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Heterosis for Seed Yield and its Component Traits in Indian Mustard [*Brassica juncea* (L.) Czern. & Coss.]

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Abstract

Forty-eight crosses of Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] were created by mating twelve genetically diverse lines with four well-adapted released varieties in a line x tester mating design. These crosses were instrumental in assessing the heterosis potential for seed yield and its associated traits. The experiment was conducted at the Agricultural Research Farm, Janta Mahavidyalaya, Ajitmal, Auraiya (U.P.) during the *Rabi* season of 2022-23. Each genotype was sown in a 3-meter row, with row-to-row and plant-to-plant spacing set at 40 cm and 10 cm, respectively. Observations were recorded for ten different characters. The analysis of variance revealed significant differences among parents, hybrids, and parent vs. hybrids for most of the studied traits. A majority of the crosses exhibited substantial heterobeltiosis across traits. Notably, the cross PRL-29 × CS-60 displayed the maximum heterosis over the better parent (73.58%) for seed yield per plant. The heterobeltiosis values were notably high, with highlights including 142.81% for 1000-seed weight (PR-36 × CS-58), 105.82% for the number of siliquae per plant (PRL-26 × Giriraj), and 36.84% for the number of secondary branches per plant (PRL-26 × CS-58). Several crosses demonstrated desirable traits, such as PRL-22 × CS-60 (24.85% for the number of seeds per siliqua) and PRL-26 × Giriraj (-9.71% for days to flower initiation), while certain combinations showed negative better parent heterosis, like PR-36 × CS-60 (-12.39% for plant height) and PR-36 × CS-58 (-9.82% for days to 50% flowering). The heterotic cross combination identified as PRL-26 × Giriraj exhibited promise across multiple traits. Noteworthy performers included PR-34 × CS-58, PRL-29 × CS-60, and PR-39 × CS-60, showing superior per se performance, substantial heterosis over the mid-parent, and desirable parent traits. These high-yielding cross combinations hold potential for further exploitation in developing superior genotypes for improved seed yield.

Keywords: *Brassica juncea*, Indian mustard, seed yield, heterosis, heterobeltiosis, yield components.

Introduction

Indian mustard (*Brassica juncea* (L.) Czern. & Coss.) is a crucial oilseed crop predominantly cultivated during the *Rabi* season, constituting over 70% of the area under rapeseed-mustard crops. It is a natural amphidiploid resulting from a cross between *B. rapa* and *B. nigr*a (Banuelos *et al*., 2013). With seed oil content ranging from 38–40%, it serves as a primary cooking and frying medium in northern India. The meal cake left after oil extraction is an essential source of cattle feed protein. Despite its significant potential, the realized yield remains below expectations due to limitations in traditional breeding methods following hybridization.

Heterosis breeding holds promise for boosting production and productivity, as seen in various crop plants. The significance of heterosis, particularly in yield improvement, is crucial, with potential economic gains in mustard oil production. However, commercializing heterosis in self-pollinated crops like Indian mustard faces technical challenges in hybrid seed production. To enhance genetic yield potential, selecting suitable parents for superior varieties/hybrids is crucial for plant breeders. Understanding the nature and extent of heterosis is key to identifying optimal cross-combinations for desirable segregants in subsequent generations. High heterosis crosses can yield transgressive segregants, enhancing yield and its components. This study aims to identify ideal parents for efficient hybridization and accelerate selection progress in segregating generations.

Material and Methods

The experimental material consisted of twelve genetically diverse lines (PRE 07, PRE 11, PRE 13, PRE 15, PRL 22, PRL 24, PRL 26, PRL 29, PR 34, PR 36, PR 38, PR 39), four testers (ROHINI, GIRIRAJ, CS 58, CS 60), and their potential 48 F_1 cross combinations. Seeds from 48 crosses and 16 parents were produced through hand emasculation-hand pollination and selfing, respectively. The crossing programme was carried out during the winter (*Rabi*) season of 2021–22 using line × tester mating design. The experiment was conducted at the Agricultural Research Farm, Janta Mahavidyalaya, Ajitmal, Auraiya (U.P.) during the *Rabi* season of 2022-23. Each genotype was sown in a 3-meter row, with row-to-row and plant-to-plant spacing set at 40 cm and 10 cm, respectively. All recommended agricultural practices were followed to ensure optimal crop growth. Observations were made on five randomly selected competitive plants in each replication for each genotype, and data were recorded for several traits, including days to flower initiation, days to 50% flowering, days to maturity, 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, 1000-seed weight (g), and seed yield per plant (g). Assessing genetic variability is a crucial step in initiating any crop improvement program. Analysis of variance (ANOVA) conducted for the experimental design revealed significant and exploitable variability within the examined material, particularly in terms of various morphological traits, as suggested by Panse and Sukhatme (1967) to determine significance. Heterosis was expressed as a percentage increase (+) or decrease (-) of F_1 value over the better parent (Hayes *et al*., 1955).

