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# Combining ability and heterobeltiosis for yield and yield-contributing traits in Indian mustard (*Brassica juncea*)

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## ABSTRACT

Line × tester analysis involving 14 lines and five testers revealed that both additive and non-additive gene actions were important in controlling yield-contributing traits. Variety Pusa Mustard 25 was identified as best general combiner among the parents. Significant and positive sca effects were observed for seed yield in 17 hybrids, 1000-seed weight in nine hybrids, number of siliquae on main shoot in nine hybrids, number of primary branches in six hybrids, point to first siliqua in six hybrids, main shoot length in five hybrids and number of secondary branches in four hybrids; and significant negative sca effects for point to first branch in four crosses and plant height in two crosses. Ten hybrids exhibited >15% heterobeltiosis, highly significant sca effects and higher *per se* performance. Parents used in generating these hybrids are suitable candidates for their conversion to cytoplasmic male sterile and/or restorer lines for the commercial exploitation of heterosis.

**Key words:** Combining ability, Gene effects, Heterobeltiosis, Indian mustard, Yield contributing traits

*Brassica* spp, commonly known as rapeseed mustard, play an important role in Indian economy by providing edible oils, vegetables, condiments and animal feed. It is the third most important source of vegetable oil of the world, after soybean and palm. Share of India in cultivated area and production of rapeseed mustard is 21.7% and 10.7% of the world, respectively (USDA 2010). Out of the four oleiferous *Brassica* species, viz. *Brassica juncea, B. napus, B. rapa* and *B. carinata*; *B. juncea* contributes more than 80% of the total rapeseed mustard production of the country. All these four oleiferous *Brassicas* are grown in about 6.49 million ha and are producing 7.41 million tonnes of oilseed with the average productivity of 1.197 tonnes/ha (Kumar *et al.* 2012). Rapeseed mustard is the second most important oilseed crop of India, next to soybean. The production and productivity of mustard in India is almost static during the last decade and productivity is hovering between 1 and 1.2 tonnes/ha, which is much below the world's average of 1.98 tonnes/ha. When we compare the productivity of Germany (4.3 tonnes/ha), France (3.8 tonnes/ha) and UK (3.4 tonnes/ha) with that of India, the yield gaps further widen (FAOSTAT 2009). It clearly demonstrates the scope of improving the productivity of Indian mustard through genetic manipulations. Heterosis breeding can be one of the most viable options for breaking the present yield barrier. Availability of effective means of hybrid seed production led to the development of few commercial hybrids in India during last decade (Kumar *et al.* 2012), however, the level of yield gain achieved from these hybrids is marginal. As a result, these hybrids could occupy very little area in the country as compared to pure line varieties. For the development of improved commercial hybrids, there is urgent need to study the combining ability of the locally developed cultivars so that well adapted heterotic parental lines can be developed and specific combiner(s), if any, can be identified. Therefore, the present study was undertaken to determine general combining ability of parental lines and specific combining ability and heterobeltiosis of different cross combinations in Indian mustard.

## MATERIALS AND METHODS

The experimental material for the present study comprised of 70 $F_1$s of *Brassica juncea* involving 14 lines, viz. Pusa Mustard 25 (SEJ 8/Pusa Jagannath), Pusa Bahar

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[(Pusa Rai 28/Varuna)/(Pusa Rai 30/T 6342)], Pusa Vijay (synthetic *Brassica juncea*/VSL 5), NPJ 139 (Pusa Jagannath/SEJ 8), RGN 48 (RSM 204/B 75), Pusa Jagannath (multicross between Varuna/inter cross derivatives/Synthetic *Brassica juncea)*, Pusa Karishma (Pusa Barani/ZEM 1), Pusa Mustard 21 (Pusa Bold/ZEM 2), NRCDR 02 (MDOC 43/NBPGR 36), Vasundhra (RH 839/RH 30), Pusa Agrani [Early mutant of *Brassica juncea*/Synthetic amphidiploid (*Brassica compestris* var. toria/*Brassica nigra*)], SEJ 8 [Synthetic (*Brassica compestris* var. toria/*Brassica nigra*) *Brassica juncea* line], Laxmi (PR 15/RH 30A), RGN 73 (RGN 8/Pusa Bold) and five testers, viz. Pusa Tarak (Agra Local/Poorbi Raya), RGN 145 (Varuna/Tobin), RB 50 (Laxmi/RH 9617), GM 2 (selection from material collected from Vendancha, Gujarat) and RH 30 (selection from P 26/3-1) were crossed in line × tester design at Indian Agricultural Research Institute, New Delhi during 2008–09. The crosses along with the parents were raised during winter 2009–10 in randomized block design with two replications. Each treatment was represented by a single row of 5 m length kept at a distance of 30 cm between rows and 15 cm between plants. Standard agronomic practices were followed to raise the crop (fertilizer N:P:K:S::60:40:40:40 kg/ha; three irrigations including pre-sowing). Observations were recorded on six competitive plants selected at random for nine quantitative traits, viz. seed yield/plant (g), plant height (cm), point to first branch (cm), number of primary branches, number of secondary branches, main shoot length (cm), point to first siliqua (cm), number of siliquae on main shoot and 1 000-seed weight (g). The combining ability analysis was done following Kempthorne (1957). The per cent heterosis over the better parent (heterobeltiosis) was calculated as deviation of $F_1$ value from the better parent.

