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Combining ability for yield and its contributing characters in Indian mustard

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Abstract

The combining ability analysis of five parents and their 10 F_1s produced by Diallel mating system revealed that there were significant differences for all the characters in both the type of combining ability. For all the characters suggesting the involvement of both additive and non-additive gene effects in regulating the expression of different characters, GCA and SCA variances were important. The estimates of specific combining ability effects revealed that as many as four cross combinations exhibited significant and positive *sca* effects for seed yield/plant. The maximum significant positive *sca* effect was exhibited by Ashriwad × IC 589690 and IC 589690 × IC 447111 thus they were good hybrid combinations, contributing towards higher seed yield. These crosses were also found promising for other desirable traits, hence could be further evaluated in heterosis breeding programme. Simultaneously these hybrids could be selfed to obtain desirable recombinants in segregating generations for the development of superior genotypes.

Keywords: *Cross combination, GCA, Indian mustard, SCA, significant*

Introduction

Indian mustard is a fairly high-paying crop with a major source of high-quality edible oil, and it is important to cultivate improved varieties that are able to provide high yields, such as hybrid varieties, to increase the productivity of mustard crops (Das *et al.,* 2019). It is highly desirable that productivity and stability be enhanced by productive plants, which may have the genes for higher seed and oil content. The creation of such lines depends on the population's understanding of combining ability and genetic architecture. Many authors have applied various techniques to boost Brassica's seed yield and quality attributes (Kumar *et al.*, 2013 and Patel *et al.*, 2015). Mustard yield and its quantitative components will be helpful in gaining awareness of the nature and magnitude of genetic variability and its relationship with the environment. Interactions between genotypes and environments are especially important because they represent environmental fluctuations when genetic composition is understood and predictions can be made in advance in most cases (Allard and Bradshaw, 1964). Genotypes can be defined as "buffered" or stable (Allard and Bradshaw, 1964), which can change their phenotypical state in response to environmental fluctuations in such a way that it provides maximum stable economic return.

Stable genotypes suitable for a large range of environments must be identified. Evaluation of breeding material for combining ability as well as the degree of heterosis for seed yield and yield contributing characteristics needed in any breeding programme aimed at developing improved hybrid genotypes. The combining ability analysis also provides information about the nature and magnitude of gene action involved in the expression of various quantitative characters. Exploitation of heterosis may play a very significant role in boosting up the production and productivity of Indian mustard. Heterosis breeding can be one of the most viable options for breaking the present yield barrier. Comprehensive analysis of the combining ability involved in the inheritance of quantitative traits and in the phenomenon of heterosis is necessary for evaluation of various breeding procedures (Allard, 1960).

Half Diallel mating system has been widely used to explain the nature of gene action involved in the expression of quantitative traits in both self- and cross-pollinated crop plants. In order to protect the available parent and to better understand the genetic make-up of these parents, the half diallel mating design has been found to be of considerable benefit to the plant breeder. It provides reliable information on the components of variance and on general combining ability and specific combining ability variances and their effects. It therefore assists in the selection of suitable hybridization parents as well as in the selection of effective breeding processes.

Materials and Methods

The experiment was conducted under normal conditions at the Experimental Farm, Mata Gujri College, Fatehgarh

Sahib in India, from 2018 to 2019. Plants of five contrasting mustard genotypes received from National Bureau of Plant Genetic Resources, New Delhi, were crossed to generate the offspring with Half Diallel Mating Design. From the crosses between the five genotypes, 10 hybrid mustard progenies were generated. From each progeny, five plants were selected from each replication. The experiment was conducted in a randomized block design with three replications of 15 plants per progeny. The analysis of variance was carried out for thirteen characters as per the procedure given by Panse and Sukhatame (1967) and the combining ability analysis was carried out defind by Kempthorne (1957).