Results and Discussion

The analysis of variance (Table 1) revealed significant differences for all the characters studied in the case of lines, which indicated the existence of genetic diversity in the parental materials. Partitioning of the treatment sum of squares showed highly significant differences among the parents for all the characters. However, on partitioning of the treatments into parents, parent vs cross, crosses, lines, testers and line × testers, the variance due to parents showed highly significant differences for all characters except days to flower initiation, days to 50% flowering, number of primary branches/plant, number of secondary branches/plant and 1000-seed weight, the variance due to parent vs cross showed highly significant differences for all the characters except number of secondary branches/plant, number of seeds/siliquae and seed yield/plant. The crosses showed highly significant differences for all the characters except the number of siliquae/plant, days to 50% flowering and days to flower initiation. The variance due to lines showed highly significant differences for plant height, 1000-seed weight, number of secondary branches/plant, number of primary branches/plant, days to flower initiation and number of siliquae/plant. Whereas, the testers showed highly significant differences for secondary branches/plant. Line × tester component was significant for most of the characters except days to flower initiation, days to 50% flowering, days to maturity, plant height, number of primary branches/plant, number of secondary branches/plant, number of siliquae/plant and 1000-seed weight. This indicated the manifestation of parental genetic variability in their crosses and the presence of uniformity among the hybrids. The higher value of parent vs. hybrids indicates the presence of heterosis in the material under study. This revealed the presence of a substantial amount of heterosis in various cross-combinations due to the effect of directional dominance.

Table 1: Analysis of variance (ANOVA) for various characters in Indian mustard.

Source of variation	d. f.	Days to flower initiation	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of primary branches /plant	No of secondary branches/ plant	No of siliquae/ plant	No of seeds/ siliqua	1000- seed weight (g)	Seed yield/plant (g)
Replication	2	134.76**	81.13**	35.04**	4977.70**	16.81**	10.96	53071.86**	243.03**	23.49**	2025.01**
Treatments	63	11.02**	9.85**	13.32**	653.05**	1.06**	19.76**	5506.58**	139.57**	2.05**	307.64**
Parent	15	8.75	6.17	17.25**	644.78**	0.91	16.17	7405.93	163.92	0.95	336.48**
P vs cross	1	252.02**	49.69**	21.16**	2476.35**	3.80**	35.48	166414.70	33.17	26.99	293.42**
Crosses	47	6.63	5.98	11.01**	616.89*	1.06*	20.58	1476.82	134.07	1.87*	15.67
Lines (L)	11	11.32**	10.01	16.89	1542.80**	2.08**	40.67	2638.88	162.84	4.60**	116.04
Tester (T)	3	9.06	8.08	14.45	223.26	1.18	36.39	235.44	114.31	0.25	95.31
L × T	33	4.84	4.88	8.73	344.04	0.71	12.44	1202.33	126.28	1.10	282.60**
Error	126	6.98	4.97	6.59	351.87	0.68	10.59	1122.49	34.52	0.76	108.60
C. V. (%)		3.47	2.84	2.40	9.52	16.31	16.61	14.91	8.82	25.16	27.63

*, ** significant at 5% and 1% level of probability, respectively.

Crosses exhibiting significant and desirable better parent heterosis for various traits were analysed to pinpoint superior cross combinations for potential utilization in hybrid breeding (Table 2). This experiment revealed the presence of noteworthy desirable heterobeltiosis across multiple traits for several crosses. Among the 48 hybrids tested, four hybrids, namely PRE-13 × ROHINI, PRE-13 × GIRIRAJ, PRL-26 × GIRIRAJ, and PRL-29 × CS-58, exhibited significant and desirable (negative) estimates of heterobeltiosis for traits such as days to flower initiation, days to 50% flowering, and days to maturity. Significant negative heterosis for these traits has also been documented by Patel et al. (2012), Dholu et al. (2014), and Kaur et al. (2019).

