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***RESEARCH PAPER***

# Heterosis and combining ability analysis in Indian mustard, *Brassica juncea* (L.) Czern & Coss

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**Abstract :** Heterosis and combining ability were studied in 8 x 8 diallel set of Indian mustard [*Brassica juncea* (L.) Czern & Coss]. Analysis of variance for combining ability revealed the presence of genetic variability due to gca among the parents and due to sca among the crosses for all the traits. The $\sigma^2$gca and $\sigma^2$sca ratio indicated that non-additive gene action was predominant for the inheritance of all the traits except days to 50% flowering, plant height, length of siliquae, seeds per siliquae and 1000 seed weight for which additive gene action was more important. Parents GM-2 and IC-560696 were good general combiners for seed yield per plant and its related attributes. On the basis of *per se* performance and estimates of heterosis hybrids, IC-491446 x IC-560696, IC-560696 x Vardan and Laxmi x GM-2 were found to be most promising for seed yield and other desirable traits, hence, could be further evaluated to exploit the heterosis or utilized in future breeding programme to obtain desirable segregants for the development of superior genotypes. The maximum positive significant heterosis over better parent for seed yield was observed in the hybrids IC-491446 x IC-560696 (45.31%) Laxmi x GM-2 (41.93%) and IC-560696 x Vardan (16.37%). The gca and sca mean squares were significant for aphid resistance. The dominance ratio ($\sigma^2$gca/$\sigma^2$sca**)** indicated the preponderance of non-additive gene effects for the inheritance of aphid resistance. The estimates of general combining ability suggested that parents GM-1 and GM-3 were good general combiner for aphid resistance. The estimates of specific combining ability effects revealed that the cross combinations *viz.*, IC-491446 x GM-2, IC-560696 x Vardan, IC-491446 x GM-1, Laxmi x Vardan and Laxmi x IC-560696 were observed to be most promising for aphid resistance. The morphological characters of plant *viz.*, siliquae per plant, seeds per siliquae and yield per plant were negatively correlated with the peak aphid population. The oil content was negatively correlated with peak aphid population while, protein content was positively correlated with peak aphid population.

**Key Words :** Heterosis, Combining ability, Diallel, Gca effect, Sca effect, Indian mustard

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## INTRODUCTION

Indian mustard is one of the most important oilseed crops, which plays a very important role in oilseeds economy of our country. To enhance the present yield level and overcome yield stagnation, it is essential to reshuffle the genes through hybridization of suitable parents. For this, it is necessary to identify the nature and magnitude of gene action involved in the expression of various yield contributing characters as well as the combining ability of the parents and the resulting crosses. The present investigation was undertaken with a view to estimate combining ability and the magnitude and direction of heterosis in Indian mustard.

## MATERIAL AND METHODS

A set of 8 x 8 diallel crosses of mustard excluding reciprocals were evaluated along with their parents (Laxmi, IC-399797, IC-491446, IC-560696, GM-1, GM-2, GM-3 and Vardan). Two sets of experiments were laid out in a Randomized Block Design (RBD) with three replications each at Plant Breeding Farm, Anand Agricultural University, Anand during *Rabi* 2011-12. One set (protected trial) was subjected to all prophylactic operations to protect the

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mustard crop from aphids (*L. erysimi*). Fourteen characters including seed yield and its components, oil and protein content were studied in this trial. The other set (unprotected) of experiment used for aphid reaction studies was not given any protective spray to control the aphid infestation. Observations were recorded for aphid index and five important yield/biochemical parameters *viz.*, seed yield per plant, seeds per siliquae, siliquae per plant, oil content and protein content. Each genotype was represented by a single row plot of 6 m length. The inter and intra row distance were 45 and 15 cm, respectively. The sowing was carried out by hand drilling. All recommended agronomical practices and plant protection measures were followed for raising the good crop. Observations were recorded on five randomly selected competitive plants in each genotype in each replication for various characters. The phenological characters *viz.*, days to flowering and days to maturity were recorded on plot basis. The analysis for combining ability was carried out as per model-I, method-II proposed by Griffing (1956). Heterosis was assessed as per standard procedure.

