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Research Article

Combining ability analysis for yield and yield contributing traits in Indian Mustard (*Brassica Juncea* L. Czern&Coss)

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Abstract
The experimental material consisted of ten parental genotypes and their 45 F_1s developed through half diallel mating design, was evaluated in Randomized Complete Block Design with three replications. The magnitude of both the estimates; σ^2*gca* and σ^2*sca*, potent ratio and predictability ratio revealed prominence of additive genetic variance for days to 50% flowering, days to 80% siliquae maturity, test weight and glucosinolate content while non-additive genetic variance preponded for plant height, number of siliquae per plant, seed yield per plant, harvesting index; and erucic acid content.The parents Pusa bold, Bio-902, NUDHYJ-3 and EC-287711 were good general combiners for seed yield and at least for two important yield attributing characters. The F_1s Bio-902 x NUDHYJ-3, Pusa Bold x EC-287711, Pusa bold x GM-3,Bio-902 x TM-2 and Bio-902 x JM-3 were good specific combiners for seed yield and represented all the good general combiners parents except JM-3, suggesting major component of pseudo additive gene effect of non-additive gene effect.

Key words
Combining ability, *gca*, gene action, mustard, potence ratio, *sca*

Introduction:

Brown or Indian mustard (*Brassica juncea* (L.) Czern.) is one of the important species in the genus *Brassica*.It is self-compatible and highly self-pollinated crop (85-90%). However, owing to insects, especially honeybees, the extent of cross-pollination varies from 4 to 16.6% (Rambhajan*et al*., 1991).Mustard seeds contain about 38-42% oil (Prakash &Hinata, 1980).India occupies the first position in area and second position in production of mustard after China in the world, and contributes 28.3 and 19.8 per cent as its share in acreage and production, respectively. It is highly essential to identify high yielding genotypes having high seed yieldand low erucic acid content. For the improvement of seed yield of mustard, breeding techniques of self pollinated crops are being employed, but in consideration to inheritance of the seed yield and its component characters emphasis should be concentrated for heterosis breeding. However, selection of parental genotypes on the basis of their nicking ability is the basic requirement for formulating future breeding programme. The concept and analysis of general and specific combining ability suggested by Griffing(1956)has been widely used toaid plant breeders in the selection of parents for hybridization.The combining ability analysis also facilitates to estimate of the components of genetic variance. However, the variances ratio, potence ratio ($\frac{1}{\text{d.f.}}\hat{\sigma}^2 gca / \frac{1}{\text{d.f.}}\hat{\sigma}^2_{sca}$) and predictability ratio (2 $\hat{\sigma}^2 gca$ / 2 $\hat{\sigma}^2 gca + \hat{\sigma}^2_{sca}$) would provide the real magnitude of components of genetic variance. Therefore, the genetic analysis of seed yield and component characters of mustard was carried out in realism of to assess gene effects and the potentiality of parents and F_1s through *gca* and *sca*effects, respectively.

Material and method

The present investigation was carried out at Regional Research Station, Anand Agricultural University, Anand during the year 2008-09. The experimental material consisted of ten diverse parents(*viz*., Varuna, Pusa Bold, GM-2, SEJ-2, BIO-902, TM-2, GM-3, JM-3, EC-287711 and NUDH-YJ-3) and their 45 F_1sderived by crossing in diallele mating design (excluding reciprocals). The experimental material was evaluated in Randomized Complete Block Design (RCBD) with three replications. An experimental unit was of a single row of 5 meter length with 45 cm and 15 cm, inter and intra row spacing, respectively. Observations for different characters were recorded on five randomly selected competitive plants in each experimental unitexcept phonological traits, days to 50% flowering and days to 80% siliquae maturity,while the biochemical analysis was carried outon mix samples of each experimental unit. The mean values were subjected to statistical analysis as suggested by Snedecor and Cochran (1967) and reviewed by Panse and Sukhatme (1978). Combining ability analysis was performed as per Griffing (1956) Model-I and method-II. The magnitude of components of gene effects wasestimated as potenceratio($\frac{1}{\text{d.f.}}\hat{\sigma}^2 gca$ /

$\frac{1}{\text{d.f.}}\hat{\sigma}^2_{sca}$)and predictability ratio (2 $\hat{\sigma}^2 gca$ / $2\hat{\sigma}^2 gca + \hat{\sigma}^2_{sca}$).

