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Research Note

Heterosis analysis for yield and yield attributed traits in Indian mustard [*Brassica juncea* (L.) Czern & Coss]

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Abstract
The present investigation entitled "Identification of promising heterotic combinations for yield and yield attributed traits in Indian mustard [*Brassica juncea* (L.) Czern & Coss]" consists analysis of 15×15 half-diallel set of crosses in Indian mustard revealed that non-additive gene effects was found to be predominant for secondary branches per plant, whereas preponderance of additive gene effects for the inheritance of rest of the characters. The evaluation of heterosis revealed that PRB-2004-3-4×PRE-2009-9(-9.627**), Bhaghirathi ×PRE-2009-9 (-16.53**), RGN-145×PR-2006-1(-4.64**) for early maturity, PRB-2008-5× PRB-2004-3-4 (-24.37**), PRB-2008-5×PRE-2009-9 (-24.89**), PRE-2009-9×NDYR-8 (-23.32**) for dwarf plant height, PR-2006-1×NDRE-4 (201.74**), PR-2006-1×NDYR-8 (137.26**), Maya×PRE-2004-3-4 (40.26**) for seed yield, PRE-2009-9×NDYR-8 (15.84**), RGN-74×PRE-2007-6 (2.91**), Maya×NDYR-8 (2.09**) for oil content, most promising were heterotic crosses for mid parent heterosis, better parent and economic heterosis respectively. All three type of heterosis with respect to over mid parent, better parent and standard check were observed significant in desirable direction for all the characters except glucosinolate content. The manifestation of high amount of heterosis for seed yield and component traits by a large number of crosses suggesting need to maintain heterozygosity in the population for maximum expression of traits in desirable direction. Foregoing results and inferences revealed that the presence of wide spectrum of exploitable variability in research material studied with respect to various quantitative traits projecting, thereby, immense scope for genetic improvement in Indian mustard. Therefore, with the help of heterosis studies, the superior cross combination of promising hybrids could be identified for developing high yielding cultivars.

Keywords
Half-diallel, Heterosis, Indian mustard, yield

Indian mustard [*Brassica juncea* L. (Czern & coss)] is an important oil seed crop of the world. It plays a major role in catering edible oil demand of the country. It has 38 to 42% oil and 24% protein. Diallel analysis provides a mating design whereby the selected parents are crossed in all possible combinations (Griffing, B. 1956a). Many studies have been conducted to address the effects of GCA and SCA on manifestation of heterosis for yield and yield components in different crops (Gupta *et al* .2010 and Maurya *et al*.2012.), but the research studies regarding gene action for yield and yield components in brassica is unsolved and needs consideration. The present study aims to identify the best crops combination among various selected F_1 hybrids on the basis of their per see performance for yield and its contributing traits, which in combinations would provide desirable segregation or may be hybridized either to exploit heterosis or to accumulate fixable genes. The magnitude of heterosis provides a basis for evaluation of genetic diversity and a guide for the choice of desirable parents for developing superior F1 hybrids to exploit hybrid vigour and for building gene pools to be employed in breeding programme.

The experimental material for present study comprised of a set of 15 diverse genotypes of Indian mustard (*Brassica juncea* L.) involving four early maturing genotypes (NDRE-4, PRE-2007-6, PR-2006-1 and PRE-2009-9), six agronomically superior genotypes (NDYR-8, Kranti, Maya, Bhaghirathi, RGN-74 and RGN-145), two late maturing genotypes (Vardan and Ashirvad) and three bold seeded genotypes (PRB-2006-5, PRB-2008-5 and PRB-2004-3-4). The parents were crossed in all possible combinations excluding reciprocals during *rabi* season 2011-12. Experiment material consisting of 15 parents and 105 F_1′s was evaluated in a randomized block design with three replications during *rabi* season 2012-13**.** Each plot comprised of 1 row of 3 meter long. The crop was sown at a distance of 30 cm and plant to plant distance of 10 cm was maintained by thinning after 20-25 days of sowing. Single row of Indian mustard cultivar NDRE-4 was sown on either side of each block as guard row. Five competitive plants from parents and F_1′s were randomly selected from each plot and tagged at the time of vegetative stage for recording of data on Days to 50% flowering, Days to maturity, Chlorophyll content (SPAD value),Plant height (cm),Length of main raceme (cm), Siliqua length (cm),Number of primary branches per plant, Number of secondary branches per plant, Number of siliquae on main raceme ,No. of Seeds per siliqua Siliqua density ,Seed yield per plant, (g),Test weight (g),Oil content (%), Glucosinolate content (µmole/g fat free meal). Heterosis, expressed as percent increase or decrease in the performance of F_1 hybrid over the check variety Kranti (standard or economic heterosis) and better parent (heterobeltiosis) was computed for each character using standard formulas (Shull, 1952).

$$\text{Mid parent heterosis} = \frac{\overline{F}_1 - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{Heterobeltiosis} = \frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Standard heterosis} = \frac{\overline{F}_1 - \overline{SV}}{\overline{SV}} \times 100$$

The significance of heterosis was tested with't' test .