## RESULTS AND DISCUSSION

The results of the present study have been presented and discussed under the following headings:

**Protected trial:**

Analysis of variance for combining ability revealed the variance due to gca as well as sca was significant for all the traits (Table 1). This indicated existence of genetic variability among parents included in the current study and the importance of additive as well as non additive gene action in the inheritance of studied characters. The variance due to sca was higher than that of due to gca for all the characters indicating the predominant role of non-additive gene action except for days to 50% flowering, plant height, length of siliquae, seeds per siliquae and 1000 seed weight for which additive gene effect was more important. Additive gene action for days to 50% flowering, plant height, length of siliquae, seeds per siliquae and 1000 seed weight has been reported by Ghosh *et al.* (2002), Monpara and Dobariya (2007), Gupta *et al.* (2011) and Nasrin *et al.* (2011). The results suggested that for exploitation of the both additive and non additive type of gene actions it would be worthwhile to resort breeding methodologies such as biparental mating, recurrent selection or reciprocal recurrent selection which would accumulate favourable genes in homozygous state or help in breaking linkage blocks thereby generating maximum variability for further selection.

A total of 16 crosses manifested significant positive heterosis for seed yield per plant. The maximum heterobeltiosis for seed yield per plant was exhibited by the hybrid IC-491446 x IC-560696 (45.31%) followed by IC-560696 x Vardan (41.93%) and Laxmi x GM-2 (16.37%). Among the above hybrids, IC-491446 x IC-560696 also exhibited maximum heterobeltiosis for number of primary branches per plant, number of secondary branches per plant and total siliquae per plant. Similarly hybrid IC-560696 x Vardan also exhibited maximum heterobeltiosis for number of secondary branches per plant, number of tertiary branches per plant and 1000 seed weight. Further, these hybrids also showed high estimates of sca effects for seed yield and its attributes. Out of 28 crosses, only three crosses *viz.*, IC-491446 x IC-560696 (16.24), IC-560696 x Vardan (14.00) and Laxmi x GM-2 (10.77) were superior combinations for seed yield per plant and involved poor x good, good x poor

**Table 1 : Analysis of variance for combining ability of different characters in Indian mustard**

| Sources of variation | d.f. | Days to 50% flowering | Days to maturity | Plant height (cm) | No. of primary branches per plant | No. of secondary branches per plant | No. of tertiary branches per plant | Length of main branch |
|---|---|---|---|---|---|---|---|---|
| GCA | 7 | 117.62** | 17.37** | 533.34** | 0.688** | 15.65** | 15.83** | 429.26** |
| SCA | 28 | 6.20** | 8.51** | 81.27* | 0.281** | 4.44** | 10.18** | 97.34** |
| Error | 70 | 1.01 | 0.56 | 60.35 | 0.060 | 0.70 | 0.35 | 4.50 |
| $\sigma^2$gca | | 11.66 | 1.68 | 47.29 | 0.062 | 1.49 | 1.54 | 42.47 |
| $\sigma^2$sca | | 5.19 | 7.95 | 20.92 | 0.22 | 3.74 | 9.83 | 92.84 |
| $\sigma^2$gca/$\sigma^2$sca | | 2.24 | 0.21 | 2.26 | 0.28 | 0.39 | 0.16 | 0.46 |

| Sources of variation | d.f. | Length of siliquae | Seeds per siliquae | Siliquae per plant | Seed yield per plant (g) | 1000 seed weight (g) | Oil content (%) | Protein content (%) |
|---|---|---|---|---|---|---|---|---|
| GCA | 7 | 0.565** | 2.372** | 9736.24** | 112.40** | 1.450** | 5.57** | 6.47** |
| SCA | 28 | 0.0622** | 0.326** | 5596.70** | 49.63** | 0.167** | 1.21** | 1.76** |
| Error | 70 | 0.0167 | 0.119 | 1551.10 | 8.016 | 0.0337 | 0.070 | 0.043 |
| $\sigma^2$gca | | 0.0548 | 0.225 | 664.83 | 10.43 | 0.141 | 0.55 | 0.64 |
| $\sigma^2$sca | | 0.0045 | 0.207 | 4196.78 | 41.61 | 0.133 | 1.14 | 1.71 |
| $\sigma^2$gca/$\sigma^2$sca | | 12.17 | 1.086 | 0.158 | 0.250 | 1.060 | 0.48 | 0.37 |

* and ** indicate significance of values at P=0.05, 0.01, respectively

and average x good general combiner, respectively (Table 4). In the present study, top three crosses which exhibited high sca effects for yield per plant involved at least one good general combiner, indicating additive x dominance type of gene interaction, which could produce desirable transgressive segregants in subsequent generations. Since only good general combiner had rarely given high sca effects in their combination, hence, the choice of parents for

