

Combining Ability Analysis for Yield and its Contributing Characters in Indian Mustard

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Abstract

The present investigation was carried out with a set of eight varieties of Indian mustard and their 28 F_1 's obtained through diallel crossing excluding reciprocals these were grown in RBD during *rabi* season of 2005 and studied for 12 quantitative characters. Out of these, white rust infections per plant were negligible to affect the economic yield. The mean squares of general combining ability (gca) and specific combining ability (sca) were highly significant at 1% for days to 50% flowering, days to maturity, numbers of siliqua/plant, seed yield/plant, 1000-seed weight, alternaria blight, aphids at full blooming stage and aphids infestation at siliqua formation stage while, plant height and oil content were significant at 5% probability level. The magnitude of variance estimates due to sca was higher for nine characters. The ratio of variance of gca to sca was less than unity for ten characters. The estimate of mean degree of dominance was higher than unity for nine characters under study indicating over dominance for characters. The predictability ratio $2\sigma^2_{gca}/2\sigma^2_{gca} + \sigma^2_{sca}$ was less than unity in all the characters. This ratio was observed highest for number of seeds/siliqua (0.901) and lowest for aphids' infestation at siliqua formation stage (0.111). The combining ability indicated that both additive and non-additive genetic components were involved in determining the characters studied but non-additive components were considerable. In the present investigation, JMM-991 was observed to be good general combiners for seed yield/plant, number of siliqua/plant, alternaria blight infection/plant, aphids' infestation/plant at full blooming stage and aphid's infestation/plant at pod formation stage and was recorded as the best parent. Varuna was good general combiner for oil content. Two best crosses selected on the basis of sca were BAUSM-92-1-1 \times JMM-991 and BR-40 \times Varuna for seed yield/plant and BR-40 \times Pusa bold and BAUSM-92-1-1 \times BIO-902 for oil content (%).

Key words : Mustard, Gene action, Additive, Non-additive, Combining ability.

Indian mustard *Brassica juncea* (L.) Czern. and Coss. is the most important *rabi* oilseed crop. It occupies a prominent position in Indian oilseeds scenario and plays a vital role in oil seed economy of our country. Its oil is most important edible oil in north-India which is difficult to be replaced by other oils. Among the nine annual oilseed crops grown in India, rapeseed-mustard has significant increasing trend in production during the last decade. The production and productivity of rapeseed-mustard had a quantum jump from 0.81 million tonnes and 362 kg/ha, respectively in 1950-51 to 5.79 million tonnes of production and 960 kg/ha productivity during 1999-2000 (1). For value added yield maximization one has to go for heterosis breeding and estimating combining ability for selection of compatible parents i.e. knowing relative importance of additive and non-additive gene actions for different characters for an efficient hybridization program. The concept of combining ability as a measure of gene action was

proposed by Sprague and Tatum (2). It refers to the capacity or ability of a genotype to transmit superior performance to its crosses.

Methods

The experiment was carried out in the field of Mustard Research Scheme of the Department of Plant Breeding and Genetics, BAU, Ranchi, geographically situated at 23°17' N latitude and 85°19' E longitude and the altitude is 625 MSL. The genetic materials comprised eight varieties of Indian mustard (*Brassica juncea* (L.) Czern. and Coss.) viz., BAUSM 92-1-1, BR-40, BIO-902, Laxmi, Varuna, JMM-991, SKM-0149 and Pusa bold. These eight varieties were sown in a crossing block on two different dates at interval of ten days during *rabi* of 2005 to synchronize flowering duration between some of the early and late flowering in all possible combinations excluding reciprocals in a diallel fashion.

Table 1. Analysis of variance for combining ability.

| Source of variation | df | Days to 50% flowering (days) | Days to maturity (days) | Plant height (cm) | Number of siliquae per plant | Number of seeds per siliqua | Seed yield per plant | 1000-seeds weight (g) | Alternaria blight infection per plant (%) | Aphids infestation per plant at full blooming stage (number) | Aphids infestation per plant at siliqua formation stage (number) | Oil content percent |
|---------------------|----|------------------------------|-------------------------|-------------------|------------------------------|-----------------------------|----------------------|-----------------------|---|--|--|---------------------|
| gca | 7 | 34.33** | 12.530** | 97.723* | 5896.179** | 0.699* | 8.243** | 0.703** | 180.721** | 1.281** | 5.356** | 2.167** |
| sca | 28 | 6.349** | 1.694** | 57.157* | 4188.842** | 0.285 | 8.932** | 0.073** | 85.824** | 1.419** | 8.30** | 0.838* |
| Error | 70 | 0.210 | 0.228 | 34.038 | 50.655 | 0.294 | 0.437 | 0.030 | 3.092 | 0.167 | 0.487 | 0.509 |

Thus, eight parents and 28 F₁ obtained from these parents constituted the experimental material for the present investigation.