(a) For mid parent heterosis

$$t = \frac{\overline{F}_1 - \overline{MP}}{\sqrt{\frac{3}{2}Me/r}}$$

(b) For heterobeltiosis

$$t = \frac{\overline{F}_1 - \overline{BP}}{\sqrt{2Me/r}}$$

(c) For standard heterosis

$$t = \frac{\overline{F}_1 - \overline{SV}}{\sqrt{2Me/r}}$$

Where, $\overline{F}_1$ = Mean performance of F_1 hybrid

$\overline{P}_1$ = Mean performance of parent one

$\overline{P}_2$ = Mean performance of parent two

$\overline{MP}$ = Mean performance of mid parent

$\overline{BP}$ = Mean performance of better parent

$\overline{SV}$ = Mean performance of standard variety

Where,
Me = Error mean square from ANOVA table and
r = number of replications

The evaluation of heterosis revealed that PRB-2004-3-4×PRE-2009-9(-9.627**), Bhaghirathi ×PRE-2009-9 (-16.53**), RGN-145×PR-2006-1(-4.64**) for early maturity, PRB-2008-5× PRB-2004-3-4 (-24.37**), PRB-2008-5×PRE-2009-9 (-24.89**), PRE-2009-9×NDYR-8 (-23.32**) for dwarf plant height, PR-2006-1×NDRE-4 (201.74**), PR-2006-1×NDYR-8 (137.26**), Maya×PRE-2004-3-4 (40.26**) for seed yield, PRE-2009-9×NDYR-8 (15.84**), RGN-74×PRE-2007-6 (2.91**), Maya×NDYR-8 (2.09**) for oil content, most promising were heterotic crosses for mid parent heterosis, better parent and economic heterosis (Relative ,Heterobeltiosis and Standard heterosis) respectively. All three type of heterosis with respect to over mid parent, better parent and standard check were observed significant in desirable direction for all the characters except glucosinolate content. The manifestation of high amount of heterosis for seed yield and component traits by a large number of crosses suggest for the need to maintain heterozygosity in the population for maximum expression of the traits in desired direction. Overall results indicate that breeding methods such as heterosis breeding with concurrent random mating could be the most suitable option for further improvement and identifying the following best cross combinations for yield and yield attributing traits in Indian mustard.

Foregoing results and inferences revealed the presence of wide spectrum of exploitable variability in the material studied with respect to various quantitative traits projecting, thereby, immense scope for genetic improvement in Indian mustard. Estimates of combining ability and heterotic responses further showed the perceptible advantage of heterozygosity in increasing the yield. This phenomenon led to identify heterosis breeding as the key methodology for improving genetic yield ceiling in Indian mustard. Therefore, with the help of combining ability and heterosis superior parents/hybrids could be identified to exploit in the breeding programme for developing high yielding cultivars.

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Table 1. Top three ranking cross combinations with respect to exploited heterosis over mid parent, better parent and standard check

