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Exploitation of Heterotic Potential for Seed Yield and its Component Characters in Indian Mustard [*Brassica juncea* (L.) Czern & Coss]

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Abstract The present study was conducted to assess the extent of heterosis for 12 characters including seed yield per plant in Indian mustard [*Brassica juncea* (L.) Czern & Coss]. Ten parents were crossed in half diallel mating design to develop 45 F_1'S hybrids. The analysis of variance revealed considerable genetic differences among the genotypes for all the characters except plant height under study was evident from highly significant genotypic mean square for experimental design. The significant mean square due to parents as well as hybrids (except plant height) depicted presence of adequate variability for all the traits, whereas parents vs hybrids comparisons were significant for most of the traits except plant height, number of branches per plant, seed yield per plant and harvest index. A perusal of mean values revealed that the parent (GM 1 (35.41 g) was superior in respect of seed yield per plant, whereas among the all the hybrids, GM 1 × GM 2 (36.89 g) recorded maximum seed yield per plant. In the present study, extent of heterosis varied from cross to cross and character to character. Significant positive standard heterosis was observed in 17 crosses for seed yield per plant. Among them best five hybrids were GM 1 × GM 2 (51.36%), GM 3 × LES 45 (46.12%), GM 1 × GM 3 (43.56%), GM 1 × P. Mustard 21 (39.47%) and GDM 4 × EC287711 (37.05%). Thus, these hybrids could be evaluated further in multilocation trials to identify superior and stable genotypes for seed yield and its component traits.

Keywords Diallel, Heterosis, Seed yield, Indian mustard.

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Introduction

Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is one of the most important oilseed crops of the country, and it occupies considerably large acreage among the *Brassica* group of oilseed crops. It belongs to family *Brassicaceae* and genus *Brassica*. Indian mus-

Table 1. Analysis of variance (mean square) for twelve characters in Indian mustard. *, ** Significant at 5% and 1% levels, respectively.

Source of variation	df	Days to flowering	Days to maturity	Plant height (cm)	No. of branches per plant	No. of silique per plant	Seed yield per plant (g)
Replication	2	7.33	37.11	374.96	0.65	1083.90	11.13
Genotypes	54	89.44**	49.69**	267.34	33.88**	3798.51**	110.57**
Parents (P)	9	130.13*	97.84**	391.88**	27.77**	4192.11**	123.06**
Hybrids (H)	44	81.39**	39.55**	247.81	35.80**	3753.59**	110.46**
Parent vs hybrid	1	77.58**	62.26*	6.06	4.45	2232.36**	2.82
Error	108	2.50	12.375	184.03	2.82	652.38	5.96

Table 1. Continued.

Source of variation	df	1000-seed weight (g)	Harvest index (%)	Oil content (%)	Oleic acid (%)	Lenoleic acid (%)	Erucic acid (%)
Replication	2	0.10	0.39	8.29**	0.22	0.04	0.03
Genotypes	54	1.12**	158.86**	15.52**	177.10**	44.07**	426.15**
Parents (P)	9	2.12**	210.17**	28.44**	416.87**	95.86**	907.25**
Hybrids (H)	44	0.92**	151.98**	12.51**	129.10**	34.40**	337.13**
Parent vs hybrid	1	0.91**	0.00	31.74**	131.21**	3.30**	13.24**
Error	108	0.12	7.50	1.30	0.13	0.16	0.19

tard or brown mustard is natural amphidiploids (2n = 36) of *Brassica rapa* (2n = 20) and *Bassica nigra* (2n = 16). India stands second in both acreage and production of rapeseed and mustard in Asia. The crops are cultivated on an area of 6.70 million ha with a net production of 7.96 million tonnes and an average yield of 1188 kg/ha. In India, mustard and rapeseed are grown largely in Uttar Pradesh, Rajasthan, Haryana, Assam, Gujarat, Punjab, West Bengal and Madhya Pradesh. In Gujarat it occupies about 0.28 millon hectares with the production of 0.45 million tonnes and productivity of 1582 kg/ha [1].