Data on days to 50% flowering, days to maturity, plant height, number of siliqua, number of siliqua/plants, average number of seeds/siliqua, seed yield, 1,000-seeds weight, percentage alternaria disease infection at maturity, percentage white rust disease infection at full blooming and maturity were recorded on each of five randomly selected plants from each plot. The oil content for the seeds of selected plants was estimated using Oxford 4000 nuclear magnetic resonance (NMR) spectrometer available at Department of Agronomy, BAU and expressed in percent-

age. Oil yield/plant was calculated as percent ratio of seed yield/plant (g) multiplied with oil content (%) gave yield/plant. The gene action for yield and yield components besides general and specific combining ability effects on the parents, were assessed by line × tester analysis given by Kempthorne (3). To understand the real picture of architecture of hybrids and parents, data observed were subjected to pooled analysis by Panse (4).

Results and Discussion

ANOVA for Combining Ability and Variance Component

The ANOVA for combining ability and estima-

Table 2. Estimates of variance components in diallel crosses in Indian mustard. *Significant at 5% probability level, **Significant at 1% probability stage (number).

| | Days to 50% flowering (days) | Days to maturity (days) | Plant height (cm) | No. of siliquae plant ⁻¹ | No. of seeds siliqua ⁻¹ | Seed yield plant (g) | 1000-seeds weight (g) | Alternaria blight infection plant ⁻¹ (%) | Aphids infestation plant ⁻¹ at full blooming stage (number) | Aphids infestation plant ⁻¹ at siliqua formation stage (number) | Oil (%) |
|--|------------------------------|-------------------------|-------------------|-------------------------------------|------------------------------------|----------------------|-----------------------|---|--|--|---------|
| σ^2 gca | 3.412 | 1.230 | 6.369 | 584.55 | 0.041 | 0.781 | 0.067 | 17.763 | 0.111 | 0.487 | 0.166 |
| σ^2 sca | 6.139 | 1.466 | 23.120 | 4138.187 | - 0.009 | 8.495 | 0.043 | 82.731 | 1.251 | 7.813 | 0.330 |
| σ^2 e | 0.210 | 0.228 | 34.038 | 50.655 | 0.294 | 0.437 | 0.030 | 3.092 | 0.167 | 0.487 | 0.509 |
| σ^2 gca/ σ^2 sca | 0.556 | 0.839 | 0.275 | 0.141 | - 4.555 | 0.092 | 1.564 | 0.215 | 0.089 | 0.062 | 0.503 |
| (σ^2 sca/ σ^2 gca) ^{1/2} | 1.341 | 1.092 | 1.905 | 2.660 | - 0.468 | 3.298 | 0.801 | 2.158 | 3.357 | 4.005 | 1.687 |
| 2 σ^2 g/(2 σ^2 gca + σ^2 sca) | 0.526 | 0.627 | 0.355 | 0.221 | - 0.901 | 0.155 | 0.757 | 0.3004 | 0.151 | 0.111 | 0.502 |

Table 3. General combining ability effects of parents for different characters in mustard. *Significant at 5% probability level, **Significant at 1% probability level.