Results and Discussion

The analysis of variance of combining ability for partitioning the total genetic variance into general combining ability, (*gca* representing additive type of gene action) and specific combining ability (*sca*, a measure of non-additive gene action) was carried out by the procedure suggested by Griffing (1956). The analysis of variance for combining ability for all the characters under study is presented in Table 1**.** Variance due to GCA as well as SCA was significant for all the characters studied. Magnitudes of *gca* variance component was higher than *sca* for all the characters.

Estimation of combining ability (GCA and SCA) effects

The estimates of general combining ability effects of parents and specific combining ability effects of the crosses for all the thirteen traits are presented in Table 2 and 3. The salient features of the result on combining ability effects for characters are presented.

The estimates of *gca* effects revealed that out of 5 parents, one parents such as RH 119 (1.58) recorded significant and positive *gca* effects. On other hand, two parents like Kanti (-0.69) and IC 447111 (-0.94) exhibited significant negative *gca* effects for days to first flowering. Only three crosses were showed positive significant *sca* effects having ranging from 1.87 (Ashriwad × IC 589690) and 3.63 (Ashriwad × IC 447111) while only two cross namely Kanti × IC 447111 (-1.55) and Ashriwad × IC 447111 (-3.51) were recorded negative significant *sca* effects for days to first flowering.

For days to 50% flowering, out of five parents, one parent such as RH 119 (1.54) had recorded significant positive *gca* effects while two parents namely Kanti (-0.91) and IC 447111 (-0.93) exhibited significant negative *gca* effects for this trait. Out of 10 crosses, three crosses were expressed the significant positive *sca* effects which

Table: 1 ANOVA for diallel analysis in Indian mustard (*Brassica juncea* L)

Source of variation	D.F.	Days to first flowering	Days to 50% flowering	Days to maturity	No. of primary branches	No. of secondary branches	Plant height (cm)	No. of siliqua /plant	Siliquae length (cm)	No. of seeds /siliqua	Biological yield	Seed yield /plant	Test weight (g)	Harvest index (%)
Replication	2	1.883	0.673	0.587	5.01**	18.2**	3.37	367.416	0.7**	3.54**	19.094**	0.050	0.38	16.19
Treatments	14	18.75**	15.3**	86.17**	1.17**	9.8**	2148.1**	2135.2*	0.4**	2.3**	4131.3**	171.4**	2.19**	44.83**
Parents	4	7.89**	7.703*	77.05**	0.697**	19.1**	2929.9**	1701.86	1.3**	0.609	600.4**	27.20**	1.46**	43.63*
Hybrids	9	21.14**	19.0**	99.14**	1.24**	5.2**	787.99**	1362.49	0.108	2.2**	4083.5**	205.2**	2.70**	50.20**
Error	28	1.698	2.076	4.043	0.147	1.173	2.379	975.72	0.090	0.492	3.351	3.336	0.35	12.25
Total	44	7.134	6.229	30.019	0.694	4.719	685.174	1317.02	0.222	1.211	1317.52	56.666	0.94	22.79

*,** Significant at 5% and 1% level, respectively.

Table: 2 Estimation of general combining ability (GCA) effects for yield characters.

Genotypes	Days to first flowering	Days to 50% flowering	Days to maturity	No. of primary branches	No. of secondary branches	Plant height (cm)	No. of siliqua /plant	Siliquae length (cm)	No. of seeds /siliqua	Biological yield	Seed yield /plant	Test weight (g)	Harvest index (%)
Ashriwad	0.045	-0.16	-1.43**	-0.12	-0.92**	-4.3**	-7.92	-0.12*	-0.173	12.7**	2.24**	-0.170	-0.239
Kanti	-0.69*	-0.91**	-4.5**	0.25**	0.385	2.69**	-6.32	0.25**	0.027	-10.5**	-3.15**	-0.34**	-0.644
RH 119	1.58**	1.54**	1.82**	0.042	0.51*	12.5**	5.465	0.042	-0.016	-8.37**	-2.60**	0.177	0.295
IC 589690	0.011	0.474	2.06**	0.18*	0.318	1.5**	4.931	-0.025	0.122	-2.48**	2.58**	0.69**	2.351**
IC 447111	-0.94**	-0.93**	2.12**	-0.3**	-0.301	-12.5**	3.855	-0.149*	0.041	8.71**	0.93*	-0.36**	-1.76*
Gi-Gj at 95%	1.11**	1.23**	1.72**	0.32**	0.92**	1.32**	26.7**	0.25**	0.60**	1.56**	1.56**	0.51**	2.99**
Gi-Gj at 99%	1.85**	2.04**	2.85**	0.54**	1.53**	2.19**	44.3**	0.42**	0.99**	2.60**	2.59**	0.84**	4.97**
h^2 Narrow Sense	0.228	0.324	0.523	0.221	0.146	0.184	-0.008	0.270	-0.023	0.115	0.195	0.434	0.191
h^2 Broad Sense	0.928	0.886	0.959	0.899	0.907	0.999	0.626	0.818	0.840	0.999	0.985	0.858	0.772

