# EVALUATION FOR COMBINING ABILITY AND HETEROSIS FOR HYBRID PRODUCTION IN MUSTARD

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## INTRODUCTION

High heterosis in rape seed and mustard has been reported by many workers (Anderson, 1950; Singh and Mehta, 1964; Das and Rai, 1972; Shelkodenke, 1972; Agrawal, 1976; Schuster and Michael, 1976; Daloi, 1977 and Singh, Singh and Lather, 1988). Present of cytoplasmic male sterility (CMS) in the Indian mustard was first reported by Rawat and Anand (1979). For commercial hybrid production through CMS lines, and evaluation for combining ability of the parents and their heterotic combinations is the prerequisite. The present study aims at evaluation of combining ability using line X tester design. The testers used in this study are well adapted varieties of mustard and CMS lines are available in these backgrounds.

## MATERIALS AND METHODS

Material for the present study consisted of parents and their $F_1$ hybrids among 14 lines and 3 testers. Lines with suffix G.P. have been selected from germplasm collections, whereas D stands for the breeding nursery. ST 1564 is one of the synthesized *B. juncea* lines. The testers i.e. Pusa Bold, Varuna and Pusa Barani are well adapted and improved varieties developed in the past. 42 $F_1$ hybrids alongwith 17 parents were grown in a rendomized block design (RBD) with three replications, under irrigated condition, at IARI, New Delhi in 1989-90 *rabi* season. Plot size consisted of a single three meter rows spaced 35 cm apart, with interplant distance maintained at 20 - 25 cms. The data were recorded on five random competetive plants in each plot. Mean values of each plot were used for combining ability analysis using the model of Kempthorne (1957).

## RESULTS AND DISCUSSION

Analysis of variance revealed that mean squares due to parents were significant only for flowering and plant height, indicating that parents did not differ for all other characters except these two. On the contrary, m.s. due to hybrids were highly significant for all the characters, suggesting differential interaction among lines and testers. Lack of variation among parents and presence of same for hybrids also indicate the present of non-allellic interaction for most of the characters, which was further confirmed by highly significant interaction of parents with hybrids for all traits except flowering, plant height and siliquae per secondary branch (S/SB) and siliquae on main shoot (S/MS).

The partitioning of the variation among hybrids, due to general combining ability (GCA) of lines and testers and due to specific combining ability (SCA) of crosses ($F_1$ hybrids) are presented in table. 1. It would be observed that lines differed significantly except maturity and No. of SB for all characters and testers for all the characters except S/SB S/MS for their general combining ability. The specific combining ability on the other hand, of the crosses, was highly significant for all characters uner study.

The relative magnitude of mean squares indicated more diversity for combining ability among the lines for flowering S/PB and S/MS, whereas testers were more diverse than lines for maturity, number of primary branches, number of secondary branches and seed yield per plant.

Highly significant interaction between lines and testers for all the characters suggest, differential performance of the lines for specific combining ability with the three testers. Thus, it would be possible to get specific cross combination with desired traits.

The estimates of componants of the genetic variance $\partial^2$ gca (general combining ability) and $\partial^2$ sca (Specific combining ability), were examined to see the magnitude and importance of additive and non-additive genetic variance if any in the inheritance of different traits (Table-1). It was observed that only for maturity the proportion of additive component was much higher than the non-additive, whereas non-additive component was more predominent in all other characters. However, additive component was consiberably in respect of flowering, plant height and seed yield per plant indicating, the importance of both additive and non-additive components of genetic variation.

The results with regard to inheritance of plant height and grain yield do not correspond with those of Yadav et al (1979) and Badwal et al (1976). Results on the components of seed yield namely number of secondary branches, siliquae on the main shoot and seed yield are in disagreement with the finding of Asthana and Pandey (1977) who reported the importance of predominantly additive genetic variance towards the inheritance of the aforesaid traits. Labana et al (1978) reported similar finding as in the present investigation in respect of components of variance for primary branches, secondary branches, and seed yield but it did differ with the present investigation in respect of flowering, maturity and plant height.

