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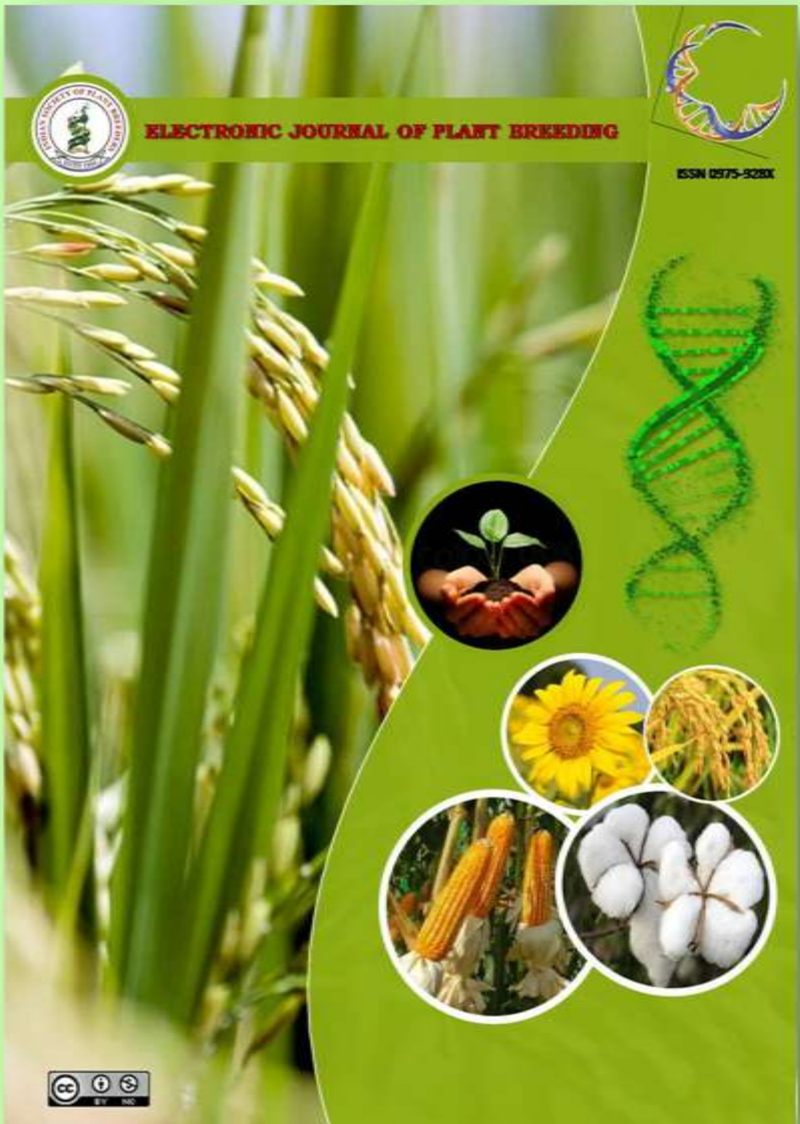

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Research Article

Combining ability analysis for yield and yield attributes in Indian mustard [*Brassica juncea* (L.) Czern & Coss.]

Ramandeep Kaur, *Ravindra Kumar, Satveer Kaur, Harjinder Singh and Ikbal Singh
Plant Breeding Laboratory, Department of Agriculture, Mata Gujri College, Fatehgarh Sahib
***E-Mail**: godwalravindra@gmail.com

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Abstract
A set of 5×5 diallel crosses of Indian mustard along with their parents were evaluated to estimate general and specific combining ability of parents and crosses, respectively during winter season 2017-18. Significant differences were observed for both general combining ability and specific combining ability for all the thirteen traits studied. The high magnitude of general combining ability and specific combining ability effects indicated the presence of both additive and non-additive gene interactions for the inheritance of different studied traits. SCA effects, the high ranking crosses for yield and its component traits were IC-589681× IC-571649, IC-589680× IC-589681.

Key words
Diallel analysis, combining ability, Indian mustard, yield-components

Introduction

Indian mustard (*Brassica juncea)* belongs to family cruciferae. Cytologically, *Brassica juncea* is an amphidiploid (2n= 36) derived from interspecific cross of *Brassica nigra* (2n= 16) and *Brassica campestris* (2n= 20) (Rout *et al*, 2018). *Brassica juncea* is a important oilseed crop plays a crucial role in edible oil economy of India and occupies premier position in Indian agriculture. In India, *B. juncea* is the predominant species and accounts for nearly 80% of cultivation followed by *B. rapa* and *B. napus* (Thakur *et al.*, 2017). It is major winter oilseed crop of the Indian subcontinent occupies more than 80% of the total rapeseed mustard cultivated area and it is a naturally autogamous species in which outcrossing varies from 5-30% depending upon environmental conditions and frequency of pollinating insects (Shrimali *et al.* 2016). Indian mustard seeds contains about 38-43 percent oil which is yellow fragment and is considered to be the healthiest and nutritious cooking medium.