## RESULTS AND DISCUSSION

The analysis of variance revealed that the mean squares due to lines, testers and line × testers were significant for all the traits, thereby suggesting that the experimental material

Table 1 Estimates for gca effects of line and testers for nine characters in Indian mustard

| Parents | Seed yield (g) | Plant height (cm) | Point to first branch (cm) | Number of primary branches | Number of secondary branches | Main shoot length (cm) | Point to first siliquae (cm) | Number of siliqua on main shoot | 1 000-seed weight (g) |
|---|---|---|---|---|---|---|---|---|---|
| *Lines* | | | | | | | | | |
| Pusa Mustard 25 | 5.66** | –17.90** | –29.73** | –0.71** | –0.67 | 17.86** | –1.07 | 2.48 | 0.31** |
| Pusa Bahar | 0.23 | –6.81** | 13.27** | –0.42 | –1.74** | –14.21** | 2.07* | –10.72** | –0.27** |
| Pusa Vijay | –1.02** | –16.99** | –9.17** | –0.77** | –1.88** | 0.56 | –0.17 | –3.25 | 0.51** |
| NPJ 139 | –0.31 | –0.81 | –0.80 | –0.25 | 1.06 | –3.68 | 2.13* | –4.92* | 0.44** |
| RGN 48 | –2.01** | –13.48** | –18.99** | –0.68** | –2.11** | 12.52** | –1.13 | 2.58 | –0.40** |
| Pusa Jagannath | –1.46** | –1.91 | –0.29 | 0.49* | 1.13 | –12.94** | –2.89* | –5.92** | 0.14 |
| Pusa Karishma | 1.41** | 23.26** | 27.57** | 0.99** | 0.32 | –0.84 | –0.93 | 6.41** | –1.05** |
| Pusa Mustard 21 | –0.65 | 23.69** | 25.01** | 1.25** | –0.91 | 1.52 | –0. 60 | 12.95** | –0.34** |
| NRCDR 02 | 2.69** | 12.72** | 6.91* | 0.92** | 3.19** | –2.91 | –0.63 | –3.39 | 0.74** |
| Vasundhra | –0.63 | 0.12 | –6.59* | 0.42 | 3.16** | –6.51* | 0.47 | –3.35 | –0.12 |
| Pusa Agrani | 1.62** | –1.17 | –20.87** | –0.62** | 2.18** | 5.20* | 2.35* | 0.90 | –0.39** |
| SEJ 8 | –2.06** | –6.74** | –0.89 | –1.28** | –2.61** | 4.69 | –1.27 | 1.88 | 0.32** |
| Laxmi | –1.29** | –3.24 | 6.31* | 0.92** | –0.71 | –5.31* | 1.27 | –2.75 | 0.57** |
| RGN 73 | –2.19** | 9.26** | 8.27** | –0.25 | –0.41 | 4.06 | 0.40 | 7.31 | –0.47** |
| SE ± | 0.42 | 2.38 | 3.22 | 0.22 | 0.60 | 2.65 | 0.96 | 1.92 | 0.09 |
| CD (*P*=0.05) | 0.82 | 4.66 | 6.31 | 0.43 | 1.18 | 5.19 | 1.88 | 3.76 | 0.18 |
| CD (*P*=0.01) | 1.07 | 6.05 | 8.17 | 0.56 | 1.52 | 6.73 | 2.44 | 4.88 | 0.23 |
| *Testers* | | | | | | | | | |
| Pusa Tarak | –2.14** | –23.26** | –11.14** | –0.85** | –1.17** | –1.64 | –1.24* | –3.91** | –0.07 |
| RGN 145 | 2.84** | 11.19** | 4.40* | 0.68** | 1.54** | –0.74 | –0.51 | 4.19** | –0.11* |
| RB 50 | –1.56** | 4.56** | 4.07* | 0.22 | –1.36** | –4.94** | 0.55 | –3.51** | 0.07 |
| GM 2 | –1.76** | –3.33** | –7.06** | –0.41** | 0.13 | 4.30** | 0.06 | –1.42 | –0.29** |
| RH 30 | 2.61** | 10.84** | 9.74** | 0.36** | 0.87** | 3.02* | 1.13* | 4.65** | 0.41** |
| SE ± | 0.23 | 1.32 | 1.79 | 0.12 | 0.33 | 1.47 | 0.53 | 1.07 | 0.05 |
| CD (*P*=0.05) | 0.45 | 2.59 | 3.50 | 0.24 | 0.65 | 2.88 | 1.04 | 2.10 | 0.10 |
| CD (*P*=0.01) | 0.58 | 3.35 | 4.55 | 0.30 | 0.84 | 3.73 | 1.35 | 2.72 | 0.13 |