| Charac- ters parents | Days to 50 per- cent flow- ering (days) | Days to matu- rity (days) | Plant height (cm) | Num- ber of siliquae per plant | Num- ber of seeds per siliqua | Seed yield per plant (g) | 1000- seeds weight (g) | Alter- naria blight infec- tion per plant (%) | Aphids infes- tation per plant at full bloo- ming stage (num- ber) | Aphids infes- tation per plant at siliqua forma- tion stage (num- ber) | Oil content percent |
|----------------------------|---|---------------------------------------|-------------------------|--|---|--------------------------------------|---------------------------------|--|--|--|---------------------------|
| BAUSM | | | | | | | | | | | |
| 92-1-1 | - 2.00** | - 0.633** | - 2.35 | 2.88 | - 0.39* | - 1.14** | - 0.03 | - 3.23** | - 0.022 | - 0.46* | - 0.02 |
| BR-40 | - 2.833** | -2.333** | - 2.74 | 39.59** | 0.25 | 0.232 | - 0.4** | 0.29 | 0.339** | - 0.14 | 0.08 |
| BIO-902 | - 0.833** | 0.867** | - 0.09 | - 7.13** | 0.04 | 1.34** | 0.48** | 0.58 | 0.36** | 0.82** | - 0.42* |
| Laxmi | 0.967** | 0.567** | - 1.44 | - 42.30** | 0.053 | - 1.07** | 0.11* | 7.06** | 0.28* | 0.28 | 0.39 |
| Varuna | 0.567** | 0.00 | - 0.20 | 4.852* | 0.37* | - 0.24 | - 0.2** | 4.82** | 0.22 | 1.20** | 0.78** |
| JMM-991 | 2.667** | 0.933** | 6.19** | 10.35** | 0.14 | 1.08** | 0.08 | - 3.87** | - 0.36** | - 0.59** | - 0.74** |
| SKM-0149 | 1.70 | 0.933** | 3.02 | - 20.65** | -0.14 | 0.25 | 0.09 | - 0.41 | - 0.22 | - 0.12 | - 0.11 |
| Pusa Bold | - 0.233 | - 0.333* | - 2.39 | 12.39** | - 0.31 | - 0.45* | - 0.09 | - 5.23** | -0.59** | - 0.99** | 0.04 |
| SE ± | 0.136 | 0.141 | 1.73 | 2.12 | 0.16 | 0.19 | 0.05 | 0.52 | 0.12 | 0.21 | 0.21 |
| CD at 5% | 0.271 | 0.282 | 3.44 | 4.19 | 0.32 | 0.39 | 0.10 | 1.04 | 0.24 | 0.41 | 0.42 |
| CD at 1% | 0.409 | 0.426 | 5.20 | 6.35 | 0.48 | 0.59 | 0.16 | 1.57 | 0.37 | 0.62 | 0.64 |

tion of variance components in mustard (Table 1 and 2). The mean squares of general combining ability (gca) and specific combining ability (sca) were highly significant at 1% for days to 50% flowering days to maturity, numbers of siliqua/plant, seed yield/plant, 1,000-seed weight, alternaria blight infection, aphids infestation at full blooming stage and aphids infestation at siliqua formation stage while, plant height and oil content were significant at 5%. Magnitude of variance estimates due to sca was higher for nine characters. Ratio of variance of gca to sca was less than unity for ten characters. The estimate of mean degree of dominance was higher than unity for nine characters under study indicating over dominance for these characters. The predictability ratio $2\sigma^2 gca / 2\sigma^2 gca + \sigma^2 sca$ was less than unity in all characters. This ratio was observed to be highest for number of seeds/siliqua (0.901), lowest for aphids infestation at siliqua formation stage (0.111). Such result was also found Mahto and Haider (5).

GCA Effects for Parents

The estimates of general combining ability (gca)

effects of eight parents for all 11 characters have been provided in (Table 3). The gca effects for days to 50% flowering ranged -2.833 (BR-40) to 2.667 (JMM-991), BAUSM-92-1-1, BR-40 and BIO-902 were good general combiners. The gca effects for days to maturity ranged -2.33 (BR-40) to 0.93 (JMM-991 and SKM-0149), BAUSM-92-1-1 and BR -40 were good general combiners while Pusa bold was average general combiners. The gca effects for plant height ranged -2.742 (BR-40) to 6.198 (JMM-991), plant height were negative for BAUSM-92-1-1, BR-40, BIO-902 Laxmi. The gca effects for number of siliqua per plant ranged from -42.302 (Laxmi) to 39.598 (BR-40), positive general combining ability effects for five parents in which BR-40, JMM-991. BR-40, JMM-991 and Pusa Bold were good general combiners while Varuna was average general combiners for number of siliqua per plant. The gca effects for number of seeds/siliqua ranged -0.390 (BAUSM-92-1-1) to 0.365 (Varuna). Five parents showed positive effects of which only Varuna (0.365) showed significant. Varuna was average general combiner for number of seeds per siliqua. The gca effect for seed yield per plant ranged -1.135 (BAUSM-92-1-1) to 1.342 (BIO-902). Four parents showed positive

