.40	130.67	81.83	14.21	5.77	24.33	38.90	19.90
p6p8	Rohini X Urvashi	72.67	206.21	7.07	16.12	87.80	130.33	86.87	13.57	4.72	16.63	38.36	14.44
p7p8	Varuna X Urvashi	69.67	204.90	4.80	9.85	84.47	128.00	65.49	11.57	5.58	21.69	37.26	14.20
	Mean	71.77	197.88	5.96	12.75	75.80	126.70	72.74	12.28	5.27	21.84	38.31	15.71
	Min	68.33	185.21	4.60	9.27	45.80	123.00	42.61	8.19	4.34	12.53	35.76	7.53
	Max	77.33	214.87	7.47	16.97	88.07	130.67	104.50	14.21	6.29	26.62	41.65	20.34
	F1 RECiprocal												
p2p1	Aashirvaad X Maya	75.33	211.99	4.80	9.67	68.80	129.33	46.91	11.53	3.92	33.51	38.99	15.71
p3p1	Azad-Mahak X Maha	66.33	192.36	5.67	9.40	76.07	131.00	65.56	15.27	4.89	31.96	36.71	20.94
p3p2	Azad-Mahak X Aashirvaad	68.67	189.76	7.73	12.00	71.27	125.33	63.96	14.19	3.46	24.65	37.74	15.77

p4p1	Kranti X Maya	67.00	218.33	4.87	8.07	79.67	130.00	55.57	12.78	4.88	23.31	37.03	12.95
p4p2	Kranti X Aashirvaad	70.00	207.97	5.20	9.27	78.42	129.33	57.41	12.16	5.72	23.57	38.62	13.53
p4p3	Kranti X Azad-Mahak	76.67	197.74	5.67	9.89	66.47	124.67	50.94	11.12	4.64	20.16	37.97	10.27
p5p1	Basanti X Maya	73.33	204.80	9.73	8.40	79.27	129.33	57.93	10.64	5.49	22.13	39.89	12.83
p5p2	Basanti X Aashirvaad	74.33	198.73	5.73	8.60	68.00	126.33	52.62	11.48	6.01	19.78	38.12	10.41
p5p3	Basanti X Azad-Mahak	70.67	204.31	5.07	8.73	73.46	126.67	56.58	11.12	5.00	23.80	38.89	13.47
p5p4	Basanti X Kranti	68.00	204.03	4.93	6.13	75.62	125.33	50.64	11.96	3.69	22.84	40.47	11.56
p6p1	Rohini X Maya	70.67	194.64	6.00	9.88	78.80	130.33	50.97	12.81	5.89	20.78	39.59	10.58
p6p2	Rohini X Aashirvaad	68.33	198.33	6.00	10.33	76.73	126.33	52.56	13.55	4.67	23.72	38.20	12.46
p6p3	Rohini X Azad-Mahak	70.00	204.40	5.27	9.20	75.53	126.67	57.62	19.31	5.63	19.52	37.06	11.24
p6p4	Rohini X Kranti	67.67	198.35	5.27	8.33	77.63	126.33	58.92	11.47	5.27	20.36	37.69	11.99
p6p5	Rohini X Basanti	71.67	196.63	5.87	8.80	83.80	129.33	64.86	10.39	4.80	19.04	38.91	12.34
p7p1	Varuna X Maya	66.67	210.90	5.80	11.89	77.97	132.33	74.61	11.63	3.91	22.36	38.15	16.69
p7p2	Varuna X Aashirvaad	66.67	208.98	8.93	10.94	82.23	125.67	41.71	11.40	4.10	22.52	37.56	9.38
p7p3	Varuna X azad-Mahak	67.33	198.49	8.63	13.67	57.87	126.00	52.98	10.87	4.92	31.34	37.46	16.60
p7p4	Varuna X Kranti	67.67	210.83	5.80	10.53	75.30	126.33	45.13	9.44	4.22	25.29	41.53	11.18
p7p5	Varuna X Basanti	73.67	208.14	5.87	10.40	66.47	131.00	46.37	10.16	4.60	23.11	38.53	10.71
p7p6	Varuna X Rohini	75.33	194.83	6.00	11.50	86.60	131.67	78.66	11.55	4.79	14.58	38.35	11.47
p8p1	Urvashi X Maya	71.33	201.04	4.93	10.53	88.45	131.00	61.46	12.80	4.98	29.26	36.82	17.98
p8p2	Urvashi X Aashirvaad	69.00	203.19	6.73	10.91	82.93	129.00	60.25	11.24	6.11	24.06	39.02	14.49
p8p3	Urvashi X Azad-Mahak	67.67	194.36	6.20	14.53	84.68	127.00	79.23	11.91	3.86	22.66	38.11	17.95
p8p4	Urvashi X Kranti	67.33	208.86	5.73	10.23	74.55	128.33	82.70	9.71	4.77	23.41	37.25	19.35
p8p5	Urvashi X Basanti	67.67	200.12	6.27	10.00	75.49	125.67	72.03	10.71	5.16	22.81	39.16	16.43
p8p6	Urvashi X Rohini	66.67	198.36	4.27	9.93	71.80	126.00	64.52	13.39	4.35	12.09	39.49	7.80
p8p7	Urvashi X Varuna	67.00	200.90	5.53	8.40	78.07	129.33	82.74	11.80	5.23	16.55	36.42	13.69
	Mean	69.74	202.19	6.02	10.01	76.14	128.06	60.19	12.01	4.82	22.83	38.35	13.56
	Min	66.33	189.76	4.27	6.13	57.87	124.67	41.71	9.44	3.46	12.09	36.42	7.80
	Max	76.67	218.33	9.73	14.53	88.45	132.33	82.74	19.31	6.11	33.51	41.53	20.94
	Mean all	70.73	199.31	5.83	11.30	75.40	127.55	67.44	12.31	4.97	22.76	38.39	15.13
	Min	66.33	185.21	4.27	6.13	45.80	123.00	41.71	8.19	3.46	12.09	35.76	7.53
	Max	77.33	218.33	9.73	16.97	88.45	132.33	104.50	19.31	6.29	33.51	41.65	20.94
	SE(d)±	0.85	1.82	0.38	0.51	1.39	0.92	1.24	0.53	0.28	0.80	0.17	0.55
	C.D. at 5%	1.69	3.60	0.74	1.02	2.75	1.83	2.45	1.05	0.55	1.59	0.34	1.09
	C.V. (%)	1.48	1.12	7.85	5.58	2.24	0.89	2.26	5.28	6.80	4.31	0.54	4.48