GCA: The GCA effects of the testers and lines are presented in table-2. Among the lines, ST 1564 had highly significant and positive GCA effects for seed yield, number of primary branches S/PB, S/SB and S/MS. Among testers, Varuna recorded highly significant and positive GCA effects for seed yield, S/PB and S/SB. Pusa Bold among testers and D.350, D.367 and D.403 among lines were best combiners for early maturity. G.P.17, G.P.549 and D.335-1 were best combiners for short plant height whereas, D.313 and D403 and Pusa Bold are good combiners for increased hight. Apart from ST 1564, G.P.549 and Pusal Bold were best combiners for number of primary branches and D.18-3, D.313 and Pusa Bold for nuber of secondary branches. In general, per se performance of the parents was not correlated to GCA except for flowering period. On the contrary, correlation between per se performance of lines and hybrid performance for all the characters was very high and significant. Similar trend was also observed for correlation between SCA and crosses and between SCA and mid-parent heterosis for almost all the characters (Table-3).

SCA: Selected cross combinations having significant SCA effects for seed yield and more than three characters in desired direction are presented in table-4, alongwith per cent heterosis over the mid-parent (MP). The cross combinations namely D.335-8 x Varuna, G.P. 549 x Varuna and ST 1564 x Varuna exhibited the highest heterosis as well as high and positive SCA effects for seed yield followed by crosses such as D.313 x Pusa Barani, D.335-1 x Pusa Bold and D.313 x Varuna.

It is interesting to note, that cross combinations such as ST 1564 x Varuna and D.313 x Varuna involved both the parents with high and positive GCA effects, though, for D.313 it did not reach the level of significance. It suggests that additive gene action might be more pronounced in these crosses. In other three crosses having high and positive SCA effects for seed yield, invariably, one of the parents had high and positive GCA effects except in cross D.335-1 x Pusa Bold where both the parents had negative GCA effects. This might suggest the roles of non-additive gene action.

It is observed that cross combinations D.335-8 x Varuna and G.P. 549 x Varuna also showed high SCA effects for number of secondary branches, S/PB and S/SB which may lead to higher seed yield through manifestation of heterosis for these characters. The level of mid-parent heterosis in these high and positive crosses ranged between 79 to 384.8 per cent providing the possibilities of exploitation of heterosis breeding through cms for commercial use. The crosses showing significant SCA effects for seed yield as well as its contributing characters alongwith heterosis for seed yield, are presented in table-2. An examination of the data would reveal, tha all the four crosses namely RK 8504 x Varuna, GP 549 x Varuna ST 1564 x Varuna and D.335-8 x Varuna showed very high heterosis ranging from 250 - 384.8 per cent. All these exhibited significant SCA effects for number of secondary branches also, stressing the importance of this trait in heterosis for seed yield. Incidently, the above mentioned four crosses involved Varuna, and adapted parent for Indian mustard.
Simultaneous examination of crosses with high heterosis, their SCA and the magnitude of GCA of the parents involved provided valuable information (table-2). It would be seen that, all these crosses mentioned above involved either one or both of their parents with high GCA effects. One cross namely ST-1564 x Varuna, exhibiting the highest heterosis (384.8%) involved both the parents with highly significant GCA effects, suggesting the role of additive genetic variance in the manifesttion of such heterosis, and possibility of fixing part of the heterosis in subsequent generations. Superiority of other four crosses involving once highly significant and another low GCA parent, may be due to dominance. Crosses, showing high to moderate value of heterosis with low GCA of the parents might perhaps throw light on the role of non-additive variances.

In general, maximum heterosis and high positive SCA effects ax were observed in the crosses where distantly related parents were involved. G.P. 549 is an exotic accession, ST 1564 is a systhesized line and D.313 is a derivative of indigenous x exotic cross.

## CONCLUSION

Combining ability analysis was carried out for nine major morphological characters including flowering period, maturity period, plant height, number of primary and secondary branches, siliquae on primary,secondary and main branches and seed yield per plant. Variations among hybrids were highly significant for all the traits except siliquae on primary branches and siliquae on the main shoot. There was differential performance of lines for GCA with the three testers. Estimates for components of variance reveal predominance of non-additive genetic variance for all the traints except maturity. However, additive component was also substantial in case of flowering, plant height and seed yield. ST 1564 among the lines and Varuna among the testers, showed significant positive GCA effects for seed yield and number of its components. Correlations between *per se* performance of lines and hybrids for all the characters were high and significant. Similar trend was also observed for correlation between SCA and mid-parent heterosis. All the crosses having high positive SCA effects, except one for seed yield invariably involved Varuna as one of the parents having high GCA effects. The level of mid-parent heterosis in crosses having significant SCA effects in respect of seed yeild, ranged between 79 and 385 per cent, ST 1564 x Varuna being the cross with the highest heterosis.