Combining ability analysis is one of the powerful tools to test the value of parental lines to produce superior hybrids and valuable recombinants (Singh *et al*. 2013). Combining ability studies emphasized the preponderance effect of GCA on yield and most of the yield components, indicating the importance of additive gene action (Wos *et al*., 1999, Singh *et al.* 2017)**.** Comprehensive analysis of the combining ability involved in the inheritance of quantitative characters and in the phenomenon of heterosis is necessary for the evaluation of various possible breeding procedures. For developing promising varieties through hybridization a careful choice of parents and breeding methodology are matters of great concern to a plant breeder. Therefore, the effort has been made to assess the genetic worth of parents and hybrids by using diallel mating design involving five lines of Indian mustard.

Materials and Methods

The material for present investigation consisted five Indigenous lines of *Brassica juncea L*. which were provided by NBPGR, New Delhi, India. The present research work was conducted at Mata Gujri College, Research Farm, Fatehgarh Sahib, Punjab, during winter 2016-17 and 2017-18 using Randomized Block Design (RBD) with three replications. This place is situated between 30°-27' and 30°-46' latitudes and 76°-04' and 76°-38'E latitudes and a mean height of 247 meters above sea level. Row to plant spacing of 70 × 25 cm was maintained and proper plant population maintained by thinning. The recommended agricultural package of practices was followed. Observation was recorded for various characters on five randomly selected plants in each genotype in each replication. Diallel mating design using was proposed by Hayman (1958). The combining ability analysis was carried out for all the parents and F_1 genotypes. Total variability was partitioned into component like general combining ability (GCA), specific combining ability (SCA) and error. Information was derived regarding the type of gene action controlling different traits and pattern of selection for improvement of the Indian mustard genotypes.

Results and Discussion

The analysis of variance revealed considerable genetic variation among parents and hybrids for almost all the traits under study (Table 1). Out of thirteen characters only six characters showed significant difference *viz.*, number of siliqua per plant, number of seeds per siliqua ,biological yield per plant, seed yield per plant, harvest index, test weight for parents and parents *vs.* hybrids comparison for all the traits except for days to first flowering, days to maturity and test weight. This results accordance with the Arifullah *et al.*, (2013). The analysis of variance for combining ability showed that general and specific combining ability variance were highly significant for almost all the characters indicating the importance of both additive and non-additive gene actions in the expression of seed yield and its component traits.

The genotypic mean squares were further portioned into variation due to general combing ability (*gca*) and specific combining ability (*sca*). It may be stated that *gca* is due to the average performance of a line in a series of crosses and *sca* is the deviations in the performance of a cross combination from that predicted on the basis of general combining ability of the parents involved in a series of crosses (Sprague and Tatum, 1942). This finding has important implication because additive gene effects are of fixable nature therefore one can expect larger genetic gain due to selection. Similar finding were reported by Banga *et al.* (2011) and Patel *et al.* (2016) in Indian mustard.

Further *gca* and *sca* effects were computed and tested for their significance. A perusal of data on *gca* effects allowed concluding that the experimental material lacked good general combiners for days to first flowering, days to 50% flowering, noumber of seeds/siliqua. This is important consideration from the agro climatic condition of Punjab, where short duration and dwarf varieties would be given preference on account of its cultivation under limited moisture condition.

Therefore in future, attempts must be done to broaden the genetic base for these three important characters. Considering other economic traits, parents IC-597879, IC-589681 and IC-589680 may be considered as good general combiners. However statistically, for seed yield one parents IC-589680 showed significant negative *gca* effect. A perusal data on *sca* effects led to the inference that for days to first flowering, siliqua length and number of seeds/siliqua the scenario was similar that observed for *gca* effects. However for seed yield certain crosses such as IC-589681 × IC-571649, IC-589680 × IC-589681 showed higher magnitude of significantly higher *sca* effect. Similar finding reported by Singh, (2007) in Indian mustard. But all 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 siliquae/plant, siliqua length, plant height, biological yield/plant, harvest index and test weight. Only one cross, like IC-589681 × IC-571649 was associated with highly significant *sca* value of seed yield/ plant as well. Similar findings were reported by Gupta, (2011) in Indian mustard. Therefore, on this ground this cross deserves more attention.