*,** Significant at 5% and 1% level, respectively.

ranging from 1.71 (Kanti × RH 119) to 2.64 (Ashriwad × IC 447111) for this trait. Two crosses such as Kanti × IC 447111 (-1.80) and Ashriwad × Kanti (-3.31) were showed negative significant *sca* effects for this trait.

The estimates of combining ability effects for number of primary branches/plant revealed that out of five, two parents namely IC 589690 (0.18) and Kanti (0.25) expressed positive significant *gca* effects while only one parent namely IC 447111 (-0.35) was recorded significant negative *gca* effects for this trait. Only one cross such as Ashriwad × IC 589690 (1.45) was found to be significant positive *sca* effects.

The estimates of *gca* effects for number of secondary branches one parent such as RH 119 (0.51) was expressed significant positive *gca* effects whereas one parent namely Ashriwad (-0.92) was showed significant negative *gca* effects for this trait. Out of ten, three combinations were recorded significant positive *sca* effects ranging from 1.72 (RH 119 × IC 447111) to 3.27 (Ashriwad × Kanti), while two crosses namely RH 119 × IC 589690 (-1.632) and Kanti × RH 119 (-1.632) were recorded significant negative *sca* effects for this trait.

Out of five parents, three parents showed significant positive *gca* effects varies from 1.57 (IC 589690) to 12.57 (RH 119) while two parents like Ashriwad (-4.33) and IC 447111 (-12.51) were exhibited significant negative *gca* effects for plant height. Eight crosses were showed significant positive *sca* effects having ranging from 5.21 (Ashriwad × IC 447111) and 50.39 (Ashriwad × IC 589690) while only two crosses *viz.* RH 119 × IC 589690 (-3.12) and Kanti × RH 119 (-18.51) were recorded negative significant *sca* effects for plant height.

The estimates of combining ability effects for number of siliquae/plant revealed that out of five parents, none of the parents expressed significant positive and negative *gca* effects for this trait. Out of the 10 crosses, none of the cross expressed significant positive and negative *sca* effects for this trait.

Out of the five parents, only one parent such as Kanti (0.25) was expressed positive significant *gca* effects for siliqua length. On the other hand, two parents namely Ashriwad (-0.12) and IC 447111 (-0.14) were expressed significant negative *gca* effects for this trait. The estimates specific combining ability for siliqua length revealed that out of 10 crosses, only one cross such as RH 119 × IC 447111 was expressed the significant positive *sca* effects for this trait. Two crosses namely Kanti × IC 447111 (-0.47) and Kanti × IC 589690 (-0.49) were showed negative significant *sca* effects for siliqua length.

Out of five parents, none of the parents showed the significant positive and negative *gca* effects for this trait. Only two crosses such as Ashriwad × IC 447111 (1.43) and Kanti × RH 119 (1.82) were recorded significant positive *sca* effects for this trait. None of the crosses exhibited significant negative *sca* effects for number of seeds/siliqua.