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Table 1. Analysis of variance for combining ability in Indian mustard.

| Source | D.F. | Mean squares | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Flowering(days) | Maturity (days) | Plant height (cm) | Primary branches PB | Second-branches SB | Pods/ PB | Pods/ SB | Pods/ main shoot | Seed yield (gm) |
| Hybrids | 41 | 44.13** | 136.99** | 543.91** | 2.71** | 36.35** | 32.13** | 63.10** | 63.10** | 87.13** |
| Lines | 13 | 94.65** | 85.31 | 677.68** | 2.11** | 28.41 | 30.41** | 5.71** | 82.44** | 75.10** |
| Testers | 2 | 21.50** | 867.11** | 660.76** | 3.96** | 65.25** | 17.05 | 8.10* | 12.05 | 286.12** |
| Lines x Testers | 26 | 20.62** | 106.67 | 468.05** | 2.91** | 38.09** | 34.14** | 9.18** | 57.35** | 77.84** |
| Error | 82 | 4.70 | 73.89 | 111.63 | 0.66 | 8.55 | 10.86 | 2.28 | 19.95 | 24.33 |
| gca | | 2.94 | 28.98 | 15.78 | 0.01 | 0.69 | -0.82 | -0.18 | -0.79 | 8.06 |
| sca | | 5.29 | 10.93 | 118.81 | 0.71 | 9.85 | 7.76 | 2.30 | 12.47 | 17.84 |

* and** denote siginificance at one and five percent level.

Table 2. General Combining Ability(GCA) effects of lines and testers.

| Parents | Flowering (days) | Maturity (days) | Plant height (cm) | Primary branches (PB) | Secondary branches (SB) | Pods per PB | Pods per SB | Pods per main shoot | Seed Yield (gm) |
|---|---|---|---|---|---|---|---|---|---|
| Lines : | | | | | | | | | |
| D. 18-3 | -0.25 | 0.63 | 8.31 | 0.30 | 3.05* | 1.29 | 0.56 | 0.95 | -0.26 |
| D. 313 | -0.48 | -0.04 | 17.64** | 0.30 | 3.08* | 2.83** | 1.18* | 4.90** | 2.33 |
| D. 350 | -2.59* | -1.26 | -0.46 | 0.13 | 1.32 | 2.29** | 1.18* | 3.35* | 0.34 |
| D. 367 | -2.14** | -1.93 | -5.84* | -0.51 | -1.31 | -1.97 | -0.18 | -1.88 | -4.68 |
| D. 403 | -2.03 | -4.14 | 8.73** | -0.03 | 0.57 | -0.44 | 0.43 | -0.58 | 0.65 |
| R.S. 99 | 1.30 | 1.18 | 4.11 | 0.03 | -0.37 | -0.03 | -0.06 | 1.36 | 0.42 |
| R.K. 8504 | -2.03 | 2.40 | -6.07 | 0.36 | 0.47 | 0.04 | 0.21 | -0.16 | 0.24 |
| G.P. 17 | 4.41 | -5.26** | -15.11** | 0.77 | -3.11 | -3.97 | -0.94 | -6.58 | -2.17 |
| G.P. 549 | 8.30 | 5.52 | -8.47** | 1.00* | -0.38 | -1.34 | -1.54 | -4.61 | 1.85 |
| ST 1564 | 2.41 | 2.07 | 8.39 | 0.53* | 0.94 | 2.08* | 0.83* | 3.47* | 6.73** |
| D. 335-1 | 0.08 | -0.93 | -7.32 | 0.54 | -2.10 | -0.69 | -0.49 | -0.16 | -1.40 |
| D. 335-2 | -0.59 | -2.71 | -1.69 | -0.47 | -1.61 | -1.02 | -0.66 | -0.56 | -3.72 |
| D. 335-3 | -3.48** | -0.26 | 0.48 | -0.23 | -0.61 | 0.45 | -0.51 | 0.12 | -2.51 |
| D. 335-8 | -2.92** | 4.74 | -2.71 | -0.09 | 0.07 | 0.39 | -0.01 | 0.40 | 2.18 |
| S.E.(±) | 0.59 | 2.33 | 2.86 | 0.24 | 0.79 | 0.89 | 0.41 | 1.21 | 1.34 |
| Testers : | | | | | | | | | |
| Pusa Bold | -0.55** | -5.02** | 4.57** | 0,20 | 1.03 | -0.25 | 0.16 | -0.62 | -1.40 |
| Varuna | -0.26 | 1.17 | -1.97 | 0.16 | 0.36 | 0.72* | 0.34* | 0.32* | 3.01** |
| Pusa Barani | 0.81 | 3.84 | -2.60 | -0.35 | -1.39 | -0.48 | -0.50 | 0.30 | -1.61 |
| S.E.(±) | 0.23 | 0.91 | 1.12 | 0.10 | 0.31 | 0.35 | 0.16 | 0.47 | 0.52 |