Table 4: Mean performance F₂ hybrids and reciprocals

S.N	Parent/Hybrids	Days to 50% flowering	Plant height (cm)	No of primary branches	No of secondary branches	No of siliquae/plant on main raceme	Days to maturity	Biological yield per plant (g)	No of seeds per siliqua	Test weight (gm)	Harvest index (%)	Oil content (%)	Seed yield per plant (gm)
	F1 Hybrids (Direct)												
p1p2	Maya X Aashirvaad	67.33	182.35	7.00	8.73	70.20	129.67	36.26	11.95	5.38	45.12	38.29	16.36
p1p3	Maya X Azad-Mahak	71.67	184.47	5.13	9.67	75.47	132.67	59.93	11.39	3.78	23.20	36.19	13.90
p1p4	Maya X Kranti	70.67	186.54	13.87	10.67	72.27	125.33	60.23	12.27	4.23	31.11	38.56	18.72
p1p5	Maya X Basanti	65.67	192.98	5.20	9.53	69.95	125.67	48.90	11.65	3.64	30.76	37.82	15.04
p1p6	Maya X Rohini	68.33	188.72	6.20	9.73	86.19	130.00	52.67	11.41	4.97	27.54	41.06	14.51
p1p7	Maya X Varuna	70.33	198.98	4.80	9.00	72.75	127.33	52.53	12.28	5.59	27.82	39.88	14.60
p1p8	Maya X Urvashi	73.67	192.81	5.27	10.80	78.49	134.00	67.57	12.80	3.65	31.38	38.90	21.20
p2p3	Aashirvaad X Azad-Mahak	70.00	202.76	7.01	12.43	71.35	124.33	86.34	13.60	4.08	27.25	37.09	23.53
p2p4	Aashirvaad X Kranti	73.67	207.42	5.33	11.87	69.60	131.00	87.12	11.52	3.83	23.97	37.16	20.88
p2p5	Aashirvaad X Basanti	70.00	164.83	6.60	9.47	55.24	124.67	55.98	16.00	3.92	36.71	37.68	20.54
p2p6	Aashirvaad X Rohini	74.00	191.94	5.20	9.33	69.40	129.00	53.67	12.56	4.69	34.18	38.91	18.34
p2p7	Aashirvaad X Varuna	70.00	182.26	5.00	10.73	74.69	126.67	43.44	12.55	5.24	47.05	40.08	20.44
p2p8	Aashirvaad X Urvashi	72.33	189.36	5.47	11.73	71.43	126.00	50.89	16.69	3.75	22.00	41.90	11.18
p3p4	Azad-Mahak X Kranti	68.00	198.85	4.63	8.00	68.87	124.33	62.25	12.60	4.68	34.26	38.13	21.32
p3p5	Azad-Mahak X Basanti	75.33	198.53	6.80	11.73	77.29	129.33	71.52	14.55	4.61	27.87	37.10	19.91
p3p6	Azad-Mahak X Rohini	69.33	189.13	5.90	11.00	74.85	125.67	50.94	10.55	3.63	37.48	37.19	19.09
p3p7	Azad-Mahak X Varuna	77.33	198.95	5.40	11.94	84.21	126.33	74.39	14.07	3.94	29.52	38.85	21.96
p3p8	Azad-Mahak X Urvashi	72.33	195.50	5.67	9.95	79.40	130.33	55.16	12.77	3.90	37.70	37.13	20.79
p4p5	Kranti X Basanti	76.33	197.75	12.73	9.07	66.77	129.33	51.31	10.21	3.25	34.55	38.21	17.73
p4p6	Kranti X Rohini	74.00	187.02	5.60	9.41	64.89	126.67	62.63	11.85	3.92	34.42	40.95	21.56
p4p7	Kranti X Varuna	66.67	193.23	6.07	12.33	69.07	127.00	65.64	13.12	5.12	30.80	38.01	20.21
p4p8	Kranti X Urvashi	76.00	184.64	7.87	13.43	64.28	125.00	49.87	15.47	4.45	36.45	37.96	18.18
p5p6	Basanti X Rohini	75.00	209.86	4.00	9.80	90.84	131.67	61.78	15.87	3.61	33.32	38.08	20.57
p5p7	Basanti X Varuna	75.67	216.49	10.73	20.67	78.60	128.33	77.33	14.60	4.91	27.95	36.14	21.62
p5p8	Basanti X Urvashi	77.33	196.87	6.40	11.33	73.93	131.00	74.40	12.28	3.55	19.77	37.82	14.71
p6p7	Rohini X Varuna	73.33	197.01	5.93	14.80	75.07	135.33	62.92	10.60	4.43	13.69	39.90	8.60
p6p8	Rohini X Urvashi	69.00	214.99	5.95	8.30	79.09	130.00	79.67	14.95	4.78	25.27	38.78	20.12
p7p8	Varuna X Urvashi	76.67	205.18	10.27	14.87	59.00	125.67	64.23	13.50	3.56	36.83	39.58	23.63
	Mean	72.14	194.62	6.64	11.08	72.97	128.30	61.41	12.99	4.25	31.00	38.48	18.54
	Min	65.67	164.83	4.00	8.00	55.24	124.33	36.26	10.21	3.25	13.69	36.14	8.60
	Max	77.33	216.49	13.87	20.67	90.84	135.33	87.12	16.69	5.59	47.05	41.90	23.63
	F1 REciprocal												
p2p1	Aashirvaad X Maya	67.00	214.10	8.47	16.54	96.24	132.67	74.05	14.40	5.06	24.73	39.24	18.31
p3p1	Azad-Mahak X Maha	67.33	209.99	6.07	9.16	94.23	125.00	60.17	10.80	4.90	21.52	37.13	12.95
p3p2	Azad-Mahak X Aashirvaad	69.00	199.46	6.00	11.40	83.31	124.33	50.60	11.60	3.97	31.42	40.16	15.90
p4p1	Kranti X Maya	69.00	196.01	6.80	15.93	73.98	127.00	50.39	10.92	3.65	26.42	39.34	13.30
p4p2	Kranti X Aashirvaad	68.33	204.39	8.27	11.76	82.60	126.33	63.04	10.68	4.73	19.98	38.55	12.59
p4p3	Kranti X Azad-Mahak	68.33	193.71	8.81	10.07	79.60	125.33	55.68	10.85	3.18	24.80	37.32	13.80
p5p1	Basanti X Maya	71.33	194.53	5.77	12.53	91.52	129.67	89.05	9.72	3.92	15.58	37.61	13.87
p5p2	Basanti X Aashirvaad	69.00	200.53	6.00	9.80	70.00	128.33	52.60	11.03	3.49	21.08	38.03	11.07
p5p3	Basanti X Azad-Mahak	72.00	212.39	5.93	11.67	82.13	130.67	43.65	10.82	3.90	33.15	39.76	14.34
p5p4	Basanti X Kranti	67.00	217.09	8.02	11.40	81.50	128.00	56.92	14.79	4.24	21.59	37.81	12.29
p6p1	Rohini X Maya	72.67	208.33	6.13	11.47	57.79	127.00	64.28	12.38	4.85	22.23	39.58	14.29
p6p2	Rohini X Aashirvaad	75.00	205.66	5.80	11.69	63.53	125.00	61.48	13.04	3.97	22.18	37.67	13.63
p6p3	Rohini X Azad-Mahak	68.33	198.46	6.80	10.00	69.91	125.33	61.72	11.41	3.73	24.81	38.12	15.30