**Table 2 : Estimates of general combining ability (gca) effects of parents for various characters in Indian mustard**

| Parents | Days to 50% flowering | Days to maturity | Plant height (cm) | No. of primary branches per plant | No. of secondary branches per plant | No. of tertiary branches per plant | Length of main branch | Length of siliquae | Seeds per siliquae | Siliquae per plant | Seed yield per plant (g) | 1000 seed weight (g) | Oil content (%) | Protein content (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LAXMI | 2.75** | 1.72** | 5.40* | 0.12 | 0.51* | -0.17 | 3.30** | 0.22** | 0.59** | -13.22 | 1.18 | 0.07 | -0.49** | -0.24** |
| IC-399797 | 6.35** | 0.73** | 12.23** | 0.12 | 1.84** | 1.63** | 13.51** | -0.53** | -0.59** | 28.83* | -4.34** | -0.75** | -0.82** | -1.00** |
| IC-491446 | 1.25** | 1.76** | -4.55* | -0.02 | -0.53* | -0.97** | 1.41* | 0.22** | 0.64** | -36.33** | -2.72** | -0.42** | -1.08** | -1.30** |
| IC-560696 | -1.62** | -0.94** | 2.80 | 0.20** | -0.69** | -0.95** | -1.53* | 0.09* | 0.00 | 16.82 | 4.13** | 0.28** | 0.59** | 0.96** |
| GM-1 | -4.45** | -1.98** | -8.74** | 0.17* | 0.56* | 0.25 | -7.50** | -0.08* | -0.59** | 16.22 | -0.76 | 0.08 | 0.99** | 0.56** |
| GM-2 | -3.12** | -0.61** | -5.18* | 0.20** | 1.23** | 2.11** | -4.46** | 0.08* | 0.35* | 45.77** | 5.40** | 0.27** | 0.26** | 0.06 |
| GM-3 | -0.38 | -0.04 | -6.51** | -0.24** | -1.02** | -1.27** | -5.14** | -0.02 | -0.30** | -20.07 | -1.16 | 0.31** | 0.64** | 0.70** |
| VARDAN | -0.78** | -0.64** | 4.55* | -0.54** | -1.92** | -0.65** | 0.42 | 0.01 | -0.11 | -38.03** | -1.71** | 0.14* | -0.08 | 0.27** |
| S. E. ± | 0.297 | 0.221 | 2.29 | 0.072 | 0.249 | 0.175 | 0.627 | 0.038 | 0.101 | 11.64 | 0.837 | 0.054 | 0.078 | 0.062 |
| Range | -4.45 to 6.35 | 1.98 to 1.76 | -8.74 to 12.23 | -0.54 to 0.20 | -1.92 to 1.84 | -1.27 to 2.11 | -7.50 to 13.51 | -0.53 to 0.22 | -0.59 to 0.64 | -38.03 to 45.77 | -4.34 to 5.40 | -0.75 to 0.28 | -1.08 to 0.99 | -1.30 to 0.96 |

* and ** indicate significance of values at P=0.05 and 0.01, respectively

**Table 3 : Range, heterosis and number of crosses showing significant heterosis in desirable direction for yield and yield contributing traits in Indian mustard**

| Characters | Range | | | | No. of crosses showing heterobeltiosis | No. of crosses showing standard heterosis |
|---|---|---|---|---|---|---|
| | Parents | Hybrids | Heterobeltiosis | Standard heterosis | | |
| Days to 50% flowering | 44.67-65.33 | 44.67-63.00 | -4.83-34.33 | -18.78-14.85 | 6 | 12 |
| Days to maturity | 107.67-119.67 | 109.33-119.00 | -4.65-9.29 | -4.10-4.39 | 4 | 4 |
| Plant height | 195.73-240.80 | 200.96-239.85 | -3.88-20.35 | 2.68-22.53 | 1 | 0 |
| Primary branches per plant | 4.36-6.29 | 4.35-7.24 | -24.34-44.37 | -13.92-44.53 | 6 | 9 |
| Secondary branches per plant | 11.06-20.25 | 13.25-21.03 | -21.57-49.38 | -2.43-54.63 | 11 | 19 |
| Tertiary branches per plant | 5.30-14.31 | 5.72-18.03 | -52.68-50.34 | -39.8-101.90 | 12 | 13 |
| Length of main branch | 79.46-129.12 | 78.98-119.24 | -25.33-35.49 | -1.50-48.72 | 6 | 23 |
| Length of siliquae | 4.32-5.71 | 4.55-5.96 | -20.00-12.84 | -8.11-21.10 | 9 | 17 |
| Seeds per siliquae | 13.44-16.18 | 13.69-16.79 | -13.29-7.33 | -2.14-20.00 | 7 | 11 |
| Siliquae per plant | 318.69-596.57 | 403.30-652.33 | -29.30-29.87 | 2.87-66.40 | 16 | 16 |
| Seed yield per plant | 21.23-45.42 | 26.30-53.13 | -37.00-45.31 | -3.56-94.83 | 16 | 16 |
| 1000 seed weight | 4.29-6.57 | 4.29-6.72 | -34.52-14.12 | -33.54-4.02 | 3 | 0 |
| Oil content | 29.49-34.39 | 28.80-34.22 | -11.85-7.10 | -12.17-4.36 | 2 | 3 |
| Protein content | 19.93-25.96 | 20.01-25.84 | -19.32-1.26 | -22.38-0.23 | 2 | 0 |