In mustard breeding program, breeding techniques of both self and cross pollinated crops such as pure line, mass selection, hybridization and recurrent selection are widely used for the development of high yielding varieties. Recently, more emphasis is being given on heterosis breeding and tissue culture techniques. Exploitation of hybrid vigor has been recognized and it is an important tool for genetic improvement of yield and may serve as a major fruitful technique to break existing yield barriers. Heterosis has extensively been explored and utilized for boosting various quality traits in *Brassica* and other crops [2]. Heterosis is a quick, cheap, and easy method for increasing crop production. With this perspective, the present investigation was undertaken to study the extent of heterosis for various characters through 10 × 10 dialled mating design (excluding reciprocals) in Indian mustard.

Materials and Methods

The crossing program was carried out through 10 × 10 dialled mating design (excluding reciprocals) during *rabi* 2012-13 at Castor-Mustard Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar (Gujarat). The experimental material including 10 parents, their 45 F_1 hybrids and one check variety i.e., BIO 902 were sown in a randomized complete block design with three replications during *rabi* 2013-14 at Agronomy Instructional Farm, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar (Gujarat). Each genotype was sown in single row of 2.0 m length. The distance between rows and plant to plant was 45 cm and 15 cm, respectively. Standard package of prac-

Table 2. The range of relative heterosis (H_1), heterobeltiosis (H_2) and economic heterosis (H_3) and number of crosses showing significant relative heterosis, heterobeltiosis and economic heterosis for twelve characters in Indian mustard. +ve = Positive, –ve = Negative.

Characters	Range of heterosis and best heterotic cross			Number of hybrids having significant heterotic effect					
				H_1		H_2		H_3	
	H_1	H_2	H_3	+ve	-ve	+ve	-ve	+ve	-ve
Days to flowering	-22.97 to 26.91 (GM3×P. Mustard 21)	-5.88 to 38.76 (P. Mustard 21×EC 287711)	6.72 to 50.42 (GM 2×SKM 9033)	20	07	13	01	39	00
Days to maturity	-9.96 to 7.22 (P. Mustard 21×RSK 28)	-7.56 to 9.25 (P. Mustard 21×RSK 28)	-4.71 to 8.24 (GM 3×EC 287711)	03	10	07	02	05	00
Plant height (cm)	-8.42 to 9.53 (GM 2×GM 3)	-7.81 to 13.07 (GM 2×GM 3)	-5.37 to 11.14 (—)	00	00	02	00	00	00
No. of branches per plant	-48.50 to 44.35 (GDM 4×Dhara)	-51.87 to 28.91 (GM3×LES 45)	-34.56 to 56.57 (GM 1×GM 2)	07	10	03	16	23	02
No. of silique per plant	-26.66 to 29.27 (GM 2 × GDM 4)	-32.48 to 24.74 (GM 2 × (GDM 4)	-9.36 to 37.60 (GDM 4 × EC 287711)	13	07	05	11	36	00
Seed yield per plant (g)	-54.51 to 51.97 (GDM 4×Dhara)	-57.53 to 16.80 (GDM 4×EC 287711)	-41.95 to 51.36 (GM 1 × GM 2)	13	09	02	17	17	08
1000-seed weight (g)	-17.72 to 35.05 (GM 1×P. Mustard 21)	-22.27 to 21.73 (GM 1×P. Mustard 21)	-41.95 to 51.36 (—)	12	03	03	12	00	20
Harvest index (%)	-29.67 to 38.98 (GM 2×P. Mustard 21)	-38.52 to 28.95 (GM 2 × GM 3)	-35.66 to 24.03 (GM 1 × RSK 28)	13	14	02	24	06	25
Oil content (%)	-5.82 to 17.76 (GDM 4×P. Mustard 21)	-14.72 to 11.61 (GDM 4×P. Mustard 21)	-12.12 to 13.62 (SKM 9033×RSK 28)	17	03	10	18	12	05
Oleic acid (%)	-55.02 to 52.13 (GM 2 × RSK 28)	-70.87 to 43.77 (GM 2 × RSK 28)	-17.54 to 218.32 (P. Mustard 21×Dhara)	12	24	03	37	34	03
Lenoleic acid (%)	-529.54 to 75.91 (GM 2 × EC 287711)	-46.09 to 60.86 (GM 2 × GM 3)	-13.67 to 77.93 (P. Mustard 21×Dhara)	21	17	11	29	29	02
Erucic acid (%)	-29.84 to 67.64 (P. Mustard 21×Dhara)	-55.67 to 8.16 (P. Mustard 21×Dhara)	-78.45 to 8.51 (P. Mustard 21×Dhara)	22	19	03	39	06	36