Table 4. Specific combining ability effects of crosses for different characters in mustard. *Significant at 5% probability level, **Significant at 1% probability level.

| Characters Crosses | Days to 50% flowering | Days to maturity | Plant height (cm) | Number of siliquae/ plant | Number of seeds/ siliqua | Seed yield/ plant (g) |
|--------------------------|-----------------------------|---------------------|-------------------------|---------------------------------|--------------------------------|--------------------------------|
| BAUSM-92-1-1 × BR-40 | - 1.65** | -3.626** | - 6.127 | - 24.63** | - 0.241 | - 0.175 |
| BAUSM-92-1-1 × BIO-902 | 0.02 | - 0.826 | - 2.307 | - 23.90** | 0.916 | - 2.079** |
| BAUSM-92-1-1 × Laxmi | - 3.12** | - 0.526 | - 0.433 | - 10.99 | 0.999* | - 0.773 |
| BAUSM-92-1-1 × Varuna | 0.29 | 0.707 | 6.067 | 17.39 | - 0.586 | 1.598* |
| BAUSM-92-1-1 × JMM-991 | -3.82** | 0.441 | 6.267 | 72.15** | - 0.658 | 7.122** |
| BAUSM-92-1-1 × SKM-0149 | - 0.85* | - 0.893* | 1.180 | 31.35** | - 0.031 | - 0.569 |
| BAUSM-92-1-1 × Pusa Bold | 0.09 | - 0.626 | 3.593 | 100.84** | 0.237 | 1.425* |
| BR-40 × BIO-902 | - 0.15 | 0.874* | 7.887 | 29.45** | 0.002 | - 2.546** |
| BR-40 × Laxmi | - 0.28 | 1.174* | 2.960 | 67.49** | - 1.11* | 2.517** |
| BR-40 × Varuna | - 0.88* | 0.407 | 2.673 | 130.40** | 0.216 | 4.338** |
| BR-40 × JMM-991 | 2.02** | - 0.859 | - 6.273 | 81.17** | 0.778 | 0.002 |
| BR-40 × SKM-0149 | - 2.69** | - 1.193* | 6.84 | 56.70** | 0.832 | 3.661** |
| BR-40 × Pusa Bold | - 2.75** | - 0.259 | - 1.28 | - 65.21** | - 0.050 | 0.035 |
| BIO-902 × Laxmi | 4.05** | 0.641 | 0.513 | 18.75** | - 0.021 | 2.806** |
| BIO-902 × Varuna | 0.12 | 1.207** | - 1.92 | 25.19** | 0.494 | 2.854** |
| BIO-902 × JMM-991 | - 0.98* | - 0.059 | 0.013 | 40.83** | - 0.245 | 2.602** |
| BIO-902 × SKM-0149 | - 3.68** | - 0.059 | 7.327 | 57.23** | - 0.144 | 1.731** |
| BIO-902 × Pusa Bold | - 1.75** | 0.207 | 0.940 | 1.45 | 0.607 | 1.878** |
| Laxmi × Varuna | 0.65 | 0.507 | - 5.98 | - 20.10** | - 0.200 | 0.543 |
| Laxmi × JMM-991 | 1.22** | -0.093 | - 6.713 | - 2.53 | 0.045 | - 0.303 |
| Laxmi × SKM-0149 | 1.19** | 0.574 | - 4.467 | - 7.53 | 0.212 | - 1.267* |
| Laxmi × Pusa Bold | - 2.88** | - 2.159** | 7.080 | - 6.25 | 0.100 | - 1.206* |
| Varuna × JMM-991 | - 0.05** | - 0.859 | 24.92** | 18.98** | - 0.227 | 1.385* |
| Varuna × SKM-0149 | - 1.75** | 0.474 | 4.367 | - 67.15** | 0.447 | - 3.47** |
| Varuna × Pusa Bold | 2.19** | 1.41** | - 5.95 | 10.87 | - 0.072 | 0.118 |
| JMM-991 × SKM-0149 | 3.15** | 0.207 | 5.767 | - 27.05** | 0.268 | 0.728 |
| JMM-991 × Pusa Bold | - 3.92** | - 0.526 | - 4.753 | 41.10** | - 0.287 | 0.506 |
| SKM-0149 × Pusa Bold | 2.39** | 0.474 | - 6.907 | 14.50* | - 0.640 | - 2.439** |
| SE ± | 0.42 | 0.433 | 5.290 | 6.45 | 0.491 | 0.599 |