The potentiality of a parent in hybridization may be assessed by its *per se* performance and *gca* effects. The results revealed that most of the genotypes had relatively high degree of correspondence between *per se* performance and *gca* effects for the observed characters. This can be ascribed to the predominant role of additive and additive × additive type of gene action for the inheritance of these traits.

The estimates of specific combining ability effects revealed that two cross combinations exhibited significant and positive *sca* effects for seed yield/plant. The maximum significant positive *sca* effect was exhibited by hybrid IC-589681 × IC-571649 (6.31) and IC-589680 × IC-589681 (4.88) thus they were good hybrid combinations, contributing towards higher seed yield.

Since among the parents IC-597879 (primary branches, siliqua length, biological yield) and IC-589681 (Secondary Branches, number of siliquae, harvest index) showed significant *gca* effect, it is not possible to classify the crosses on the basis of high/low *gca* value of the parents. 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.

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 (Darrah and Hallauer, 1972). In the present study, one of the top four crosses which exhibited high *sca* effects for yield/plant, the cross, IC-589680 × IC-571649 involved no one good general combiner indicating additive × dominance type of gene interaction which is expected to produce desirable transgressive segregants in subsequent generations. Singh *et al.* (2007) and Falk *et al*. (2014) have 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 crosses, 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-597879 was good general combiner. Considering mean performance, heterosis and combining ability, none of the hybrid was found promising for commercial exploitation.

The perusal of data on component analysis, in general, revealed that both additive gene action and dominant gene action are important for all the traits studied. Thus this finding is consistent with the inferences drawn from combining ability analysis that both additive and non-additive types of gene action are important.

The major objective of performing diallel analysis is to find out genetic architecture of the parents, so that the right type of parents may be selected along with a suitable breeding plan. In the present investigation it was found that for all the characters (except days to 50% flowering) additive gene action is more important and hence, should be exploited. Since Indian mustard is largely self-pollinated therefore, exploitation of additive gene action is feasible and should be given due to importance. Further, in component analysis the ratio H_1/D was higher than unity for all the traits studied indicating preponderance of dominant gene actions, however, the inference of combining ability analysis was just reverse, in that the additive gene action was found to be more important.
Conclusively, these two crosses (IC-589681× IC-571649 and IC-589680× IC-589681) were found promising for other desirable traits, indicating that these crosses may be further tested for commercial utilization and could be further evaluated in heterosis breeding programme.

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Table 1. Analysis of variance for combining ability, estimates of components of variance and their ratio for various characters in Indian mustard

Source of variation	Degree of freedom	Days to First Flowering	Days to 50% Flowering	Primary Branches/ Plant	Secondary Branches/ Plant	Plant Height (cm)	Siliquae/ Plant	Siliqua Length(cm)	Seeds/ Siliqua	Days to Maturity	Biological Yield/ Plant (g)	Seed Yield/ Plant (g)	Harvest Index (%)	Test weight(g)
Parent Vs.Hybrids	1.00	46.41	187.23**	102.08**	114.08**	780.85*	39997.65**	39997.65**	13.65**	6.75	27782.56**	155.52**	310.92**	0.40
GCA	4.00	8.78	8.43	1.46	13.89**	157.80*	3104.67**	0.15**	0.31	8.40**	1870.91**	14.88*	12.65**	0.12
SCA	10.00	13.34**	24.32**	5.45**	5.96**	89.29	5895.58**	0.06	1.62**	3.32	2410.44**	50.40**	24.14**	0.20*
Reciprocal	10.00	9.51	7.46	3.00	3.86	40.55	7082.45	0.05	0.61	4.54	1931.55	101.94	28.82	0.11
Error	48.00	3.76	5.59	0.64	1.27	45.60	347.52	0.03	0.25	1.86	185.33	5.33	2.23	0.06
$\sigma^2 g$		0.50	0.28	0.08	1.26	11.22	275.72	0.01	0.01	0.65	168.56	0.95	1.04	0.01
$\sigma^2 s$		9.58	18.73	4.81	4.69	43.69	5548.07	0.02	1.37	1.46	2225.11	45.07	21.91	0.14
$\sigma^2 g/\sigma^2 s$		0.05	0.02	0.02	0.27	0.26	0.05	0.51	0.00	0.45	0.08	0.02	0.05	0.04

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Table 2. General Combining ability effects for different characters in Indian mustard.