p6p4	Rohini X Kranti	67.00	201.60	5.80	9.00	68.30	129.00	62.46	11.15	4.98	33.60	37.63	20.97
p6p5	Rohini X Basanti	71.67	189.13	6.93	13.67	80.60	131.67	94.03	12.95	3.53	18.10	41.29	17.02
p7p1	Varuna X Maya	70.33	202.80	7.80	16.27	71.05	125.00	76.08	12.48	5.35	18.79	37.97	14.29
p7p2	Varuna X Aashirvaad	66.67	198.60	6.07	15.88	66.44	128.00	55.87	12.37	4.37	37.37	38.41	20.87
p7p3	Varuna X azad-Mahak	68.00	199.91	8.80	11.00	76.44	125.33	75.41	13.74	4.71	25.68	39.05	19.36
p7p4	Varuna X Kranti	67.33	189.67	12.00	18.40	79.27	131.00	58.16	13.20	3.50	27.11	36.70	15.77
p7p5	Varuna X Basanti	76.00	210.75	8.89	11.78	85.06	128.33	65.98	14.59	4.07	25.37	37.25	16.73
p7p6	Varuna X Rohini	75.00	196.57	7.47	9.89	71.62	131.67	66.66	13.03	5.85	23.47	39.13	15.64
p8p1	Urvashi X Maya	72.00	173.99	6.00	12.27	64.80	124.67	60.00	12.37	3.90	24.83	38.61	14.90
p8p2	Urvashi X Aashirvaad	73.00	196.81	7.73	11.53	74.47	124.67	61.40	13.37	3.58	25.74	37.33	15.81
p8p3	Urvashi X Azad-Mahak	71.33	205.60	6.93	18.53	69.33	128.33	53.23	15.04	4.95	26.05	37.96	13.87
p8p4	Urvashi X Kranti	71.00	187.11	5.40	10.27	68.87	124.33	60.68	13.45	3.90	25.78	37.56	15.66
p8p5	Urvashi X Basanti	66.67	196.03	9.20	21.15	73.87	130.67	66.23	12.04	5.30	27.80	37.23	18.40
p8p6	Urvashi X Rohini	73.00	216.76	8.87	15.47	78.13	129.00	81.71	12.34	6.01	19.55	39.88	15.97
p8p7	Urvashi X Varuna	69.00	197.44	5.73	11.62	70.23	127.33	61.66	13.68	4.79	21.92	39.16	13.51
	Mean	70.08	200.62	7.23	12.86	75.89	127.63	63.69	12.44	4.37	24.67	38.41	15.37
	Min	66.67	173.99	5.40	9.00	57.79	124.33	43.65	9.72	3.18	15.58	36.70	11.07
	Max	76.00	217.09	12.00	21.15	96.24	132.67	94.03	15.04	6.01	37.37	41.29	20.97
	Mean all	71.11	197.62	6.94	11.97	74.43	127.96	62.55	12.71	4.31	27.83	38.44	16.96
	Min	65.67	164.83	4.00	8.00	55.24	124.33	36.26	9.72	3.18	13.69	36.14	8.60
	Max	77.33	217.09	13.87	21.15	96.24	135.33	94.03	16.69	6.01	47.05	41.90	23.63
	SE(d)±	1.03	1.73	0.47	0.70	1.08	0.78	1.28	0.65	0.24	1.06	0.23	0.58
	C.D. at 5%	2.05	3.44	0.94	1.38	2.14	1.56	2.55	1.29	0.48	2.09	0.45	1.15
	C.V. (%)	1.78	1.07	8.32	7.12	1.77	0.75	2.51	6.28	6.82	4.64	0.73	4.19