**,* significant at *P*=0.01 and *P*=0.05, respectively possessed considerable variability and both gca and sca were involved in the genetic expression of these traits. The variation due to parents vs. hybrids was significant for seed yield/ plant, plant height, number of primary branches, number of secondary branches and number of siliquae on main shoot indicating the presence of heterosis for these traits in the series of crosses. Lines, testers and parents exhibited significant differences for all the traits suggesting the good genetic variation between the parental genotypes. Moreover, the variance due to hybrids was also significant indicating that the sufficient amount of genetic variability was generated in the hybrids. The variance due to parents vs. hybrids was significant for seed yield, plant height, number of primary branches, number of secondary branches and number of siliquae on main shoot; reveals that the hybrids differed considerably from parents, at least, for these traits. Relative estimates of sca variances were higher than gca variances for seed yield/plant, number of primary branches, number of secondary branches, main shoot length, point to first siliqua, number of siliquae on main shoot and 1 000-seed weight reflecting the predominance of non-additive gene action for these traits. It is suggested that selection and inter-mating in early segregating generation would be desirable for utilizing non-additive gene effects. On the other hand, gca variances were higher than the sca variances for plant height and point to first branch indicating that these traits are governed by the additive gene action and genetic progression can be achieved simply through hybridization followed by selection. Since both additive and non-additive gene actions are governing the yield contributing traits, therefore, hybridization methods such as multiple or reciprocal recurrent selection would be helpful in genetic improvement of traits under study. Furthermore, the combining ability variances for lines, testers and line × tester are significant for almost all the nine traits indicating the sufficient variation for combining ability in the parents and hybrids as well.

The estimates of gca are presented in Table 1. Among lines, Pusa Mustard 25, Pusa Karishma, NRCDR 02 and Pusa Agrani were found to exhibit positive and highly significant gca effects for seed yield indicating the presence of additive gene action or additive × additive interaction effects. However, in the hybrids developed from Pusa Karishma and NRCDR 02, there is positive complementation for plant height and point to first branch, whereas there is reduction of seed size in the hybrids developed from Pusa Karishma. In hybrids developed from Pusa Agrani there is negative effect on the seed size. Among testers RGN 145 and RH 30 exhibited positive and highly significant seed yield, however, there is positive complementation for plant height and point to first branch. Moreover, in the hybrids developed from RGN 145, there is negative effect on the seed size. Generally, gca rank for seed yield is attributed to gca of major yield components. Thus, Pusa Mustard 25 is the best general combiner under study, complementing good traits

Table 2 Highly significant (positive except for plant height and point to first branch) SCA effects for nine yield and yield-contributing traits in crosses of Indian mustard genotypes