tices were followed to raise the healthy crop. Data were recorded for 12 different characters. For days to flowering, days to maturity data were recorded on plot basis; while for plant height (cm), number of branches per plant, number of silique per plant, seed yield per plant (g), 1000 seed weight (g), harvest index (%), oil content (%), oleic acid, lenoleic acid and erucic acid content data were recorded on five randomly selected plants in each treatment over replications. The mean values for each character were statistically analyzed for randomized complete block design. Heterosis expressed as per cent increase or decrease in the mean value of F_1 hybrid over mid parent i.e., relative heterosis, over better parent i.e., heterobeltiosis and over standard check (BIO 902) i.e., standard heterosis were computed for each character. For the characters viz., days to flowering, days to maturity and plant height, low scoring parents were considered as better parents for the estimation of heterobeltiosis and standard heterosis whereas, high scoring parents were considered as better parents for the rest of the characters.

Results and Discussion

The analysis of variance was performed to test the difference among the parents and hybrids for all the 12 characters and is presented in Table 1. The results revealed that mean square due genotypes were highly significant for all the characters except for plant height. This indicated that sufficient amount of genetic variability was present in the experimental material for all the characters under study. The mean square due genotypes were further partitioned into parents, hybrids and parents vs hybrids.

The parent differed significantly for all the traits indicated enough variation among the parents. The

Table 3. Five most heterotic crosses for seed yield per plant along with *per se* performance and their heterotic effects for component characters in Indian mustard. *, ** Significant at 5% and 1% levels, respectively.

Crosses	Mean seed yield per plant (g)	Relative heterosis for seed yield per plant (g)	Hetero-beltiosis for seed yield per plant (g)	Standard heterosis for seed yield per plant(g)	Also desirable significant for other traits
GM 1 × GM 2	36.89	11.99*	4.18	51.36**	Number of branches per plant, number of silique per plant and harvest index.
GM 3 × LES 45	35.61	28.68**	6.88	46.12**	Number of branches per plant, number of silique per plant, oleic acid, lenoleic acid and erucic acid (%).
GM 1 × GM 3	34.99	1.82	-1.19	43.56**	Number of branches per plant, number of silique per plant, harvest index, lenoleic acid and erucic acid (%)
GM 1 × P. Mustard 21	33.99	14.51*	-4.00	39.47**	Number of branches per plant, number of silique per plant, oleic acid and erucic acid (%)
GDM 4×EC 287711	33.40	28.10**	16.80*	37.05**	Number of branches per plant, number of silique per plant, oil content, oleic acid and erucic acid (%)

hybrids showed significant differences for all the traits except for plant height, which exerted the variability among the crosses for most of the traits. Parent vs hybrid comparisons were significant for all the traits except plant height, number of branches per plant, seed yield per plant and harvest index suggesting adequate amount of difference for these traits.