Table 5: Heterosis for hybrids

Var	Hybrids	Days to 50% Flowering			Plant Height (cm)			No of Primary Branches			No of Secondar-y Branches		
		BP	MP	IDB	BP	MP	IDB	BP	MP	IDB	BP	MP	IDB
p1p2	Maya X Aashirvaad	-2.29	-3.18	5.16**	-4.03 **	-5.50	2.03	44.29 **	44.29 **	-3.97	60.82 **	50.97 **	44.02**
p1p3	Maya X Azad-Mahak	0.24 **	-1.85 **	-1.42	0.94	-0.78	5.93**	-5.96	-12.35	-8.45	3.49	1.88	11.04
p1p4	Maya X Kranti	-3.72 **	-4.17 **	-2.42*	3.39 **	2.38 **	6.41**	-11.39	-20.45 **	-197.13**	0.43 **	-3.73 **	1.66
p1p5	Maya X Basanti	-2.12	-3.70	5.29**	2.31 **	1.43 **	2.06	49.25 **	42.86 **	22.00**	42.17 **	35.29	31.81**
p1p6	Maya X Rohini	2.86	0.00	5.09**	4.87 **	4.68 **	5.91**	62.32 **	60.00 **	16.97**	60.63 **	57.16 **	42.66**
p1p7	Maya X Varuna	2.55 *	2.31 *	4.53**	-1.32 **	-4.72	-1.84	3.27	-4.82	8.87	-1.72	-6.06	15.47*
p1p8	Maya X Urvashi	7.95 **	3.70	1.34	4.52 **	4.27 **	3.14*	39.13 **	37.14 **	17.61**	16.15	11.98	13.37
p2p1	Aashirvaad X Maya	3.67	2.73	11.06**	9.30 **	7.62	-1.00	2.86 **	2.86 **	-76.40**	-0.34 **	-6.45 **	-71.10**
p2p3	Aashirvaad X Azad-Mahak	-3.51 **	-6.36 **	-1.94	2.09	1.92	-0.66	40.40 **	30.86 **	0.85	43.92 **	33.12 **	12.44
p2p4	Aashirvaad X Kranti	-1.84 *	-3.18 **	-3.76**	3.61 **	3.01 **	-2.23	29.11 *	15.91	21.57**	44.92 **	30.77	19.45*
p2p5	Aashirvaad X Basanti	0.23 *	-2.27	2.33*	-5.32 *	-5.97 **	11.00**	65.67 **	58.57 **	10.81	73.19 **	70.71 **	40.58**
p2p6	Aashirvaad X Rohini	2.36	-1.36 **	-2.30*	-3.64	-4.95 *	-2.52*	43.48 **	41.43 **	21.21**	43.62 **	32.10 **	34.58**
p2p7	Aashirvaad X Varuna	-2.07 **	-3.18 **	1.41	-1.81	-3.75	7.66**	25.49 **	15.66 **	21.88**	30.72 **	17.65	19.50*
p2p8	Aashirvaad X Urvashi	10.26 **	5.00	6.06**	-1.91	-3.65	0.23	42.03 **	40.00 **	16.32**	42.57 **	29.34 **	18.52*
p3p1	Azad-Mahak X Maha	-5.91 **	-7.87 **	-1.51	-0.98	-2.67	-9.16**	12.58	4.94	-7.06	-10.48	-11.87	2.55
p3p2	Azad-Mahak X Aashirvaad	-3.51 **	-6.36 **	-0.48	-3.82	-3.98	-5.11**	53.64 **	43.21 **	22.41**	21.62 **	12.50 **	5.00
p3p4	Azad-Mahak X Kranti	2.14 **	0.47 **	5.12**	2.85 *	2.09	1.44	1.78	-2.27	19.19**	14.89	11.83	36.51**
p3p5	Azad-Mahak X Basanti	5.77 **	5.26 **	-2.73*	0.63 **	-0.23	-0.68	11.72	0.00	-25.93**	16.00	8.75	-1.15
p3p6	Azad-Mahak X Rohini	9.49 **	8.70 **	7.56**	2.05 **	0.49 *	4.77**	-3.36	-11.11	-22.85**	-9.32 **	-9.88 **	-13.05
p3p7	Azad-Mahak X Varuna	3.79	1.86	-5.94**	1.72	-0.12	2.86*	-14.63 **	-15.66 **	-15.71*	-7.58 *	-10.29	-17.44*
p3p8	Azad-Mahak X Urvashi	6.90 **	4.83	0.00	5.96 **	3.91	4.80**	14.09 **	4.94	0.00	19.08 **	16.59 **	23.32**
p4p1	Kranti X Maya	-6.51 **	-6.94 **	-2.99*	13.24 **	12.15 **	10.22**	-7.59	-17.05 **	-39.72**	-25.31 **	-28.40 **	-97.51**
p4p2	Kranti X Aashirvaad	-3.23 *	-4.55 **	2.38*	6.20 **	5.58 **	1.72	-1.27 *	-11.36	-58.98**	-8.85 **	-17.75	-26.87**
p4p3	Kranti X Azad-Mahak	9.26 **	7.48 **	10.87**	0.81 *	0.05	2.04	0.59	-3.41	-55.51**	-9.79	-12.19	-1.76
p4p5	Kranti X Basanti	-1.18 *	-2.34 **	-9.57**	5.08 **	4.97 **	3.24*	7.89	-6.82	-132.91**	1.42 **	-7.28 **	13.21
p4p6	Kranti X Rohini	-1.91 *	-4.21 **	-8.29**	11.25 **	10.37 **	12.96**	-7.69	-18.18 *	-16.67*	-10.57 **	-12.43 **	4.66
p4p7	Kranti X Varuna	-3.50 **	-3.72 **	3.38**	-3.29	-5.74	0.03	7.60	4.55	1.08	-13.27 *	-13.53 *	-25.85**
p4p8	Kranti X Urvashi	-0.24	-3.74 **	-10.68**	-3.59 **	-4.75	0.43	-11.54	-21.59	-71.02**	-17.26 **	-17.75 **	-44.96**
p5p1	Basanti X Maya	3.53	1.85	2.73*	6.34 **	5.42 **	5.02**	117.91 **	108.57 **	40.75**	-14.58 **	-18.71	-49.20**
p5p2	Basanti X Aashirvaad	3.96 *	1.36	7.17**	1.59 *	0.89 **	-0.91	28.36 **	22.86 **	-4.66	-6.52 **	-7.86 **	-13.95
p5p3	Basanti X Azad-Mahak	1.92 **	1.44 **	-1.89	4.26 **	3.38	-3.95**	4.83	-6.17	-17.09**	-12.67	-18.13	-33.60**
p5p4	Basanti X Kranti	-3.55 *	-4.67 **	1.47	4.91 **	4.80 **	-6.40**	-2.63	-15.91	-62.58**	-40.45 **	-45.56 **	-85.88**
p5p6	Basanti X Rohini	5.08 **	3.83 **	-3.69**	3.71 **	3.00 *	-4.88**	39.39 **	35.29 **	34.78**	19.54	11.42	18.56*
p5p7	Basanti X Varuna	9.43 **	7.91 **	2.15*	-3.42	-5.96 *	-12.26**	21.09 **	7.23	-80.90**	35.94 **	23.94	-47.13**
p5p8	Basanti X Urvashi	6.37 **	3.83	-6.91**	1.78 **	0.66 *	-0.67	40.91 **	36.76 **	-3.23	34.17 **	23.32	17.46*
p6p1	Rohini X Maya	0.95	-1.85	-2.83*	1.77 **	1.59 **	-7.03**	30.43 **	28.57 **	-2.22	-6.50 **	-8.52 **	-16.06*
p6p2	Rohini X Aashirvaad	-3.30	-6.82 **	-9.76**	2.08	0.69 *	-3.70*	30.43 **	28.57 **	3.33	4.03 **	-4.32 **	-13.16
p6p3	Rohini X Azad-Mahak	2.19 **	1.45 **	2.38*	5.03 **	3.42 *	2.91*	6.04	-2.47	-29.11**	-14.29 **	-14.81 **	-8.70
p6p4	Rohini X Kranti	-2.87 *	-5.14 **	0.99	2.69 **	1.88 **	-1.64	1.28	-10.23 *	-10.12	-24.47 **	-26.04 **	-8.00
p6p5	Rohini X Basanti	4.12 **	2.87 **	0.00	1.91 **	1.21 *	3.81**	33.33 **	29.41 **	-18.17**	-12.58	-18.52	-55.31**
p6p7	Rohini X Varuna	3.58 **	0.93 *	-1.38	-0.21	-3.49 **	0.45	35.10 **	22.89 *	12.75	48.95 **	45.44 **	10.21
p6p8	Rohini X Urvashi	8.19 **	6.86	5.05**	8.08 **	7.63 **	-4.25**	55.88 **	55.88 **	15.85*	46.99 **	44.79 **	48.51
p7p1	Varuna X Maya	-7.19 *	-7.41 *	-5.50**	6.52 **	2.85	3.84*	13.73	4.82	-34.48**	9.78	4.94	-36.78
p7p2	Varuna X Aashirvaad	-8.05 **	-9.09 **	0.00	3.96	1.91	4.97**	75.16 **	61.45 **	32.08**	7.25 **	-3.47	-45.16
p7p3	Varuna X azad-Mahak	-4.27	-6.05	-0.99	-1.42	-3.20	-0.71	57.93 **	56.02 **	-1.93	24.24 *	20.59	19.51
p7p4	Varuna X Kranti	-5.36 **	-5.58 **	0.49	5.49	2.82	10.04**	1.75	-1.14	-106.90**	-6.78 *	-7.06 *	-74.69
p7p5	Varuna X Basanti	4.25 **	2.79 **	-3.17*	4.25	1.51 *	-1.25	19.73 **	6.02	-51.58**	0.65 **	-8.24	-13.27