| Trait | Crosses |
|---|---|
| Seed yield (g) | Pusa Mustard 25/ RGN 145 (3.64), Pusa Bahar/ RGN 145 (7.66), Pusa Bahar/RH 30 (3.72), Pusa Vijay/Pusa Tarak (3.46), Pusa Vijay/RGN 145 (4.87), NPJ 139/GM 2 (2.58), RGN 48/Pusa Tarak (2.13), Pusa Jagannath/RH 30 (4.50), Pusa Karishma/Pusa Tarak (6.65), Pusa Mustard 21/GM 2 (3.64), NRCDR 02/RB 50 (5.42), Vashundhra/GM 2 (4.57), Pusa Agrani/Pusa Tarak (3.40), SEJ 8/RB 50 (3.37), SEJ 8/RH 30 (2.47), Laxmi/RB 50 (4.67), RGN 73/Pusa Tarak (3.10) |
| Plant height (cm) | SEJ 8/Pusa Tarak (-14.47), RGN 73/RGN 145 (-12.92) |
| Point to first branch (cm) | NPJ 139/RH 30 (-19.01), Pusa Jagannath/GM 2 (-16.37), Pusa Karishma/Pusa Tarak (-30.16), Vasundhra/RGN 145 (-15.03) |
| Number of primary branches | NPJ 139/RGN 145 (1.52), Pusa Karishma/GM2 (1.71), Pusa Mustard 21/GM 2 (1.44), NRCDR 02/RH 30 (1.18), Laxmi/Pusa Tarak (1.55), RGN 73/RH 30 (1.67) |
| Number of secondary branches | NPJ 139/GM 2 (3.74), Pusa Karishma/Pusa Tarak (3.11), Pusa Mustard 21/GM 2 (5.87), Vashundhra/RGN 145 (5.55) |
| Main shoot length (cm) | Pusa Bahar/ RGN 145 (19.47), NPJ 139/RH 30 (13.85), Pusa Jagannath/GM 2 (20.00), Vashundhra/RH 30 (15.10), Laxmi/RB 50 (15.28) |
| Point to first siliqua (cm) | Pusa Mustard 25/RB 50 (6.05), NPJ 139/RH 30 (7.94),NRCDR 02/GM2 (7.78), Pusa Agrani/GM 2 (7.80), SEJ 8/RH 30 (5.00), RGN 73/RGN 145 (8.97) |
| Number of siliquae on main shoot | Pusa Bahar/ RGN 145 (12.25), NPJ 139/RGN 145 (11.28), RGN 48/GM 2 (9.22), Pusa Jagannath/GM 2 (12.55), Pusa Jagannath/RH 30 (11.65), Pusa Karishma/RB 50 (12.81), Pusa Mustard 21/GM 2 (11.02), NRCDR 02/RB 50 (11.45), Laxmi/RB 50 (14.48) |
| 1 000-seed weight (g) | Pusa Bahar/ RGN 145 (0.55), Pusa Bahar/RH 30 (0.59), Pusa Vijay/Pusa Tarak (0.45), NPJ 139/Pusa Tarak (0.85), RGN 48/RB 50 (0.87), Pusa Mustard 21/RGN 145 (0.52), Vashundhra/GM 2 (0.85), Pusa Agrani/Pusa Tarak (0.50), Laxmi/RB 50 (0.59) |

Table 3 Mean performance and estimates of heterobeltiosis for seed yield in Indian mustard genotypes

| Lines | Testers | | | | | Mean seed yield of lines (g) |
|---|---|---|---|---|---|---|
| | Pusa Tarak | RGN 145 | RB 50 | GM 2 | RH 30 | |
| Pusa Mustard 25 | 16.72<br>(47.66*) | 23.58<br>(54.38**) | 16.76<br>(67.71) | 13.73<br>(37.49) | 14.74<br>(–13.35**) | 17.11 |
| Pusa Bahar | 4.59<br>(–59.47**) | 22.18<br>(45.13**) | 8.73<br>(–9.59) | 4.86<br>(–40.62**) | 18.01<br>(5.91**) | 11.68 |
| Pusa Vijay | 11.76<br>(3.82**) | 18.15<br>(18.78**) | 4.75<br>(–50.80**) | 5.48<br>(–39.64**) | 12.02<br>(–29.36) | 10.43 |
| NPJ 139 | 7.48<br>(–39.96) | 13.27<br>(–13.21) | 7.28<br>(–41.52**) | 11.96<br>(–4.02**) | 15.72<br>(–7.61*) | 11.14 |
| RGN 48 | 9.43<br>(–16.73**) | 10.72<br>(–29.85) | 8.06<br>(–16.62) | 7.51<br>(–17.74) | 11.46<br>(–32.62) | 9.43 |
| Pusa Jagannath | 4.03<br>(–64.41**) | 13.70<br>(–10.31) | 6.26<br>(–35.15**) | 8.84<br>(1.67) | 17.10<br>(0.56**) | 9.99 |
| Pusa Karishma | 17.37<br>(53.42**) | 15.32<br>(0.29) | 7.66<br>(–20.68**) | 7.76<br>(–5.29**) | 16.16<br>(–5.03) | 12.85 |
| Pusa Mustard 21 | 6.82<br>(–39.69*) | 11.70<br>(–23.43*) | 8.24<br>(–15.00) | 12.68<br>(30.94**) | 14.56<br>(–14.42) | 10.80 |
| NRCDR 02 | 9.82<br>(–32.53**) | 15.40<br>(0.77) | 17.99<br>(23.65**) | 10.32<br>(–29.05*) | 17.14<br>(0.73) | 14.13 |
| Vasundhra | 6.31<br>(–44.24**) | 14.57<br>(–4.66) | 7.01<br>(–29.14**) | 13.63<br>(37.78**) | 12.59<br>(–26.00) | 10.82 |
| Pusa Agrani | 14.34<br>(26.64**) | 13.65<br>(–10.64**) | 12.20<br>(26.29) | 12.58<br>(49.21) | 12.57<br>(–26.11**) | 13.07 |
| SEJ 8 | 3.06<br>(–72.97**) | 10.10<br>(–33.87*) | 11.19<br>(15.91**) | 8.09<br>(–1.22) | 14.47<br>(–14.95**) | 9.38 |
| Laxmi | 8.40<br>(–25.79) | 10.33<br>(–32.38**) | 13.27<br>(37.30**) | 9.78<br>(6.78) | 9.01<br>(–47.07**) | 10.16 |
| RGN 73 | 10.22<br>(–40.73**) | 7.34<br>(–57.40**) | 9.01<br>(–47.79) | 8.40<br>(–51.30) | 11.33<br>(–34.31) | 9.26 |
| Mean seed yield of testers (g) | 9.31 | 14.29 | 9.89 | 9.69 | 14.06 | |