The estimates combining ability effects for days to maturity revealed that out of five parents, three parents showed the positive significant *gca* effects which ranging from 1.82 (RH 119) to 2.12 (IC 447111) for this trait. On the other hand, two parents namely Ashriwad (-1.43) and Kanti (-4.57) were showed the significant negative *gca* effects for maturity. Three crosses were showed significant positive *sca* effects which varied from 2.74 (Ashriwad × IC 447111) and 5.31 (Ashriwad × RH 119). On the other hand, three crosses were recorded significant negative *sca* effects which ranging from -2.97 (Kanti × IC 447111) and -4.74 (Kanti × RH 119) for days to maturity.

For biological yield per plant, two parents namely IC 447111 (8.71) and Ashriwad (12.70) were expressed positive significant *gca* effects whereas, three parents were showed the negative significant *gca* effect varied from -2.48 (IC 589690) to -10.56 (Kanti) for biological yield/plant. Out of 10 crosses, seven were recorded significant positive *sca* effects having ranging from 3.64 (Ashriwad × Kanti) to 66.15 (Ashriwad × IC 589690) while, three cross combinations were recorded significant negative *sca* effects ranging from -7.02 (RH 119 × IC 589690) to -30.55 (RH 119 × IC 447111) for biological yield/plant.

Out of five parents, three parents were expressed positive significant *gca* effects having ranging from 0.93 (IC 447111) to 2.58 (IC 589690) while two parents namely RH 119 (-2.60) and Kanti (-3.15) were expressed negative significant *gca* effects for this trait. The estimates combining ability for seed yield revealed that out of 10 crosses, five crosses were expressed the significant positive *sca* effects which ranging from 2.40 (RH 119 × IC 447111) to 13.09 (Ashriwad × RH 119) for this trait. Two cross namely RH 119 × IC 589690 (-3.78) and Ashriwad × RH 119 (-8.37) were showed negative significant *sca* effects for seed yield/plant.

Only one parent IC 589690 (0.69) was expressed significant positive *gca* effects for this trait. Two parents such as Kanti (-0.34) and IC 447111 (-0.36) were exhibited significant negative *gca* effects for this trait. Two cross combination namely RH 119 × IC 447111 (0.77) and Ashriwad × IC 589690 (1.10) were recorded significant

Table: 3 Estimation of specific combining ability (SCA) effect for yield characters.

Cross combinations	Days to first flowering	Days to 50% flowering	Days to maturity	No. of primary branches	No. of secondary branches	Plant height (cm)	No. of siliqua /plant	Siliquae length (cm)	No. of seeds /siliqua	Biological yield	Seed yield /plant	Test weight (g)	Harvest index (%)
Ashriwad x Kanti	-3.51**	-3.311**	-0.351	0.317	3.273**	18.80**	-2.829	-0.16	0.044	3.64**	3.44**	-0.459	0.407
Ashriwad x RH 119	0.308	0.632	5.316**	-0.406	-1.194	5.79**	27.38	0.087	0.487	3.78**	-8.37**	-0.811*	-6.19**
Ashriwad x IC 589690	1.879*	0.565	2.744*	1.451**	0.540	50.39**	17.58	0.087	-0.051	66.1**	13.09**	1.10**	-0.142
Ashriwad x IC 447111	3.63**	2.641**	2.744*	0.060	1.959**	5.21**	34.32	0.011	1.43**	38.3**	4.02**	-0.706*	0.283
Kanti x RH 119	1.917*	1.717*	-4.74**	0.422	-1.632*	-18.5**	-7.21	-0.194	1.8**	18.7**	3.063**	-0.306	3.713
Kanti x IC 589690	1.422	0.651	-3.513**	0.146	0.568	13.01**	30.64	-0.49**	0.749	-17.1**	-0.565	-0.092	4.150*
Kanti x IC 447111	-1.559*	-1.806*	-2.979*	-0.244	-0.413	19.17**	1.190	-0.47*	-0.703	33.6**	-0.841	0.365	-3.95*
RH 119 x IC 589690	0.741	0.260	0.421	-0.244	-1.365*	-3.124**	-32.14	-0.046	-0.475	-7.02**	-3.784**	0.256	-3.279
RH 119 x IC 447111	2.42**	2.203*	1.687	0.298	1.721*	13.69**	12.26	0.37*	-0.760	-30.5**	2.406*	0.779*	5.68**
IC 589690 x IC 447111	-0.535	0.137	1.249	-0.178	0.587	7.42**	28.46	0.211	0.735	34.5**	9.744**	-0.940*	-1.851
Sij<>0 at 95%	1.486	1.642	2.292	0.436	1.235	1.758	35.610	0.341	0.800	2.087	2.082	0.679	3.990
Sij<>0 at 99%	2.134	2.360	3.293	0.627	1.774	2.526	51.158	0.490	1.149	2.998	2.991	0.976	5.732