* and ** denote significance at five and one percent respectively.

Table 3. Estimates of specific combining ability effects for the crosses exhibiting desirable and significant effects and high MP heterosis for seed yield.

| Crosses | Flowering (days) | Maturity (days) | Plant height (cm) | Primary branches | Secondary branches | Pods on PB | Pods on SB | Pods main shoot | Seed yield(gm) SCA | Seed yield(gm) MP heterosis (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| D.313 X Pusa Barani | 0.86 | 4.16 | 3.20 | 0.42 | 0.81 | -0.46 | 0.41 | 2.07 | 4.44 | 97.8 |
| D.313 X Varuna | -1.40 | -0.84 | -6.43 | -0.36 | -1.40 | -0.26 | -0.96 | -0.87 | 4.09 | 100.6 |
| D.350 X Pusa Barani | 0.97 | -7.29 | 0.43 | 1.20* | 4.90** | 2.74* | 1.27* | 2.63 | 0.57 | 22.1 |
| D.403 X Pusa Barani | -1.59 | 1.60 | 4.64 | 0.29 | 1.72 | 1.68 | 0.56 | 2.10 | 5.81 | 82.0 |
| RK8504 X Varuna | 0.82 | 4.83 | 0.28 | 0.55 | 3.11* | 1.23 | 0.02 | 1.93 | 4.34* | 283.5 |
| G.P. 17 X Pusa Bold | -0.01 | 10.57 | 10.45 | 0.62 | 2.65* | 3.65* | 1.88* | 6.95* | 0.62 | 13.0 |
| G.P.549 X Pusa Bold | -3.56* | 0.13 | 15.47** | -0.30 | 3.45 | 2.05 | 2.54** | 5.51* | 1.90 | 71.7 |
| G.P.549 X Varuna | -4.18* | 1.27 | 20.45** | 2.74* | 6.25** | 6.18** | 2.96** | 5.74* | 6.97** | 250.7 |
| ST-1564 X Varuna | 2.37 | 2.17 | 7.79 | 0.45 | 3.03* | 3.43* | 1.03 | 4.06* | 6.44** | 384.8 |
| D.335-1 X Pusa Bold | -0.67 | 6.24 | 8.86* | 0.72 | 0.64 | 0.02 | -0.10 | 1.93 | 4.38* | 79.6 |
| D.335-1 x Pusa Barani | -2.37* | -7.62* | 8.93* | 0.20 | 1.45 | 4.65* | 1.88* | 3.61* | 2.30 | 36.9 |
| D.335-8 X Varuna | 0.37 | 1.05 | 13.86** | 0.66 | 2.71* | 3.08* | 1.46* | 0.26 | 8.93** | 262.1 |
| S.E.(±) | 0.83 | 3.29 | 4.05 | 0.34 | 1.12 | 1.26 | 0.58 | 1.71 | 1.89 | 3.1 |

* and ** denote significance at 5 and 1 percent respectively.