p7p6	Varuna X Rihini	7.88 **	5.12 *	0.44	-1.76	-4.99 **	-0.90	19.21 **	8.43 *	-24.45**	3.92 **	1.47 **	13.97
p7p8	Varuna X Urvashi	0.97	-2.79 **	-10.05**	3.73 **	-0.07	-0.14	-4.64	-13.25	-113.90**	-12.34 **	-13.12 **	-50.98
p8p1	Urvashi X Maya	3.13 **	-0.93	-0.94	5.56 **	5.30 **	13.45**	7.25 **	5.71 **	-21.63**	-1.86	-5.39	-16.46
p8p2	Urvashi X Aashirvaad	-1.19 **	-5.91	-5.80**	5.01	3.15	3.14*	46.38 **	44.29 **	-14.85*	7.99 **	-2.04 **	-5.74
p8p3	Urvashi X Azad-Mahak	-0.00 **	-1.93	-5.42**	0.28 **	-1.66	-5.78**	24.83 **	14.81	-11.82	33.33 **	30.54 **	-27.52
p8p4	Urvashi X Kranti	-2.18	-5.61 **	-5.45**	8.59 **	7.28	10.42**	10.26	-2.27	5.81	-8.66 **	-9.20 **	-0.36
p8p5	Urvashi X Basanti	-0.49 **	-2.87	1.48	4.16 **	3.01 *	2.04	42.58 **	38.38 **	-46.66**	-2.28 **	-10.18	-111.47
p8p6	Urvashi X Rohini	-0.74 **	-1.96	-9.50**	3.96 **	3.53 **	-9.28**	-5.88 **	-5.88 **	-107.80**	-9.42 **	-10.78 **	-55.71
p8p7	Urvashi X Varuna	-2.90	-6.51 **	-2.99**	1.71 **	-2.03	1.72	9.93	0.00	-3.61	-25.22 **	-25.88 **	-38.33
	SE±	0.85	0.74		1.82	1.58		0.38	0.33		0.51	0.44	
	CD at 5%	1.67	1.45		3.57	3.09		0.74	0.64		1.01	0.87	
	CD at 12%	2.24	1.94		4.78	4.14		0.99	0.86		1.35	1.17	