**Table 4 : The three top ranking hybrids with respect to *per se* performance and sca effects and heterosis over better parent and check variety (GM-3) for seed yield per plant**

| Cross | *Per se* performance | *sca* effects | gca status of parents | Heterosis over | |
|---|---|---|---|---|---|
| | | | | BP | SC |
| IC-491446 x IC-560696 | 53.13 | 16.24** | P x G | 45.31** | 94.83** |
| Laxmi x GM-2 | 52.83 | 10.77** | A x G | 16.37** | 93.73** |
| IC-560696 x Vardan | 51.89 | 14.00** | G x P | 41.93** | 90.32** |

* and ** indicate significance of values at P=0.05 and 0.01, respectively
G = Good, A = Average; P = Poor.

hybridization should be based on combining ability. High estimates of heterosis for seed yield and its components have been also reported earlier by Singh *et al.* (2003), Mahak (2008) and Patel *et al.* (2010) in Indian mustard. Therefore, heterosis breeding could be suggested for yield advancement in Indian mustard.

Estimates of general combining ability effects (Table 2) revealed that the genotypes GM-2 and IC-560696 were found to be good general combiners for seed yield and its attributes. Thus, on the basis of their *gca* effects these genotypes could be exploited either involving them in hybridization programme or in recurrent crossing for obtaining desirable segregants.

**Table 5 : Analysis of variance for combining ability of aphid resistance in Indian mustard**

| Sources of variation | d.f | Aphid resistance |
|---|---|---|
| gca | 7 | 0.245** |
| sca | 28 | 0.456** |
| Error | 70 | 0.052 |
| $\sigma^2$gca | | 0.019 |
| $\sigma^2$sca | | 0.404 |
| $\sigma^2$gca/$\sigma^2$sca | | 0.047 |

* and ** indicate significance of values at P=0.05 and 0.01, respectively

**Table 6 : gca effects of parents for aphid resistance in Indian mustard**

| Parents | GCA effects | |
|---|---|---|
| Laxmi | 0.19** | (P) |
| IC-399797 | 0.04 | (A) |
| IC-491446 | 0.15* | (P) |
| IC-560696 | 0.04 | (A) |
| GM-1 | -0.26** | (G) |
| GM-2 | 0.08 | (A) |
| GM-3 | -0.16* | (G) |
| Vardan | -0.08 | (A) |
| S.E ± | 0.068 | |
| Range | -0.26 to 0.19 | |

* and ** indicate significance of values at P=0.05 and 0.01, respectively
G= Good, A= Average, P= Poor