*,** Significant at 5% and 1% level, respectively.

positive *sca* effects while three cross combination were recorded significant negative *sca* effects ranging from -0.70 (Ashriwad × IC 447111) to -0.94 (IC 589690 × IC 447111) for test weight.

The estimates combining ability for harvest index revealed that out of five parents, one parent IC 589690 (2.351) was reported significant positive *gca* effects while one parent namely IC 447111 (-1.76) was reported significant negative *gca* effects for this trait. Two crosses were showed positive significant *sca* effects such as RH119 × IC 447111 (5.68) and Kanti × IC 589690 (4.15). On the other hand, two crosses namely Kanti × IC 447111 (-3.95) and Ashriwad × RH 119 (-6.19) were recorded significant negative *sca* effects for harvest index.

Crosses were also supported by highly significant and higher magnitude of *sca* effects for other important yield characters (such as number of primary branches/plant, number of secondary branches/plant, number siliquae/plant, siliqua length, biological yield/plant and harvest index). Only one cross, Ashriwad × IC 589690 that is, was associated with highly significant *sca* value of seed yield/plant as well. Considering other economic traits, parents namely Ashriwad and IC 589690 may be considered as good general combiners. The similar findings were reported by Gideon *et al.* (2015); Gupta *et al.* (2006); Ahsan *et al.* (2013) and Patel *et al.* (2016) in Indian mustard.

A cross combination exhibiting high *sca* effects as well as high *per se* performance involving at least one parent as good general combiner for a particular trait, is expected to throw desirable segregants in the segregating generations. Significant *sca* effects of those combinations involving good × good combiners showed the major role of additive type of gene effects, which is fixable. However, two good general combiners may not necessarily yield desirable segregants. Similarly, from the superior crosses involving both the poor × poor general combiners, very little gain is expected in their segregating generation because high *sca* effects may dissipate with increased homozygosity. Similar findings were reported by Ahsan *et al*. (2013).

Better performance of hybrids involving average poor general combiners indicated dominance × dominance (epistasis) type of gene action (Jinks, 1956). Such crosses could be utilized in the production of high yielding homozygous lines.

In the present study, one of the top two crosses which exhibited high *sca* effects for yield per plant, the cross, Ashriwad × IC 589690 involved one good general combiner (IC 589690) indicating additive × dominance type of gene interaction which is expected to produce desirable transgressive segregants in subsequent generations. Kumari *et al*. (2017); Singh *et al*. (2014); Synrem *et al*. (2017); Kaur *et al.* (2019) reported the involvement of additive × additive, additive × dominance and epistatic type of gene action in expression of yield and other traits in Indian mustard.

The cross combination where poor × poor and poor × good general combiners produced high *sca* effects may be attributed due to presence of genetic diversity in the form of heterozygous loci for specific traits. Thus, the ideal crosses would be the one, which have good *per se* performance, high heterosis or heterobeltiosis, at least one good general combiner parent and high *sca* effects. On the basis of combining ability, the parent IC 589690 was good general combiner. Considering mean performance, heterosis and combining ability, none of the hybrid was found promising for commercial exploitation. This may be due the presence of genetic diversity in the form of dispersed genes for these characters (Dar *et al*., 2012).