effects of which BIO-902 and JMM-991 showed highly significant. BIO-902 and JMM-991 were good general combiners for seed yield per plant. The gca effects for 1000-seed weight ranged from -0.42 (BR-40) to 0.48 (BIO-902). Four parents showed positive effects of which BIO-902 showed highly significant general combining ability effect while Laxmi showed significant at 5% probability. BR-40 and Varuna showed highly significant negative gca effects. BIO-902 was the good general combiner while Laxmi was average general combiner for 1,000-seed weight. The gca effects for alternaria blight infection ranged from -5.233 (Pusa Bold) to 7.060 (Laxmi). Four parents namely BAUSM-92-1-1, JMM-991, SKM-0149 and Pusa Bold showed negative gca effects and of this BAUSM-92-1-1, JMM-991 and Pusa Bold showed

highly significant. The remaining parents showed positive, out of which Laxmi and Varuna showed highly significant. BAUSM-92-1-1, JMM-991 and Pusa Bold were good general combiners for alternaria blight infection per plant. The gca effects for aphids infestation per plant at full blooming stage (number) ranged from -0.596 (Pusa Bold) to 0.359 (BIO-902). Four parents showed positive gca effects of which BR-40 and BIO-902 showed significant at 1% probability while Laxmi showed significant at 5%. The remaining parents showed negative, out of which JMM-991 and Pusa Bold showed highly significant. BAUSM-92-1-1, JMM-991 and Pusa Bold were good general combiners for aphid's infestation. The gca effects for aphids infestation per plant at siliqua formation stage (number) ranged from -0.985 (Pusa

Table 5. Specific combining ability of crosses for different characters in mustard. *Significant at 5% probability level. **Significant at 1% probability level.

| Characters Crosses | 1000-seeds weight (g) | Alternaria blight infection/ plant | Aphids infesta- tion per plant at full blooming stage (number) | Aphids infesta- tion per plant at siliqua forma- tion stage (number) | Oil content percent |
|--------------------------|--------------------------|---|--|---|---------------------------|
| BAUSM-92-1-1 × BR-40 | - 0.021 | - 1.031 | 1.051** | - 0.550 | - 0.412 |
| BAUSM-92-1-1 × BIO-902 | - 0.313 | - 6.658** | - 0.435 | - 2.710** | 1.185 |
| BAUSM-92-1-1 × Laxmi | - 0.258* | - 4.338* | - 0.3153 | 0.095 | - 0.809 |
| BAUSM-92-1-1 × Varuna | 0.353* | 7.502** | 0.706 | 0.375 | - 0.651 |
| BAUSM-92-1-1 × JMM-991 | - 0.007 | 5.796** | - 0.886* | - 2.639** | - 0.166 |
| BAUSM-92-1-1 × SKM-0149 | - 0.175 | - 1.671 | - 1.828** | - 4.273** | 0.435 |
| BAUSM-92-1-1 × Pusa Bold | 0.156 | - 3.511* | 0.586 | 2.826** | - 0.931 |
| BR-40 × BIO-902 | - 0.012 | - 8.844** | - 0.286 | - 1.787** | 0.008 |
| BR-40 × Laxmi | 0.369* | 2.276 | 3.153** | 6.774** | 0.727 |
| BR-40 × Varuna | - 0.280 | - 0.018 | 1.011* | 2.854** | 0.399 |
| BR-40 × JMM-991 | - 0.100 | 5.742** | - 0.780* | - 1.026 | - 0.540 |
| BR-40 × SKM-0149 | - 0.32* | 3.846* | - 0.822* | - 2.361** | 0.941 |
| BR-40 × Pusa Bold | - 0.026 | - 7.298** | 0.225 | 0.505 | 1.509* |
| BIO-902 × Laxmi | 0.060 | 5.716** | - 0.80* | - 1.853** | - 1.496* |
| BIO-902 × Varuna | 0.361* | 10.622** | 1.525** | 2.094** | - 0.294 |
| BIO-902 × JMM-991 | 0.04 | - 8.684** | 0.100 | 1.480* | 0.496 |
| BIO-902 × SKM-0149 | 0.50** | - 8.151** | - 0.075 | 2.523** | 0.098 |
| BIO-902 × Pusa Bold | 0.225 | - 3.591* | 0.271 | 2.368** | 0.942 |
| Laxmi × Varuna | - 0.031 | - 25.991** | 0.207 | 1.298* | 0.675 |
| Laxmi × JMM-991 | 0.046 | - 18.631** | - 0.901* | - 1.982** | 0.053 |
| Laxmi × SKM-0149 | 0.031 | 1.636 | 2.307** | 5.550** | 1.181 |
| Laxmi × Pusa Bold | - 0.49** | 8.329** | - 1.179** | - 2.984** | 0.545 |
| Varuna × JMM-991 | 0.047 | - 7.324** | - 1.093** | - 2.769** | 0.662 |
| Varuna × SKM-0149 | - 0.158 | 5.476** | - 0.301 | - 2.770** | - 1.464* |
| Varuna × Pusa Bold | - 0.140 | 3.902* | 0.212 | - 0.371 | 0.240 |
| JMM-991 × SKM-0149 | 0.012 | - 1.831 | 1.207** | 2.617** | - 0.826 |
| JMM-991 × Pusa Bold | - 0.323* | - 2.338 | 0.321 | - 0.384 | 0.998 |
| SKM-0149 × Pusa Bold | - 0.421* | 1.662 | - 0.221 | - 1.452* | 0.106 |
| SE ± | 0.158 | 1.594 | 0.371 | 0.633 | 0.647 |