S. No	Characters	High Heterotic Cross Combinations Mid Parent Heterosis	Better Parent Heterosis	Standard Heterosis
1.	Days to 50 percent flowering	RGN-74 × NDRE-4	RGN-145× PR-2006-1	Maya × RGN-145
		RGN-74× PRE-2007-6	RGN-145×PRE-2007-6	Maya × Ashirwad
		PRE-2007-6 × NDRE-4	Bhaghirathi × NDYR-8	RGN-145 × RGN-74
2.	Days to maturity	PRB-2004-3-4× PRE-2009-9	Bhaghirathi×PRE-2009-9	RGN-145×PR-2006-1
		PRB-2008-5× PRB-2004-3-4	PRB-2004-3-4× NDYR-8	PRE-2007-6×NDRE-4
		Bhaghirathi×PRB-2004-3-4	PRE-2009-9 × Ashirwad	PRE-2009-9×NDYR-8
3.	Chlorophyll content	Bhaghirathi × Vardan	RGN-145 × PRE-2009-9	RGN-74 × NDYR-8
		RGN-145 × PRE-2009-9	Bhaghirathi × Vardan	Vardan × Ashirwad
		Vardan × PRE-2009-9	RGN-145 × PR-2006-1	RGN-145 × NDRE-4
4.	Plant height (cm)	PRB-2008-5×PRB2004-3-4	PRB-2008-5×PRE-2009-9	PRE-2009-9×NDYR-8
		PRB-2008-5 × PR-2006-1	PRB-2008-5 × RGN-74	PRB-2008-5×PRE-2009-9
		PRB-2008-5 × Ashirwad	PRE-2004-3-4×PRE-2009-9	Ashirwad × NDYR-8
5.	Lentgh of main raceme	Ashirwad × Kranti	Ashirwad × PRE-2007-6	PRB-2006-5 × Ashirwad
		PRB-2006-5 × Ashirwad	PRE-2006-5 × Ashirwad	Vardan × NDRE-4
		Kranti × NDYR-8	Maya × Ashirwad	Maya × NDYR-8
6.	Lentgh of siliqua	PRB-2008-5 × PR-2006-1	Maya × Vardan	PRB-2006-5×PRB2004-3-4
		Maya × PRB-2008-5	Maya × PRE-2004-3-4	PRB-2006-5 × NDYR-8
		PRB-2006-5 × RGN-74	PRB-2006-5×PRE-2007-6	Maya × PRB-2008-5
7.	Number of primary branches	Bhghirathi × Ashirwad	Bhaghirathi × PRE-2006-1	Bhaghirathi × PR-2006-1
		PR-2006-1 × Kranti	PR-2006-1 × PRE-2007-6	PR-2006-1× PRE-2007-6
		PRB-2004-3-4 × Kranti	PRB-2004-3-4×PR-2006-1	MAYA×PR-2006-1
8.	Number of secondary branches	Bhaghirathi × PRB-2008-5	Bhaghirathi×PRB-2004-3-4	RGN-145×RGN-74
		Vardan × NDRE-4	PRE-2009-9 × NDYR-8	Bhaghirathi×PRB-2004-3-4
		Vradan × Kranti	PRB-2004-3-4 × Kranti	Maya × Bhaghirathi
9.	Number of siliqua on main raceme	Vardan × Kranti	Vardan × PRE-2007-6	Bhaghirathi × NDYR-8
		Vardan × PRB-2008-5	Bhaghirathi × NDYR-8	Vardan × Kranti
		Vardan × RGN-74	Bhaghirathi × Kranti	Vardan × PRE-2007-6
10	Number of seeds per siliqua	Kranti × PRE-2007-6	Kranti × NDRE-4	Kranti × NDRE-4
		PR-2006-1 × NDRE-4	PR-2006-1 × NDYR-8	Maya × PRB-2008-5
		Maya × PRB-2008-5	Maya × PRB-2008-5	Ashirwad × Kranti
11	Siliqua density on main raceme	PRE-2009-9 × Ashirwad	PRE-2009-9 × PR-2006-1	PRB-2008-5×PRE-2009-9
		Ashirwad × Kranti	Ashirwad × NDRE-4	Ashirwad × PRE-2007-6
		Ashirwad × PR-2006-1	PRB-2008-5 × PRE-2009-9	PRE-2009-9×PRE-2006-1

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12	Seed yield per plant	PR-2006-1 × NDRE-4 PR-2006-1 × RGN-74 PRB-2004-3-4 × PR-2006-1	PR-2006-1 × NDYR-8 Bhaghirathi × PR-2006-1 PR-2006-1 × Kranti	Maya × PRE-2004-3-4 PR-2006-1 × NDYR-8 PRB-2008-5×PRE-2009-9
13	Test weight (g)	NDRE-4 × NDYR-8 Ashirwad × NDYR-8 Maya × PRE-2007-6	Maya × PRE-2007-6 Ashirwad × NDYR-8 NDRE-4 × NDYR-8	PRE-2009-9 × RGN-74 PRB-2006-5×PRB2004-3-4 PRE-2009-9 × Ashirwad
14	Oil content (%)	PRE-2009-9 × NDYR-8 Bhaghirathi × NDYR-8 RGN-145 × NDYR-8	RGN-74 × PRE-2007-6 Bhaghirathi×PRE-20007-6 RGN-74 × NDYR-8	Maya × NDYR-8 PRE-2009-9 × Ashirwad Ashirwad × PR-2006-1
15	Glucosinolate content (%)	Bhaghirathi × RGN-145 Vardan × Ashrvad Maya × Bhaghirathi	Bhaghirathi × RGN-145 Maya × Bhaghirathi Vardan × Ashirwad	-