**Table 7 : sca effects of hybrids for aphid resistance in Indian mustard**

| Hybrids | | sca effects |
|---|---|---|
| LAXMI | × IC-399797 | 0.07 |
| LAXMI | × IC-491446 | 0.25 |
| LAXMI | × IC-560696 | -0.44* (P × A ) |
| LAXMI | × GM-1 | -0.32 |
| LAXMI | × GM-2 | 0.53** |
| LAXMI | × GM-3 | 0.28 |
| LAXMI | × VARDAN | -0.91** ( P × A) |
| IC-399797 | × IC-491446 | -0.10 |
| IC-399797 | × IC-560696 | 0.46* |
| IC-399797 | × GM-1 | 0.67** |
| IC-399797 | × GM-2 | -0.12 |
| IC-399797 | × GM-3 | 0.62** |
| IC-399797 | × VARDAN | 0.72** |
| IC-491446 | × IC-560696 | 0.60** |
| IC-491446 | × GM-1 | -0.97** (P × G) |
| IC-491446 | × GM-2 | -1.65** (P × A) |
| IC-491446 | × GM-3 | 0.11 |
| IC-491446 | × VARDAN | 0.73** |
| IC-560696 | × GM-1 | 0.21 |
| IC-560696 | × GM-2 | 0.08 |
| IC-560696 | × GM-3 | -0.08 |
| IC-560696 | × VARDAN | -0.98** (A × A) |
| GM-1 | × GM-2 | 0.49* |
| GM-1 | × GM-3 | 0.66** |
| GM-1 | × VARDAN | 0.04 |
| GM-2 | × GM-3 | 0.19 |
| GM-2 | × VARDAN | 0.00 |
| GM-3 | × VARDAN | 0.44* |
| S.E. ± | | 0.21 |
| Range | | -1.65 to 0.73 |

* and **indicate significance of values at P=0.05 and 0.01, respectively
G= Good, A= Average, P= Poor

## Unprotected trial

*Combining ability analysis for aphid resistance (unprotected trial):*

Variance due to gca as well as sca was significant indicating the importance of additive as well as non additive gene action in the inheritance of resistance against aphid. However magnitudes of variance components of sca were higher than gca indicating that non additive type of gene action was more important (Table 5).

The estimates of gca effects revealed that out of 8 parents, two parents GM-1 (-0.26) and GM-3 (-0.16) exhibited significant negative gca effects, indicating that they are good general combiners for resistance against mustard aphid. (Table 6).

Out of 28 hybrids, 5 hybrids showed significant negative sca effects and it varied from -0.44 (Laxmi x IC-560696) to -1.65 (IC-491446 x GM-2). The maximum estimate of sca effects was depicted by hybrid IC-491446 x GM-2 (-1.65) followed by IC-560696 x Vardan (-0.98), IC-491446 x GM-1 (-0.97), Laxmi x Vardan (-0.91) and Laxmix IC-560696 (-0.44). These hybrids can be exploited further for resistance against mustard aphid (Table 7).

*Simple correlation analysis:*

The simple correlation analysis (Karl Pearson correlation) was carried out for establishing association between aphid incidence(aphid count) and seed yield, seeds per siliquae, number of siliquae per plant, oil content and protein content (Table 8). The yield component characters *viz.*, siliquae per plant (-0.75981**), seeds per siliquae (-0.74986**) and yield per plant (-0.77842**) were negatively correlated with the peak aphid population (Table 7). An increase in aphid population was found to be responsible for reduction of siliquae per plant, seeds per siliquae and seed yield per plant.

The oil content (-0.77842**) was negatively correlated with aphid population, while protein content (0.82825**)

**Table 8 : Mean performance and character association of parent hybrids for aphid resistance and other yield parameters in Indian Mustard**