Table 6: Heterosis for hybrids

Var	Hybrids	No of Siliquae/plant on main raceme			Days to maturity			Biological yield Per Plant (g)			No of Seeds Per Siliqua		
		BP	MP	IDB	BP	MP	IDB	BP	MP	IDB	BP	MP	IDB
p1p2	Maya X Aashirvaad	-37.50 **	-40.05 **	-53.28**	-3.59 **	-4.08 **	-3.46**	9.60	1.40 **	50.11**	-0.69	-12.97 **	5.93
p1p3	Maya X Azad-Mahak	-11.42	-11.73	-21.85**	-4.71 **	-5.79 **	-6.42**	17.57 **	8.39	23.42**	-27.60 **	-32.19 **	-15.02**
p1p4	Maya X Kranti	-13.38	-15.25	-21.53**	-2.61	-3.87 *	-0.80	-3.42 **	-9.08 **	4.03	4.25	-3.01 *	13.37**
p1p5	Maya X Basanti	1.50 **	1.28 **	1.58	-2.10	-3.87 **	-1.07	49.44 **	40.52 **	49.71**	-35.33 **	-43.93 **	-42.34**
p1p6	Maya X Rohini	-3.85	-8.57 *	-21.17**	-3.78	-4.90 **	-5.69**	16.82 **	4.02 **	35.11**	-8.48 **	-10.32 **	12.83**
p1p7	Maya X Varuna	-12.71 **	-19.04 **	-9.50*	-2.06	-2.31	-0.26	6.11 **	-5.32 **	28.56**	-30.88 **	-36.58 **	-10.76**
p1p8	Maya X Urvashi	-6.07 **	-10.57	-13.09**	-2.31	-2.56	-5.79**	16.43 **	8.80	11.45*	-6.49	-12.51 **	-0.21
p2p1	Aashirvaad X Maya	-6.12 **	-9.95 **	-39.88**	-0.51 **	-1.02 **	-2.58*	-14.17	-20.60 **	-57.87**	-9.86	-21.00 **	-24.86**
p2p3	Aashirvaad X Azad-Mahak	-2.94	-7.22 **	-0.65	-4.94 **	-5.54 **	0.53	34.16 **	33.66 **	10.54*	3.24 **	-3.87	-10.99**
p2p4	Aashirvaad X Kranti	14.67 **	7.71 **	15.42**	-1.56	-3.32 **	-3.69**	32.26 **	29.81 **	6.36*	-12.72	-18.20 *	-12.06**
p2p5	Aashirvaad X Basanti	5.24	0.74 **	28.23**	1.31	-1.02 **	3.61**	18.59 *	16.55 **	32.98**	14.11 *	12.71	-29.17**
p2p6	Aashirvaad X Rohini	8.95 **	7.97	17.38**	-1.95 **	-3.57 **	-2.38*	39.62 **	33.93	48.64**	6.55 *	-4.95	5.71
p2p7	Aashirvaad X Varuna	-2.65	-6.01	3.17	-1.28 **	-1.53 **	1.55	5.39 **	1.32 **	44.79**	-22.82 **	-37.15 **	-14.20**
p2p8	Aashirvaad X Urvashi	10.03 **	9.18 **	15.68**	0.00	-0.26	3.32*	-1.93 **	-2.98 **	26.82**	1.90	-5.03 *	-38.19**
p3p1	Azad-Mahak X Maha	8.81	8.42	-23.86**	0.13 **	-1.01 **	4.58**	-1.52 **	-9.21	8.21*	11.68 *	4.59 **	29.27**
p3p2	Azad-Mahak X Aashirvaad	-2.42	-6.72 **	-16.90**	-4.69 **	-5.29 **	0.80	-11.09 **	-11.42 **	20.89**	19.53 **	11.30	18.24**
p3p4	Azad-Mahak X Kranti	26.40 **	24.10 **	20.35**	-4.26 **	-6.55 **	-0.54	6.78 **	4.42 **	17.44**	-0.13	-0.84	0.32
p3p5	Azad-Mahak X Basanti	18.77 **	18.60 **	6.72	-1.95 **	-4.79 **	-2.65*	-15.14 **	-16.91 **	-19.20**	16.56	7.30	-6.36
p3p6	Azad-Mahak X Rohini	6.87 **	1.29	5.01	-3.09 **	-5.29 **	-0.27	-38.63 **	-40.92 **	-10.49*	-7.92 **	-12.08 **	14.39**
p3p7	Azad-Mahak X Varuna	14.89 **	6.21 **	3.40	-3.68 **	-4.53 **	0.00	-43.13 **	-45.13 **	-74.57**	-6.13 **	-18.84 **	0.85
p3p8	Azad-Mahak X Urvashi	10.19 **	4.55 **	2.14	-2.92 **	-3.78 **	-2.36*	-19.02 *	-20.18 **	4.29	1.47	1.36	1.14
p4p1	Kranti X Maya	16.05	13.54	7.14	1.83	0.52 *	2.31*	-14.47 **	-19.48 **	9.33*	-5.91	-12.47 *	14.55**
p4p2	Kranti X Aashirvaad	9.27 **	2.64 **	-5.33	0.78	-1.02 **	2.32*	-18.39 **	-19.89 **	-9.81*	3.24	-3.24 *	12.17**
p4p3	Kranti X Azad-Mahak	-2.83 **	-4.59 **	-19.76**	-3.48 **	-5.79 **	-0.53	-27.86 **	-29.45 **	-9.29*	-12.14	-12.76	2.46
p4p5	Kranti X Basanti	17.08 **	14.79 **	16.74**	1.06	0.53	-2.10	-28.37 **	-28.46 **	-3.66	10.74	2.60	20.79
p4p6	Kranti X Rohini	-8.19	-14.48 **	2.47	-0.66	-0.79	-1.06	-27.28 **	-31.48 **	-17.14**	-21.44 **	-25.50 **	-13.53**
p4p7	Kranti X Varuna	-11.80 **	-19.83 **	-4.98	-2.08 **	-3.59 **	-1.33	-37.98 **	-41.43 **	-44.29**	-21.81 **	-32.80 **	-11.69**
p4p8	Kranti X Urvashi	2.34	-4.57 *	13.20**	-1.04	-2.56 **	1.32	-25.48 *	-26.07 *	3.82	-0.45 **	-1.05 **	-22.88**
p5p1	Basanti X Maya	13.21 **	12.97 **	-15.46**	1.84	0.00 **	-0.26	-10.96 **	-16.28 **	-53.71**	-15.96 **	-27.12 **	8.65*
p5p2	Basanti X Aashirvaad	-7.02	-10.99 **	-2.94	-1.04	-3.32 **	-1.58	-25.29 *	-26.57 **	0.04	5.76 *	4.46	3.95
p5p3	Basanti X Azad-Mahak	5.29 **	5.14 **	-11.81*	-1.43 **	-4.28 **	-3.16	-19.98 **	-21.65 **	22.84**	-5.23	-12.76	2.70
p5p4	Basanti X Kranti	10.39 **	8.23 **	-7.78	0.00	-0.53	-2.13	-26.72 **	-26.82 **	-12.40**	2.72	-4.83	-23.64**
p5p6	Basanti X Rohini	6.96 **	1.51 **	-15.03**	1.73 **	1.06 *	-3.13*	7.11	1.06 **	21.65**	2.43	-9.61 **	-25.26**
p5p7	Basanti X Varuna	15.93	7.31 **	10.75*	1.31 **	-0.77	0.52	31.36	24.20 **	19.84**	-6.48 **	-24.56 **	-10.72**
p5p8	Basanti X Urvashi	4.94 *	-0.29	4.45	0.79	-1.28 **	-2.08	11.28 **	10.54 **	4.03	1.48	-6.50 **	-3.25
p6p1	Rohini X Maya	6.51	1.29 *	26.67**	1.96	0.77 **	2.56*	-26.64 **	-34.67 **	-26.10**	-10.44 **	-12.24 **	3.38
p6p2	Rohini X Aashirvaad	-0.48 **	-1.37	17.20**	-1.69 **	-3.32 **	1.06	-29.78 **	-32.64	-16.98**	8.36 *	-3.33	3.74
p6p3	Rohini X Azad-Mahak	2.44 **	-2.91	7.45	-2.06 **	-4.28 **	1.05	-23.29 **	-26.15 **	-7.12*	44.29 **	37.77 **	40.89**
p6p4	Rohini X Kranti	7.13	-0.21 **	12.02*	0.13	0.00	-2.11	-19.87 **	-24.49 **	-6.01	-13.72 **	-18.17 **	2.79
p6p5	Rohini X Basanti	13.50 **	7.71 **	3.82	3.05 **	2.37 *	-1.80	-11.89	-16.87 **	-44.96**	-16.01	-25.88 **	24.68**
p6p7	Rohini X Varuna	1.83 **	-0.81	7.78	1.95 **	0.51	-3.57**	5.12 *	4.87	23.11**	-9.74 **	-18.69 **	25.42**
p6p8	Rohini X Urvashi	13.00	12.85	9.92*	1.69	0.26 *	0.26	17.26	11.33	8.29*	1.50	-3.19	-10.17*
p7p1	Varuna X Maya	2.44 **	-4.99 **	8.88	2.06	1.79	5.54**	7.67 **	-3.93 **	-1.97	-27.51 **	-33.49 **	-7.34
p7p2	Varuna X Aashirvaad	3.79	0.20	19.21**	-3.58 **	-3.83 **	-1.86	-44.14 **	-46.30 **	-33.95**	-19.92 **	-34.78 **	-8.54*
p7p3	Varuna X azad-Mahak	-23.73 **	-29.49 **	-32.10**	-3.94 **	-4.79 **	0.53	-29.30 **	-31.79 **	-42.34**	-28.10 **	-37.83 **	-26.44**
p7p4	Varuna X Kranti	0.94 **	-8.25 **	-5.27	-1.30 **	-2.82 **	-3.69**	-38.46 **	-41.89 **	-28.86**	-37.16 **	-46.00 **	-39.83**
p7p5	Varuna X Basanti	-12.51	-19.01 **	-27.97**	2.88 **	0.77	2.04	-36.86	-40.30 **	-42.29**	-27.94 **	-41.88 **	-43.57**
p7p6	Varuna X Rihini	8.34 **	5.52	17.30**	2.73 **	1.28	0.00	1.04 *	0.81	15.25**	-26.67 **	-33.94 **	-12.82**
p7p8	Varuna X Urvashi	5.80	2.92	30.15**	-1.54	-1.54	1.82	-11.38	-15.68 **	1.91	-23.40 **	-33.83 **	-16.71**
p8p1	Urvashi X Maya	19.72 **	13.99	26.74**	1.03	0.77	4.83**	-6.22 **	-12.37	2.38	-6.30	-12.33 **	3.34
p8p2	Urvashi X Aashirvaad	7.71 **	6.87 **	10.21*	-1.02	-1.28	3.36*	-15.03 **	-15.93 **	-1.91	-5.19	-11.64 *	-18.98**
p8p3	Urvashi X Azad-Mahak	15.01 **	9.13 **	18.13**	-3.18 **	-4.03 **	-1.05	11.32 *	9.72 **	32.81**	-6.49	-6.59	-26.31**
p8p4	Urvashi X Kranti	3.02	-3.93 *	7.63	0.26	-1.28 **	3.12*	18.86 *	17.92 *	26.63**	-23.23 **	-23.69 **	-38.53**
p8p5	Urvashi X Basanti	2.38 *	-2.72	2.14	-1.31	-3.33 **	-3.98**	3.39 **	2.70 **	8.05*	-8.65	-15.83 **	-12.45**
p8p6	Urvashi X Rohini	-7.59	-7.71	-8.82	-1.69	-3.08 *	-2.38*	-12.91	-17.31	-26.65**	0.15	-4.47	7.84*
p8p7	Urvashi X Varuna	-2.21	-4.87	10.04	-0.51	-0.51	1.55	11.97	6.54 **	25.48**	-21.85 **	-32.49 **	-15.93**
	SE±	1.39	1.20		0.92	0.80		1.24	1.07		0.53	0.46	
	CD at 5%	2.72	2.35		1.81	1.57		2.42	2.10		1.04	0.90	
	CD at 12%	3.65	3.16		2.43	2.11		3.25	2.82		1.39	1.20	