Bold) to 1.20 (Varuna). Five parents showed negative of which JMM-991 and Pusa Bold showed highly significant negative gca effects of three parents showing positive gca effects, BIO-902 and Varuna showed highly significant JMM-991 and Pusa Bold were good general combiner while BAUSM-92-1-1 was average general combiners for aphids infestation per plant at siliqua formation stage. The gca effects for oil content ranged -0.744 (JMM-991) to 0.784 (Varuna). Four parents showed positive effects of which Varuna showed highly significant. The remaining parents showed negative of which JMM-991 showed highly significant gca effects while BIO-902 showed significant gca effects at 5% probability. Varuna was

the good general combiner for oil content. These results were in general agreement with the finding of Singh et al. (6).

SCA Effects for Crosses

The sca effects of 28 crosses for eleven characters have been presented in Tables 4 and 5. The sca for days to 50% flowering ranged from -3.915 in (JMM-991 × Pusa Bold) to 4.052 (BR-40 × Laxmi). Seven crosses showed highly significant positive effects. The maximum sca shown by JMM-991 × Pusa Bold (-3.915). Crosses BAUSM-92-1-1 × Laxmi, BAUSM-92-1-1 × JMM-991, BR-40 × SKM-

0149, BR-40 × Pusa Bold, BIO-902 × SKM-0149 and Laxmi × Pusa Bold exhibited moderate negative effects. The sca for days to maturity ranged from -3.626 (BAUSM-92-1-1 × BR-40) to 1.407 (Varuna × Pusa Bold). Similarly, four crosses showed positive effect out of which two crosses were significant at 1% while two crosses were significant at 5%. Maximum negative sca was shown by BAUSM-92-1-1 × BR-40 (-3.626). Crosses BR-40 × SKM-0149 and Laxmi × Pusa bold exhibited moderate negative effects. The sca for plant height ranged from -6.907 (SKM-0149 × Pusa Bold) to 24.92 (Varuna × JMM-991), but name of the crosses showed negative significant effect. The maximum sca was shown by SKM-0149 × Pusa Bold (6.907). Crosses BAUSM-92-1-1 × BR-40, BR-40 × JMM-991, Laxmi × Varuna, Laxmi × JMM-991, Laxmi × SKM-0149, Varuna × Pusa Bold and JMM-991 × Pusa Bold exhibited moderate negative effects. The sca for number of siliqua per plant ranged from -67.153 (Varuna × SKM-0149) to 130.40 (BR-40 × Varuna). Six crosses showed highly significant negative sca effects. Maximum was shown by BR-40 × Varuna (130.40) followed by crosses BR-40 × JMM-991, BAUSM-92-1-1 × Pusa Bold, BAUSM-92-1-1 × JMM-991, BR-40 × Laxmi, BIO-902 × SKM-0149 and BR-40 × SKM-0149 exhibited moderate positive effects. The sca for number of seeds per siliqua ranged from -1.112 (BR-40 × Laxmi) to 0.999 (Bausm-92-1-1 × Laxmi). Maximum was shown by BAUSM-92-1-1 × Laxmi (0.999). Crosses BAUSM-92-1-1 × BIO-902, BR-40 × JMM-991, BR-40 × SKM-0149 and BIO-902 × Pusa Bold exhibited moderate positive effects. The sca for seed yield per plant ranged from -3.47 (Varuna × SKM-0149) to 7.12 (BAUSM-92-1-1 × JMM-991). Ten crosses showed negative effect, eighteen crosses showed positive effect out of which nine crosses were significant at 1% while three crosses were significant at 5% probability. Maximum was shown by BAUSM-92-1-1 × JMM-991 (7.12). Crosses BR-40 × SKM-0149, BIO-902 × Laxmi, BIO-902 × Varuna and BIO-902 × JMM-991 showed moderate positive effects. The sca for 1,000-seed weight ranged from -0.49 (Laxmi × Pusa Bold) to 0.500 (BIO-902 × SKM-01497). Sixteen crosses showed negative effect, three crosses showed positive significant effect at 5% probability level. The maximum was shown by BIO-902 × SKM-01497 (0.50), which was highly sig-