Table 2: Per cent heterosis in F_1s over better parent for various characters in Indian mustard.

S. No.	Crosses	Days to Flower initiation	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches/ plant	No of siliquae/ plant	No of seeds/siliqua	1000-seed weight (g)	Seed yield/ plant (g)
1	PRE-07 × ROHINI	-4.74	-7.49**	0.91	-4.86	-14.29	**30.18***	-14.11	-1.34	-11.31	4.00
2	PRE-07 × GIRIRAJ	-9.48**	-5.73*	-1.20	-4.08	9.57	5.73	0.63	-11.13	-13.24	**-31.13***
3	PRE-07 × CS-58	-5.21	-5.29*	-1.52	0.06	-8.68	19.15	2.53	**-25.71****	-13.01	3.77
4	PRE-07 × CS-60	-1.42	-8.37*	-2.09	-1.43	2.08	11.29	4.42	3.16	-3.39	**28.30***
5	PRE-11 × ROHINI	-4.37	-2.76	-1.23	-7.92	-5.15	8.15	-4.99	**-17.75****	-15.35	**-36.67***
6	PRE-11 × GIRIRAJ	-4.85	-0.46	-2.11	-3.33	-2.14	-4.89	-3.00	**-12.26***	-8.70	-11.63

S. No.	Crosses	Days to Flower initiation	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches/ plant	No of siliquae/ plant	No of seeds/siliqua	1000-seed weight (g)	Seed yield/ plant (g)
7	PRE-11 × CS-58	-7.28*	-4.91*	-0.39	-6.91	**-30.14***	0.00	8.56	-4.60	-13.72	**-30.23***
8	PRE-11 × CS-60	-6.31*	-3.23	-2.39	-3.64	-2.08	-9.15	5.69	**-22.48****	-0.51	13.18
9	PRE- 13 × ROHINI	**-6.25***	**-6.79****	**-6.32****	1.44	0.00	12.84	**26.13***	-0.59	4.43	**-38.67***
10	PRE-13 × GIRIRAJ	**-8.17***	**-5.43***	**-7.47****	-5.92	-12.22	-9.50	**60.27****	-3.22	14.25	**55.95****
11	PRE-13 × CS-58	-3.37	-4.46	-7.76**	2.89	-8.68	1.12	**50.33****	**-14.34***	-20.41	24.21
12	PRE-13 × CS-60	-5.77	-1.36	-6.90**	-5.40	0.00	4.29	**62.53****	-12.12	-3.56	**-33.33***
13	PRE- 15 × ROHINI	0.00	-0.92	0.00	-13.21	17.42	-9.68	**26.08***	-5.22	2.98	-15.33
14	PRE-15× GIRIRAJ	-2.49	-3.67	-2.41	-12.10	10.89	-18.07	**87.78****	-4.47	31.79	19.05
15	PRE-15 × CS-58	-3.43	-5.80*	0.92	4.36	13.05	-11.77	**84.51****	**-14.34***	9.27	2.11
16	PRE-15 × CS-60	-2.49	-1.38	-2.09	4.12	-14.27	-15.97	**75.86****	-0.02	10.49	8.33
17	PRL- 22 × ROHINI	-4.46	-3.69	0.61	**26.83****	22.58	10.67	18.24	-3.96	0.74	**-28.49***
18	PRL-22× GIRIRAJ	-3.47	-7.34**	0.30	13.93	19.46	25.28	**58.37****	**-22.91****	-14.63	**-30.73***
19	PRL-22 × CS-58	-5.88	-5.80*	1.85	**20.58***	4.37	12.37	**78.00****	**-34.50****	-5.56	**-30.17***
20	PRL-22 × CS-60	0.00	0.00	-2.69	6.96	-2.02	-3.76	**75.85****	9.37	0.00	**-49.72****
21	PRL-24 × ROHINI	-5.77	-6.28*	-0.91	5.68	14.87	9.70	20.97	-2.25	**56.71***	-18.00
22	PRL-24× GIRIRAJ	-5.77	-6.73**	-1.20	2.63	-8.55	**32.01***	**25.20***	**-15.02***	39.33	6.29
23	PRL-24 × CS-58	-6.73*	-7.59**	-0.91	5.86	-4.28	17.14	21.21	**-29.59****	**51.08***	-11.89