Table 7: Heterosis for hybrids

Var	Hybrids	Test Weight (gm)			Harvest Index (%)			Oil Content (%)			Seed Yield Per Plant (g)		
		BP	MP	IDB	BP	MP	IDB	BP	MP	IDB	BP	MP	IDB
p1p2	Maya X Aashirvaad	27.89	22.21	-0.37	-4.93	-9.81 *	-86.54**	2.22 **	1.02	2.95*	4.71	1.97	6.94
p1p3	Maya X Azad-Mahak	25.05 **	17.11 *	26.30**	3.38 **	-10.97	3.85	1.43	0.40 **	5.48**	23.27 **	14.40 **	26.38**
p1p4	Maya X Kranti	-7.57	-13.27	2.47	3.91	-6.67 **	-26.94**	-1.69 **	-4.75 **	0.46	1.04 *	-3.87 **	-21.66**
p1p5	Maya X Basanti	28.98 **	21.52 **	39.61**	-4.06	-24.58 **	-49.33**	-2.55 *	-3.00	-1.31	45.88 **	20.39	24.92**
p1p6	Maya X Rohini	16.05 **	11.31 **	6.40	-0.62 **	-13.58 **	-17.50*	-2.25 **	-3.77	-11.87**	18.28 **	15.13 **	23.71**
p1p7	Maya X Varuna	1.89	-0.86	-21.77**	-3.36 **	-18.32 **	-28.98**	-5.59 **	-7.75 **	-8.18**	4.95	-1.38 *	7.96
p1p8	Maya X Urvashi	20.30 **	18.31 *	31.89**	-5.71	-16.67 **	-41.22**	-2.21 **	-2.53 **	-3.97**	10.85 *	4.37	-25.00**
p2p1	Aashirvaad X Maya	-6.41	-10.57	-29.08**	4.50	-0.86 *	26.20**	1.01 **	-0.18	-0.66	-9.90	-12.25	-16.55**
p2p3	Aashirvaad X Azad-Mahak	25.32	22.70	16.80*	-4.88	-14.15 **	-29.26**	5.40 **	3.12	7.90**	27.69 **	15.64	-15.67**
p2p4	Aashirvaad X Kranti	16.60 **	4.87	27.01**	-12.20	-17.13 **	-19.12*	-2.76 **	-4.69 **	4.13**	15.98	7.60	-11.54*
p2p5	Aashirvaad X Basanti	3.99 **	-6.12	15.69*	17.82 **	-3.51 **	-55.61**	6.73 **	5.95 **	8.93**	39.15 **	12.47 **	-4.26
p2p6	Aashirvaad X Rohini	25.86 **	15.57	14.99*	-24.36 **	-31.03 **	-106.33**	6.53 **	3.65	3.88**	6.05 **	0.59 **	-5.99
p2p7	Aashirvaad X Varuna	44.36 **	34.39	15.85*	-3.80 *	-14.89 **	-136.16**	-1.32**	-2.44 **	-2.80*	2.01 **	-6.49 **	-28.79**
p2p8	Aashirvaad X Urvashi	17.83 **	10.81 **	25.40**	6.39	-1.30 **	6.37	-0.89	-1.74 *	-9.18**	4.31 **	-4.19 **	31.57**
p3p1	Azad-Mahak X Maha	19.04 **	11.48 *	-0.33	18.19 **	1.78	32.66**	-2.76	-3.75 **	-1.15	17.99 **	9.50 **	38.17**
p3p2	Azad-Mahak X Aashirvaad	-11.59	-13.44	-14.93*	-3.05	-12.50 **	-27.44**	-1.24 **	-3.38	-6.41**	-13.74 **	-21.88	-0.84
p3p4	Azad-Mahak X Kranti	15.71	2.13	8.36	20.28 **	14.69 **	-65.31**	-4.68 **	-8.55 **	-2.53*	28.48	25.15	-36.60**
p3p5	Azad-Mahak X Basanti	25.54 **	11.23	16.38*	10.88 **	-0.63 **	-122.45**	-2.65	-4.07 **	-0.48	-6.12	-17.39 **	-164.55**
p3p6	Azad-Mahak X Rohini	22.09 **	9.99 *	30.80**	62.23 **	60.39 **	-54.82**	6.33 **	5.75 **	5.87**	-0.46 **	-5.23 **	-71.06**
p3p7	Azad-Mahak X Varuna	24.19 **	13.38	25.00**	67.58 **	63.86 **	-27.85**	-3.03 **	-6.18 **	-3.63**	-4.54	-5.81	-123.10**
p3p8	Azad-Mahak X Urvashi	26.87	16.99	26.51**	42.59 **	38.39 **	-64.31**	1.79 **	0.43	3.69**	15.63 **	13.85 **	-57.13**
p4p1	Kranti X Maya	4.09	-2.33	25.25**	1.79	-8.57 **	-13.33*	-6.02 **	-8.94 **	-6.24**	-12.33 *	-16.59 **	-2.70
p4p2	Kranti X Aashirvaad	27.13 **	14.33	17.26*	8.29	2.20 **	15.23*	-3.12 **	-5.04 **	0.17	-11.72	-18.10	6.95
p4p3	Kranti X Azad-Mahak	5.06	-7.27	31.49**	9.25 **	4.17 **	-23.02**	-2.67 **	-6.62 **	1.72	-21.11	-23.15	-34.40**
p4p5	Kranti X Basanti	17.71	17.20	44.49**	31.21 **	12.75 **	-49.25**	-5.94 **	-8.46 **	-2.63*	-6.00	-19.13 **	-54.67**
p4p6	Kranti X Rohini	28.65 **	25.73 **	37.65**	5.43	1.64 **	-65.92**	-5.06 **	-9.40 **	-11.14**	-23.14 **	-24.93 **	-94.38**
p4p7	Kranti X Varuna	2.42	-1.33	-3.79	37.60 **	28.43 **	-15.70*	-7.08 **	-7.89 **	-1.46	-14.28 **	-15.39 **	-66.89**
p4p8	Kranti X Urvashi	10.07	4.93	15.25*	10.48	8.48	-63.39**	-3.35 **	-6.07 **	0.63	-17.62	-18.51	-57.10**
p5p1	Basanti X Maya	17.56 **	10.76 **	28.54**	7.16	-15.75 **	29.61**	4.13 *	3.65	5.72**	-2.88 **	-19.85	-8.11*
p5p2	Basanti X Aashirvaad	34.38 **	21.32	41.96**	6.35 **	-12.91 **	-6.56	-1.67 **	-2.39 **	0.24	-20.84 **	-36.02 **	-6.34
p5p3	Basanti X Azad-Mahak	13.85 **	0.87	21.94**	38.85 **	24.44 **	-39.27**	2.55	1.06 **	-2.24	10.86	-2.44 **	-6.41
p5p4	Basanti X Kranti	-25.81	-26.13	-14.73*	29.26 **	11.08 **	5.49	2.27 **	-0.48 **	6.57**	-5.37	-18.59 **	-6.34
p5p6	Basanti X Rohini	7.85	5.85	31.20**	15.39	2.37 *	-40.16**	1.50 **	-0.53	0.53	22.58	3.41 **	-9.86*
p5p7	Basanti X Varuna	-0.87	-4.10	-3.24	-5.15	-13.26	-48.66**	6.18 **	4.22	13.24**	23.86	7.75 **	-19.31**
p5p8	Basanti X Urvashi	3.90	-0.54	27.99**	16.17 **	1.40	19.10**	-6.95 **	-7.08 **	-5.75**	29.17 **	12.15	22.38**
p6p1	Rohini X Maya	28.72 **	23.46 **	17.65*	-23.88 **	-33.81 **	-6.96	5.45 **	3.81	0.03	-43.15 **	-44.67 **	-35.03**
p6p2	Rohini X Aashirvaad	6.54 **	-2.16	14.99*	-7.69 **	-15.83 **	6.48	0.52 **	-2.19	1.39	-34.92 **	-38.27 **	-9.41*
p6p3	Rohini X Azad-Mahak	31.01 **	18.02 *	33.73**	-14.93 **	-15.90 **	-27.09**	-0.25 **	-0.80 **	-2.86*	-34.80 **	-37.92 **	-36.15**
p6p4	Rohini X Kranti	7.91 **	5.47 **	5.56	-15.57	-18.61 **	-65.04**	-2.87 **	-7.31 **	0.17	-32.19 **	-33.76 **	-74.85**
p6p5	Rohini X Basanti	-1.40	-3.23	26.35**	-7.55	-17.98 *	4.94	3.15 **	1.09	-6.12**	-19.19	-31.83 **	-37.87**
p6p7	Rohini X Varuna	22.75 *	20.95	23.32**	8.41 **	4.83 **	43.72**	1.14	-2.67 **	-2.57*	13.95 **	9.90 **	56.77**
p6p8	Rohini X Urvashi	1.50	-1.05	-1.21	-19.64 **	-21.13 **	-51.97**	1.84 **	-0.06 **	-1.10	-5.66 **	-8.82 **	-39.33**
p7p1	Varuna X Maya	-13.27	-15.61	-36.83**	-15.73 **	-28.78 **	15.99*	-2.30 **	-4.53 **	0.49	-7.14	-12.74 *	14.40**
p7p2	Varuna X Aashirvaad	-4.87 **	-11.44	-6.43	-9.67 *	-20.09 **	-65.98**	-4.94 **	-6.01 **	-2.26*	-49.30 **	-53.53 **	-122.53**
p7p3	Varuna X azad-Mahak	16.23 **	6.12	4.15	41.33 **	38.19 **	18.04**	-3.11 **	-6.26 **	-4.24**	0.02	-1.31	-16.63**
p7p4	Varuna X Kranti	-12.39	-15.60	17.06*	6.28 **	-0.80 **	-7.20	3.01 **	2.12 **	11.63**	-34.40 **	-35.25 **	-41.06**
p7p5	Varuna X Basanti	-4.00	-7.13	11.58	16.55	6.60	-9.78	-1.77 **	-3.59	3.31**	-26.80	-36.33 **	-56.24**
p7p6	Varuna X Rohini	1.91 *	0.42	-22.05**	-35.02 **	-37.17 **	-60.94**	-0.29	-4.05 **	-2.04	-34.34 **	-36.67 **	-36.39**
p7p8	Varuna X Urvashi	21.82 **	20.50 **	36.23**	19.22	13.22 **	-69.79**	-4.88 **	-6.76 **	-6.22**	6.01 *	5.78 *	-66.35**
p8p1	Urvashi X Maya	11.63 **	9.78 *	21.58**	5.44	-6.82 **	15.14*	-3.76 **	-4.06 **	-4.84**	-0.19 *	-6.01	17.13**
p8p2	Urvashi X Aashirvaad	43.32 **	34.78 **	41.46**	-7.94	-14.60 **	-6.98	0.77	-0.09 *	4.32**	-21.82 **	-28.19 **	-9.07*
p8p3	Urvashi X Azad-Mahak	-7.58	-14.78	-28.06**	-3.15 **	-6.00 **	-14.99*	0.62 **	-0.71	0.40	7.94 **	6.27 **	22.73**
p8p4	Urvashi X Kranti	0.14	-4.53	18.35**	-4.68	-6.41	-10.15	-5.76 **	-8.40 **	-0.84	13.31	12.08	19.10**
p8p5	Urvashi X Basanti	8.75	4.10	-2.71	8.44 **	-5.35	-21.86**	1.89 **	1.75 **	4.93**	11.99 **	-2.76	-12.01*
p8p6	Urvashi X Rohini	-6.52	-8.87	-38.16**	-48.91 **	-49.85 **	-61.74**	4.83 **	2.87 **	-0.99	-55.43 **	-56.92 **	-104.74**
p8p7	Urvashi X Varuna	14.11 **	12.88 **	8.41	-27.70	-31.34 **	-32.43**	-7.04 **	-8.87 **	-7.52**	-18.77 *	-18.94 *	1.36
	SE±	0.28	0.24		0.79	0.68		0.17	0.15		0.54	0.47	
	CD at 5%	0.54	0.47		1.54	1.33		0.33	0.29		1.06	0.92	
	CD at 12%	0.73	0.63		2.07	1.79		0.45	0.39		1.43	1.24	