Characters Genotype	Days to First Flowering	Days to 50% Flowering	Primary Branches/ Plant	Secondary Branches/ Plant	Plant Height (cm)	Siliquae/ Plant	Siliqua Length(cm)	Seeds/ Siliqua	Days to Maturity	Biological Yield/ Plant (g)	Seed Yield/ Plant (g)	Harvest Index (%)	Test Weight (g)
IC-589680	0.94	0.99	-0.37	-0.23	5.99**	12.61*	0.02	-0.01	0.77	0.49	-1.68*	-0.54	0.08
IC-589681	0.54	0.86	0.27	1.93**	-1.28	23.08**	-0.04	0.19	-0.60	-20.47**	-0.88	1.60**	0.08
IC-597879	0.54	-0.11	0.47*	-0.03	1.92	-2.82	0.14**	-0.25	-1.30**	14.93**	0.52	-1.11*	-0.05
IC-571649	-0.96	-0.64	-0.40	-1.27**	-3.31	-15.49**	0.06	0.15	0.77	-4.31	1.05	0.72	-0.17*
IC-405235	-1.06	-1.11	0.03	-0.40	-3.31	-17.39**	-0.19**	-0.08	0.37	9.36	0.99	-0.68	0.05
Gi--Gj at 95%	2.41**	2.94**	1.00**	1.40**	8.38**	23.15**	0.22**	0.62**	1.70**	16.90**	2.87**	1.86**	0.30**
Gi--Gj at 99%	3.99**	4.87**	1.65**	2.32**	13.90**	38.38**	0.37**	1.03**	2.81**	28.03**	4.75**	3.08**	0.50**
h^2Narrow Sense	0.06	0.02	0.02	0.26	0.21	0.06	0.26	0.01	0.22	0.09	0.02	0.05	0.05
h^2 Broad Sense	0.61	0.75	0.70	0.74	0.61	0.62	0.52	0.76	0.46	0.71	0.47	0.62	0.65

Table 3. Specific Combining ability effects for different characters in Indian mustard.

Crosses	Days to First Flowering	Days to 50% Flowering	Primary Branches/ Plant	Secondary Branches/ Plant	Plant Height (cm)	Siliqua/ Plant	Siliqua Length (cm)	Seeds/ Siliqua	Days to Maturity	Biological Yield/ Plant (g)	Seed Yield/ Plant (g)	Harvest Index (%)	Test Weight (g)
IC-589680×IC-589681	-2.27	-3.49*	1.63**	2.33**	0.11	17.25	0.13	1.18**	0.17	-4.83	4.88**	3.05**	0.28
IC-589680×IC-597879	-1.61	-1.03	-0.40	1.63*	5.58	6.65	0.15	0.11	0.70	-53.56**	-0.19	3.71**	-0.21
IC-589680×IC-571649	4.89**	4.67**	0.30	-0.30	-7.85	46.65**	-0.01	-1.12**	-1.53	14.01	2.45	-0.15	0.47**
IC-589680×IC-405235	0.49	1.47	0.20	0.00	-0.85	-6.95	0.05	-0.72*	0.20	-1.99	1.18	0.61	-0.24
IC-589681×IC-597879	0.96	0.94	-0.03	-0.37	-11.49*	86.02**	-0.01	-0.25	-1.93*	5.41	-2.15	-2.03*	0.12
IC-589681×IC-571649	-2.04	-1.53	0.17	0.53	0.75	43.69**	-0.05	-0.65*	-0.17	-6.86	6.31**	5.22**	-0.10
IC-589681×IC-405235	0.73	0.11	1.57**	1.17	-0.25	-64.75**	0.01	-0.09	2.07*	11.64	0.21	-1.22	-0.04
IC-597879×IC-571649	-0.04	-0.89	0.30	1.00	6.38	-51.08**	-0.15	-0.72*	-0.13	-27.43**	-7.42**	-2.28	-0.26
IC-597879×IC-405235	-1.61	-2.59	2.20**	0.47	-2.29	32.49*	-0.09	0.18	-0.57	-29.26**	1.48	3.07**	-0.06
IC-571649×IC-405235	-3.44*	-5.56**	-0.10	-0.30	-6.22	5.49	-0.19	-0.05	-0.30	-3.36	0.45	0.20	-0.32*
Sij <> 0 at 95%	2.56	3.12	1.06	1.48	8.91	24.59	0.24	0.66	1.80	17.96	3.05	1.97	0.32

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