24	PRL-24 × CS-60	-8.17*	-6.28*	-3.58	-1.34	-8.14	10.76	23.74	-3.60	35.25	**-38.46***
25	PRL-26 × ROHINI	-3.88	-5.48*	3.92*	18.32	23.08	22.49	18.24	-6.96	32.98	9.33
26	PRL-26× GIRIRAJ	**-9.71****	**-4.57**	**-4.22***	13.87	19.46	21.14	**91.11****	-11.26	4.62	**-36.30***
27	PRL-26 × CS-58	-7.77*	-7.14**	-3.61	**21.65***	10.89	26.05	**80.39****	-9.43	8.93	**-45.19****
28	PRL-26 × CS-60	-2.91	-5.02*	-3.58	9.19	6.12	-2.15	**60.73****	**-16.28***	26.05	7.41
29	PRL-29 × ROHINI	-4.43	-1.38	-2.42	0.18	19.55	4.66	19.73	-3.17	**58.39***	-13.33
30	PRL-29 × GIRIRAJ	-6.40*	-4.59	-3.31	-8.56	14.63	1.73	**63.53****	0.53	43.98	11.32
31	PRL-29 × CS-58	**-6.86***	**-8.04****	**-4.23***	2.08	10.89	7.57	**56.28****	-7.75	9.14	-15.09
32	PRL-29 × CS-60	-6.40*	-6.91**	-3.28	1.07	14.33	5.37	**58.97****	**24.85****	23.33	**73.58****
33	PR-34 × ROHINI	-4.46	-5.00*	-0.61	-0.14	-15.97	-6.56	20.31	**17.21****	**59.92***	**-43.33***
34	PR-34 × GIRIRAJ	-6.44*	-3.64	-3.01	5.47	-9.96	-6.06	**24.87***	-12.87*	**53.75 ***	-2.38
35	PR-34 × CS-58	-4.41	-4.02	-1.54	10.37	-12.00	-15.15	10.35	**-21.06****	30.35	**43.16***
36	PR-34 × CS-60	-3.96	-4.09	-3.88*	9.12	0.06	-12.62	19.36	8.68	**55.66***	-4.17
37	PR-36 × ROHINI	-5.97	-5.96*	-4.82*	-4.50	-16.99	1.19	-4.44	-9.57	-7.07	**-34.67***

S. No.	Crosses	Days to Flower initiation	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches/ plant	No of siliquae/ plant	No of seeds/siliqua	1000-seed weight (g)	Seed yield/ plant (g)
38	PR-36 × GIRIRAJ	-4.48	-5.05*	-5.72**	-6.65	8.56	-3.43	-11.29	1.60	**57.99****	0.88
39	PR-36 × CS-58	-5.88	-9.82**	-5.12**	-8.61	-8.49	-4.24	1.02	**-11.50***	**92.21****	22.81
40	PR-36 × CS-60	-7.96*	-4.59	-1.79	-15.14	-10.17	**-43.55****	**-35.74****	-2.00	**50.22***	-5.26
41	PR-38 × ROHINI	-4.93	-4.61	-1.53	2.08	-4.47	-6.78	7.87	-2.70	**78.62****	**-30.00***
42	PR-38 × GIRIRAJ	-5.42	-4.59	-3.92*	-9.90	-15.53	-3.14	10.09	-7.37	**85.52****	19.61
43	PR-38 × CS-58	-3.43	-5.36*	-0.31	-4.29	-10.83	-13.56	16.83	**-21.32****	37.62	1.96
44	PR-38 × CS-60	-3.45	-1.88	-7.16**	-6.89	-8.14	-13.03	0.39	**-19.60****	20.03	0.00
45	PR-39 × ROHINI	-1.02	-3.23	2.15	8.67	-7.08	**29.58***	4.80	-0.47	**57.31 ***	**-40.00***
46	PR-39 × GIRIRAJ	-1.99	-2.75	-0.90	**31.71****	14.37	-16.68	-0.70	-11.40	5.81	**-33.93***
47	PR-39 × CS-58	-2.94	-4.91*	-1.85	3.28	-4.37	3.76	3.38	-9.30	41.63	-10.71
48	PR-39 × CS-60	0.50	5.66*	-3.88*	-1.49	-10.17	-22.60	21.18	1.48	**54.80 ***	**33.04***

*, ** Significant at 5% and 1% levels, respectively.