nificant. Crosses BAUSM-92-1-1 × Varuna and BIO-902 × Varuna exhibited moderate positive effects. The sca for alternaria blight infection per plant (percent) ranged from -25.991 (Laxmi × Varuna) to 10.622 (BIO-902 × Varuna). 16 crosses showed negative effect, out of which nine crosses were significant at 1%, twelve crosses showed positive effect out of which six crosses were significant at 1%. The maximum was shown by Laxmi × Varuna (-25.991). The sca for aphids' infestation per plant at full blooming stage ranged from -1.83 (BAUSM-0149 × SKM-0149) to 3.153 (BR-40 × Laxmi). 15 crosses showed negative effect out of which three crosses were significant at 1%. Five crosses showed highly significant positive effect while one cross was significant at 5%. Maximum was shown by BAUSM-0149 × SKM-0149 (-1.828). The crosses Laxmi × Pusa bold, Varuna × JMM-991, Laxmi × JMM-991 and BAUSM-92-1-1 × JMM-991, exhibited moderate negative effects. The sca for aphid infestation per plant at siliqua formation stage ranged from -4.27 (BAUSM-0149 × SKM-0149) to 6.74 (BR-40 × Laxmi). Eleven crosses showed significant negative sca effect out of which 10 crosses were significant at 1% and one cross was significant at 5%. Ten crosses showed significant positive sca effect eight crosses were significant at 1% while two crosses were significant at 5%. Maximum sca was shown by BAUSM-0149 × SKM-0149 (-4.273). Crosses BAUSM-92-1-1 × BIO-902, BAUSM-92-1-1 × JMM-991, BR-40 × SKM-0149, Laxmi × Pusa Bold, Varuna × JMM-991 and Varuna × SKM-0149 exhibited moderate negative sca effects. The sca for oil content ranged from -1.49 (BIO-902 × Laxmi) to 1.509 (BR-40 × Pusa Bold). Two crosses showed negative sca effect at 5%. One cross showed significant positive sca effect at 5% probability level. BR-40 × Pusa Bold (1.51) showed maximum sca. Crosses BAUSM-92-1-1 × BIO-902, BAUSM-92-1-1 × BIO-902, BR-40 × SKM-0149, BIO-902 × Pusa Bold, Laxmi × SKM-0149 and JMM-991 × Pusa Bold exhibited moderate positive sca effects.

References

1. Anonymous. 2006. Directorate of economics and statistics. Min. Agric., Govt. of India, New Delhi, India.
2. Sparague G. F. and L. A. Tatum. 1942. General ver-

- sus specific combining ability in single crosses of corn. *Agron. J.* 34 : 923—932.
3. Kempthorne O. 1955. The correlations between relatives in inbred populations. *Genetics* 40 : 681—691.
 4. Panse V. G. 1956. Genetics of quantitative characters in relation to plant breeding. *Indian J. Genet.* 17 : 318—327.
 5. Mahto J. L. and Z. A. Haider. 2004. Heterosis and combining ability study in *Brassica juncea*. *J. Res. (BAU)* 16 : 239—248.
 6. Singh S. K., Z. A. Haider and S. Ram. 2005. Combining ability and heterosis for seed yield and its components in Indian mustard (*Brassica juncea*). *Indian J. Agric. Sci.* 75 : 228—229.