Conclusion

The present investigation conducted in Brassica juncea revealed considerable genetic variability among the parents and hybrids for all the characters studied, indicating sufficient scope for genetic improvement through selection and hybridization. The presence of significant heterosis and

inbreeding depression suggested the involvement of both additive and non-additive gene actions in the inheritance of yield and its contributing traits.

Crosses such as Varuna × Aashirvaad and Azad-Mahak × Kranti exhibited desirable negative heterosis for days to flowering and maturity, indicating their usefulness for

developing early maturing genotypes. Basanti × Maya and Aashirvaad × Basanti showed high heterosis for branching traits, while Azad-Mahak × Kranti and Maya × Basanti were identified as promising combinations for siliquae per plant and biological yield, respectively. Rohini × Azad-Mahak and Aashirvaad × Varuna were superior for seeds per siliqua and test weight, whereas Azad-Mahak × Varuna and Aashirvaad × Basanti performed better for harvest index and oil content.

For seed yield per plant, Maya × Basanti, Aashirvaad × Basanti and Basanti × Urvashi exhibited high positive heterosis, indicating strong hybrid vigour and favourable gene interactions. The wide range of inbreeding depression among the crosses suggested differential stability of hybrids in F₂ generation. Therefore, crosses exhibiting high heterosis coupled with low or negative inbreeding depression may be effectively utilized in heterosis breeding as well as selection programmes for developing high yielding and stable mustard varieties in future breeding programmes.

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