In present investigation, several crosses depicted conspicuous heterotic response over mid parental values for different characters. However, apart from indicating genetic interactions, the measure of relative heterosis has relatively less importance than heterobeltiosis. Therefore, it is better to measure the heterosis in terms of superiority over the parent rather than mid parent. However, the commercial usefulness of a hybrid would primarily depend on its performance in comparison with the best commercial variety of the concerned crop species. Overall performance of the hybrids with respect to relative heterosis for seed yield per plant, yield components and quality parameters (Table 2) revealed that 20 hybrids for days to flowering, three hybrids for days to maturity, seven hybrids for number of branches per plant, 13 hybrids for number of silique per plant, seed yield per plant and harvest index, 12 for 1000-seed weight, 17 hybrids for oil content, 12 for oleic acid, 21 hybrids for lenoleic acid, 22 for erucic acid manifested significant desirable relative heterosis.

Thus, it is revealed that the majority of hybrids for most of the traits viz., seed yield per plant, number of branches per plant, number of silique per plant, harvest index, 1000 seed-weight, oil per cent, oleic acid and lenoleic acid exhibited positive significant relative heterosis, thereby indicating that for these traits the genes with positive effects were dominant. While, for the traits such as plant height, days to flowering, days to maturity and erucic acid majority of the hybrids showed negative significant relative heterosis suggesting that for these traits genes with negative effects were dominant.

The heterotic response over mid parent in *Brassica* were also reported by Parmar et al. [3], Singh et al. [4], Prajapati et al. [5], Sabaghnia et al. [6] and Dar et al. [7], Dholu et al. [8], Niranjana et al. [9] and Akabari and Sasidharan [10].

An examination of performance of hybrids over better parent revealed that two hybrids manifested significant positive heterobeltiosis for seed yield per plant. The maximum heterobeltiosis for seed yield per plant was depicted by the hybrid GDM 4 × EC 287711

(16.80%). A number of hybrids exhibited significant heterosis over better parent in desirable direction for different component traits (Table 2) such as days to flowering (P. Mustard 21 × EC 287711), days to maturity (P. Mustard 21 × RSK 28 and P. Mustard 21 × EC 287711), number of branches per plant (GM 3 × LES 45, GDM 4 × EC 287711 and GDM 4 × Dhara), number of silique per plant (5), 1000-seed weight (GM 1 × P. Mustard 21 and GM 1 × Dhara), harvest index (GM 2 × GM 3 and GM 2 × Dhara), oil percentage [5], oleic acid percentage (GM 2 × RSK 28, GM 1 × EC 287771 and GM 2 × EC 287711), lenoleic acid percentage [6] and erucic acid percentage. These findings were also supported by Prajapati et al. [5], Sabaghnia et al. [6] and Dar et al. [7].

The variety, BIO 902 is used as standard check in order to obtain information regarding superiority of new hybrids over best cultivated variety. A perusal of the results (Table 2) revealed that 17 hybrids showed significant heterosis over standard check variety, BIO 902 in desired direction for seed yield per plant. The maximum significant and positive heterosis over check variety BIO 902 was observed in hybrid GM 1 × GM 2 (51.36%) followed by GM 3 × LES 45 (46.12%), GM 1 × GM 3 (43.56%), GM 1 × P. Mustard 21 (39.47%) and GDM 4 × EC 287711 (37.05%). The heterotic response over standard check in Indian mustard were also reported by Parmar et al. [3], Singh et al. [11], Patel et al. [12], Dholu et al. [8], Niranjana et al. [9] and Akabari and Sasidharan [10] which are in accordance with the present findings.

For oil content, lenoleic acid and oleic acid, the value for relative heterosis, heterobeltiosis and standard heterosis were high. Similarly, the value for erucic acid was low. Similar results were also found by Singh et al. [11] and Wang et al. [13].

It is clear from the above discussion that five crosses, GM 1 × GM 2, GM 3 × LES 45, GM 1 × GM 3, GM 1 × P. Mustard 21 and GDM 4 × EC 287711 were found to be the most promising for seed yield, and other desirable traits (Table 3), hence these hybrids could be further evaluated in heterosis breeding program and simultaneously advanced in segregating generations to obtain desirable segregants for the development of superior genotypes for seed yield and its component traits.

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