| Sr. No. | Parents | Aphid index | Siliquae/Plant | Seeds/Siliquae | Yield/Plant | Oil content % | Protient content % |
|---|---|---|---|---|---|---|---|
| 1. | LAXMI | 3.35 | 230.60 | 15.12 | 18.34 | 29.87 | 23.64 |
| 2. | IC-399797 | 1.63 | 494.83 | 10.65 | 30.63 | 33.57 | 21.93 |
| 3. | IC-491446 | 3.52 | 342.51 | 10.44 | 15.27 | 28.78 | 23.73 |
| 4. | IC-560696 | 2.85 | 280.53 | 14.13 | 24.41 | 32.69 | 22.41 |
| 5. | GM-1 | 1.80 | 326.29 | 13.68 | 20.02 | 33.65 | 21.51 |
| 6. | GM-2 | 3.10 | 265.05 | 12.65 | 20.74 | 30.82 | 22.72 |
| 7. | GM-3 | 1.26 | 373.95 | 12.99 | 26.02 | 33.34 | 20.89 |
| 8. | VARDAN | 2.50 | 420.28 | 11.28 | 24.24 | 31.34 | 21.18 |
| Mean | | 2.50 | 341.76 | 12.62 | 22.46 | 31.75 | 22.25 |
| **Hybrids** | | | | | | | |
| 1. | LAXMI x IC-399797 | 3.00 | 417.59 | 14.49 | 21.29 | 30.25 | 23.33 |
| 2. | LAXMI x IC-491446 | 3.30 | 322.65 | 13.23 | 22.90 | 29.29 | 24.08 |
| 3. | LAXMI x IC-560696 | 2.50 | 397.81 | 13.69 | 25.38 | 31.45 | 22.82 |
| 4. | LAXMI x GM-1 | 2.31 | 349.57 | 14.03 | 28.48 | 30.55 | 20.55 |
| 5. | LAXMI x GM-2 | 3.50 | 337.96 | 13.01 | 21.30 | 28.79 | 23.63 |
| 6. | LAXMI x GM-3 | 3.00 | 243.23 | 12.11 | 20.24 | 30.08 | 22.57 |
| 7. | LAXMI x VARDAN | 1.90 | 366.76 | 15.31 | 29.66 | 34.43 | 20.97 |
| 8. | IC-399797 x IC-491446 | 2.80 | 345.42 | 13.46 | 22.58 | 31.5 | 21.78 |
| 9. | IC-399797 x IC-560696 | 3.25 | 334.70 | 13.93 | 18.50 | 30.24 | 24.2 |
| 10. | IC-399797 x GM-1 | 3.15 | 301.89 | 12.75 | 19.18 | 29.26 | 23.34 |
| 11. | IC-399797 x GM-2 | 2.70 | 393.65 | 15.29 | 23.02 | 28.48 | 21.95 |
| 12. | IC-399797 x GM-3 | 3.20 | 397.57 | 12.90 | 22.04 | 31.97 | 22.33 |
| 13. | IC-399797 x VARDAN | 3.38 | 324.72 | 11.60 | 22.49 | 30.28 | 23.38 |
| 14. | IC-491446 x IC-560696 | 3.50 | 308.28 | 13.45 | 20.98 | 29.85 | 24.25 |
| 15. | IC-491446 x GM-1 | 1.62 | 275.13 | 13.40 | 30.09 | 33.45 | 21.85 |
| 16. | IC-491446 x GM-2 | 1.28 | 311.72 | 12.88 | 36.82 | 34.87 | 20.14 |
| 17. | IC-491446 x GM-3 | 2.80 | 411.32 | 13.59 | 22.81 | 32 | 22.07 |
| 18. | IC-491446 x VARDAN | 3.50 | 240.84 | 13.03 | 17.67 | 28.24 | 23.76 |
| 19. | IC-560696 x GM-1 | 2.70 | 342.82 | 12.76 | 23.19 | 32.08 | 22.54 |
| 20. | IC-560696 x GM-2 | 2.90 | 269.61 | 12.15 | 22.06 | 33.28 | 22.9 |
| 21. | IC-560696 x GM-3 | 2.50 | 311.43 | 13.77 | 24.98 | 31.86 | 21.21 |
| 22. | IC-560696 x VARDAN | 1.68 | 438.62 | 13.29 | 32.44 | 34.93 | 20.15 |
| 23. | GM-1 x GM-2 | 3.00 | 391.65 | 13.08 | 21.39 | 29.61 | 23.63 |
| 24. | GM-1 x GM-3 | 2.90 | 265.48 | 13.53 | 29.16 | 31.56 | 21.73 |
| 25. | GM-1 x VARDAN | 2.40 | 325.19 | 12.53 | 25.70 | 32.88 | 21.93 |
| 26. | GM-2 x GM-3 | 2.80 | 401.95 | 11.75 | 26.57 | 32.87 | 22.33 |
| 27. | GM-2 x VARDAN | 2.70 | 327.78 | 13.75 | 28.77 | 34.58 | 21.49 |
| 28. | GM-3 x VARDAN | 2.90 | 310.61 | 12.20 | 22.48 | 31.21 | 23.98 |
| Mean | | 2.76 | 338.07 | 13.25 | 24.36 | 31.42 | 22.46 |
| | | | (-0.75981**)++ | (-0.74986**)++ | (-0.78491**)++ | (0.77842**)++ | (0.82825**)++ |

* and ** indicate significance of values at P=0.05 and 0.01, respectively

++ The figure in paranthesis is simple correlation co-efficient (r) between the aphid index and yield components was positively correlated with aphid population (Table 8). It is being inferred that reduction in seed mass during aphid infestation may be causing reduction in oil content, however leaving protein content unaffected. The minimum aphid population was recorded in variety GM-3 which had highest oil and lowest protein content *i.e.* 33.34% and 20.89%, respectively, whereas, the maximum aphid population was found in variety IC-491446 which had lowest oil and highest protein content *i.e.* 28.78% and 25.73%, respectively.

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