The plant height is an important trait by which the growth and vigour of plants are measured. A significant and high degree of heterosis for plant height was observed in comparison to the better parent. Four cross combinations displayed significant positive heterosis over better parents, ranging from 20.58% (PRL-22 × CS-58) to 31.71 % (PR-39 × GIRIRAJ). Similar findings were documented by Patel et al. (2010), Meena et al. (2014), and Kaur et al. (2019).

The heterobeltiosis estimates for the number of primary branches/plant ranged from -30.14 to 23.08 per cent. However, none of the crosses showed significant positive heterosis over the better parent.

Three cross combinations exhibited significant positive useful heterobeltiosis ranging from 29.58% (PR-39 × ROHINI) to 32.01% (PRL-24× GIRIRAJ), while one cross PR-36 × CS-60 (-43.55) showed negative significance for number of secondary branches/plant. The similar results were also reported by Singh et al. 2007, Aher et al. (2009) and Kaur et al. (2019).

Nineteen crosses had a higher number of siliquae/ plant than their better parent. The heterobeltiosis varied between 24.87% (PR-34 × GIRIRAJ) to 91.11% (PRL-26 × GIRIRAJ). However, only one cross PR-36 × CS-60 (-35.74%) showed significant negative heterosis for this trait. The similar findings were also reported by Meena et al. (2014).

The crosses namely, PRL-29 × CS-60 (24.85%) and PR-34 × ROHINI (17.21%) showed significant positive heterosis over a better parent for the number of seeds per siliquae. Fifteen cross combinations exhibited significant negative heterobeltiosis which ranged from -11.50 (PR-36 × CS-58) to -58-34.50 (PRL-22 × CS-58) for the number of seeds/siliqua. The similar results were also reported by Mahto and Haider (2004).

In the case of 1000-seed weight (g), the heterosis over better parent ranged from -20.41% (PRE-13 × CS-58) to 92.21% (PR-36 × CS-58), however, thirteen crosses showed a significant increase over their better parent. On the other hand, none of the crosses showed significant negative heterobeltiosis. Significant desirable heterosis for this character has been reported by Meena et al. (2014).

Five cross combinations showed significant positive heterobeltiosis ranging from 28.30% (PRE-07 × CS-

60) to 73.58% (PRL-29 × CS-60) for seed yield/plant. The similar results were also reported by Aher *et al*. (2009) and Yadava *et al*. (2012). Although, three cross combinations showed significant positive heterobeltiosis varies from 32.86% (IC-589670 × IC-571648) to 49.75% (IC-589669 × IC-338586) over better parent for harvest index. Fourteen cross combinations exhibited significant positive useful heterosis ranging from 30.19% (IC-597879 × IC-338586) to 91.77% (IC-589669 × IC-338586) over the commercial check for harvest index. The similar results were also reported by Ghosh *et al*. (2002) and Dholu *et al*. (2014).

Regarding seed yield/plant, estimates of heterobeltiosis ranged from -49.72 (PRL-22 × CS-60) to 73.58% (PRL-29 × CS-60) and the highest heterosis over better parent in the desirable direction was recorded by the cross PRL-29 × CS-60 (73.58%) followed by PRE-13 × GIRIRAJ (55.95%), PR-34 × CS-58 (43.16), PR-39 × CS-60 (33.04%) and PRE-07 × CS-60 (28.30%). This complied with earlier findings of Meena *et al*. (2014), Barupal *et al*. (2017), Srivastava *et al*. (2020) and Shekhawat *et al*. (2022).

The results of the present study suggest some concepts on breeding methodology to be followed in mustard and cross combination for further improvement. Seed yield and major yield components brought out that heterosis component could be exploited in hybrid development in Indian mustard.

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