Conclusion

The estimates of specific combining ability effects revealed that as many as four cross combinations exhibited significant and positive *sca* effects for seed yield/plant. The maximum significant positive *sca* effect was exhibited by Ashriwad × IC 589690 and IC 589690 × IC 447111 thus they were good hybrid combinations, contributing towards higher seed yield. these crosses were also found promising for other desirable traits, hence could be further evaluated in heterosis breeding programme.

References

Ahsan MZ, Khan FA, Kang SA and Rasheed K. 2013. Combining ability and Heterosis analysis for seed yield and yield components in *B. napus* (L.). *J Biol Agric Health* **3**(9): 31-36.

Allard RW and Bradshaw AD. 1964. Implications of genotype- Environmental Interactions in Applied Plant Breeding. *Crop Sci* **4**: 503-508.

Allard RW. 1960. Principle of Plant Breeding. John Wiley and Sons. New York.

Dar ZA, Wani SA, Gulzaffar and Habib M. 2012. Genetic studies in brown Sarson (*B. rapa* L.). *Trends Biosci* **5**(4): 317-320.

Das A, Ray M and Murmu K. 2019. Yield and Yield Attributes of Hybrid Mustard as Affected by Crop Geometry and Varieties. *Int J Curr Microbiol App Sci* **8**(04):2160-2166

Gideon JS, Rangare NR, Choudhary AK, Kumar S and Myrthong I. 2015. Combining ability analysis for seed yield and component traits in Indian mustard [*B. juncea* (L.) Czern & Coss.]. *Electron J Plant Breed* **6**: 445-453.

Griffing B. 1956. concept of general and specific combining ability in relation to diallel crossing systems. *Aust J Biol Sci* **9:** 463-493.

Gupta SK, Karuna N and Dey T. 2006. Heterosis and combining ability in rapeseed (*B. napus* L.). SKAUST- J Res **5**: 42–47.

Jinks JL. 1956. The F_2 and backcross generations from set of diallel crosses. *Heredity* **10**: 1-30.

Kaur S, Kumar R, Kaur R, Singh I, Singh H and Kumar V. 2019. Heterosis and combining ability analysis in Indian mustard (*B. juncea* L.). *J Oilseeds Res* **10** (1): 38-46

Kempthorne O. 1957. *An Introduction of General Statistics*. John Wiley and Sons. New York, pp. 468-471.

Kumar B, Pandey A and Singh SK. 2013. Genetic diversity for agro morphological and oil quality traits in Indian mustard [*B. juncea* (L.) Czern & Coss.] *The Bioscan* **8**(3): 771- 775.

Kumari P, Singh D, Manjunath H and Phogat DS. 2017. Genetic analysis of seed yield and yield attributes in Indian mustard (*B. juncea* (L.) Czern & Coss). *Electron J Plant Breed* **8**(1): 182-186.

Panse VG and Sukhatme PV. 1967. Statistical method for agricultural workers (2nd Ed. ICAR, New Delhi: pp. 381

Patel A, Prajapati KP, Patel PJ, Shah SK and Patel PS. 2015. Genetic studies of yield and quality traits in Indian mustard (*B. juncea* L.). *J Oilseeds Res* **6**(2): 289-295.

Patel R, Solanki SD, Gami RA, Prajapati KP, Patel PT and Bhadauria HS. 2016. Genetic study for seed yield and seed quality traits in Indian mustard. [*B. juncea* (L.) Czern & Coss.] *Electron. J. Plant Breed* **6**(3): 672-679.

Singh N, Yadava DK, Vasudev S, Singh R, Giri SC, Dass B, Barun S and Prabhu KV. 2014. Combining ability and heterobeltiosis for yield and yield contributing traits in high quality oil Indian mustard (*B. juncea*) genotypes. *Indian J Agric Sci* **85**(4): 498–503.

Synrem GJ, NR Rangare, Choudhari AK, Kumar S and Myrthong I. 2015. Combining ability analysis for seed yield and component traits in Indian mustard [*B. juncea* (L.) Czern & Coss.]. *Electron J Plant Breed* **6**(2): 445-453.