Values in parentheses represent heterobeltiosis

**,*: heterobeltiosis with sca effects significant at *P*=0.01 and *P*=0.05, respectively

like high seed yield/plant, reduced plant height, reduced point to first branch, higher main shoot length and improved 1 000-seed weight in the hybrids, followed by NRCDR 02 and RH 30 (Table 1). Similar observations were also made by Singh *et al.* (2005) with a different set of material. These outcomes clearly reflect that there is a scope for improving combining ability of parents for component traits, as good combiners for seed yield traits were not good for number of other yield-contributing traits, therefore, one should breed to improve the combining ability of yield-contributing traits which would ultimately improve the gca of seed yield directly. Parents, viz. Pusa Mustard 25, NRCDR 02, Pusa Agrani, RH 30, Pusa Karishma and RGN 145 possessing high gca for seed yield-contributing traits like reduced plant height, reduced point to first branch, higher main shoot length and improved 1000 seed weight shall be included in the breeding programme for accumulation of favourable alleles in a single genetic background.

For plant height highly significant but negative sca effects were recorded for the crosses SEJ 8/Pusa Tarak and RGN 73/RGN 145, whereas, for point to first branch similar effects were observed for the crosses NPJ 139/RH 30, Pusa Jagannath/GM 2, Pusa Karishma/Pusa Tarak and Vasundhra/RGN 145 indicating that the reduction in plant height may be due to negative heterosis for plant height and point to first branch in these crosses, which is desirable (Table 2). Significant and positive sca effects were observed for seed yield in 17 hybrids, 1 000-seed weight in nine hybrids, number of siliquae on main shoot in nine hybrids, number of primary branches in six hybrids, point to first siliqua in six hybrids, main shoot length in five hybrids and number of secondary branches in four hybrids. It is quite evident that the parents involved in these crosses are good specific combiners; however, relative contribution of the parents to sca effect for seed yield is through different yield-contributing traits in different hybrids (Table 2). Furthermore, the results indicate that there is no direct relationship between sca effects and better parent heterosis (Table 3).

Out of 70 hybrids, 10 hybrids, viz. Pusa Mustard 25/ RGN 145 (54.38%), Pusa Bahar/RGN 145 (45.13%), Pusa Vijay/RGN 145 (18.78%), Pusa Karishma/Pusa Tarak (53.42%), Pusa Mustard 21/GM 2 (30.94%), NRCDR 02/ RB 50 (23.65%), Vasundhra/GM 2 (37.78%), Pusa Agrani/ Pusa Tarak (26.64%), SEJ 8/RB 50 (15.91%) and Laxmi/RB 50 (37.30%) exhibited >15% heterobeltiosis, highly significant sca effects and higher *per se* performance (Table 3). Vaghela *et al.* (2011) reported 44.8% heterobeltiosis in the hybrid RSK 28/RH(0E)0103 with highly significant sca effect and higher *per se* performance. Verma *et al.* (2011) also reported heterosis for seed yield to the extent of 24.36 to 80.97% in 15 crosses, whereas, Aher *et al*. (2009) reported moderate level of heterosis for seed yield/plant, number of siliquae/plant and number of secondary branches/plant.

Parents involved in developing heterotic hybrids in this study shall be converted to well adapted cytoplasmic male sterile or restorer lines and the high yielding $F_1$ combinations can further be exploited for their commercial utilization.

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