Result and discussion

The mean square values due to parents and hybrids were significant for all the characters suggesting existing of genetic difference among parents and hybrid for eachcharacter under study and scope for the improvement of the characters(Sheoran*et. al.*, 2000, Tuncturk&Ciftci, 2007). The variance due to both general combining ability ($\sigma^2 gca$) andspecific combining ability ($\sigma^2 sca$) were significant for days to 50% flowering, days to 80% siliquae maturity, plant height, number of siliquae per plant, test weight, seed yield per plant, harvest index, erucic acid and glucosinolate content revealing importance of both additive and non-additive genetic variance for inheritance of these characters.However, the potence ratio above one for days to 50% flowering, days to 80 % siliquae maturity, test weight, erucic acid content and glucosinolate content and above 0.5 values predictability ratio for days to 50% flowering and glucosinolate content revealed preponderance of additive genetic variance. The similar results are also reported by Monalisa*et. al.* (2005), Kemparajn*et. al.* (2009), Lal*et al* (2010), Mishra (2010) and Gupta *et al*. (2011). Whereas, below one value of potence ratio and less than 0.5 value of predictability ration for plant height, number of siliquae per plant, seed yield per plant and harvest indexsuggested preponderance of non-additive genetic variance for inheritance of thesecharacters.Singh and Dixit (2007), Lal*et al.* (2010), Mahak Singh *et al.* (2010) and Gupta*et al.* (2011) observed preponderance of non-additive for seed yield per plant. The predictability ratio was close to 0.5 value for days to 80% siliquaematurity, test weight and erucic acid content indicated importance of both additive and non-additive genetic variances.The below unity value of average degree of dominance for days to 50 % flowering, and glucosinolate content suggested behavior of interacting alleles and the close to one value of average degree of dominance for days to 80% siliquae maturity, test weight and erucic acid content indicated presence of complete dominance(Table1).The differences in magnitude of gene effects for different characters through various approaches would be because of differences in weightage given to the components of genetic variance.

Among the parental genotypes, TM-2, Bio-902, Pusa Bold, NUDHYJ-3, and EC-287711 were found to be good general combiners for seed yield per plant and at least for two to three important yield contributing characters (Table 2). Among these parents, Bio-902, Pusa Bold, NUDHYJ-3 were found to be good general combiner for seed yield per plant and early maturity therefore, these parents can be used to develop high yielding with early maturing hybrid. NUDHYJ-3 and EC-287711 were found to be good general combiners for high seed yield with low level of erucic acid content and glucosinolate content but these parent also shows poor combining ability for oil and protein content. Hence, these parents may therefore be used in crop breedingprogramme aimed at improvement of respective characters. Further, in consideration of *per se* performance in combination with combining ability estimates was reported to provide a better criteria for choice of superior parents in hybridization programme (Khan and Khan., 2005 and Dar *et al.*, 2011).

The hybrids which had high desired *per se* performance alongwithhigh and significant *sca* effects are presented in Table.3. The crosses having combination of good x good general combiner parents indicates additive x additive types of interaction between parents for the expression of the characters and its possibility of fixation through single plant selection could be practiced in future segregating generations to isolate superior pure lines from such cross combinations.The crosses exhibited high *sca* effects but involve good x poor, poor x good, good x average, average x average, *gca*effects of parents there by suggesting importance of intra as well as inter- allelic interactions*i.e.* complementary epistasis (additive x dominance) and may be due to the presence of genetic diversity in the form of dispersed genes for these characters (Yogeshwar and Sachan, 2003 and Amiri-Oghan *et al.*, 2009). Among, all crosses none of crosses showed significant *sca* effects and *per se* per formance for all the characters which indicates yield is complex character which is cumulative effects of all other traits.But Bio-902 x NUDHYJ-3, Pusa Bold x EC-287711, Pusa Bold x GM-3, Bio-902 x TM-2 and Bio-902 x JM-3 were good specific combiner for seed yield per plant and atleast one important yield contributing characters like average siliquae length, test weight, number of siliquae per plant, no. of secondary branches per plant and oil content.

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

Source of variation	d.f.	Days to 50 % flowering	Days to 80 % siliquae maturity	Plant height(cm)	Number of primary branches / plant	Number of secondary branches / plant	Effective length of main branch	Number of siliquae per plant	Average siliqua length(cm)
Parents (GCA)	9	22.89**	58.94**	385.69**	1.54**	2.72**	9.40**	18547.73**	0.32**
Hybrids (SCA)	45	3.39**	9.81**	156.45**	1.11**	4.08**	4.59**	11055.63**	0.39**
Error	108	1.50	1.66	5.04	0.03	0.53	0.77	173.46	0.02
Estimates									
σ^2gca (Σg_i^2)		1.62**	4.09**	19.10**	0.04	-0.11	0.40	624.34**	-0.01
σ^2sca ($\Sigma\Sigma s_{ij}^2$)		1.89*	8.15**	151.41**	1.08**	3.55**	3.82**	10882.17**	0.37**
Potence ratio		4.30	2.51	0.63	-	-	-	0.29	-
Predictability ratio		0.63	0.50	0.20	-	-	-	0.10	-
σ^2A		3.25	8.19	38.21	0.07	-0.23	0.80	1248.68	-0.02
σ^2D		1.89	8.15	151.41	1.08	3.55	3.82	10882.17	0.37
$[\sigma^2D / \sigma^2A]^{0.5}$		0.76	1.00	1.99	3.88	3.93	2.18	2.95	

Table 1 Contd.

Source of variation	d.f.	Number of seeds / siliquae	Test weight (g)	Seed yield per plant(g)	Harvest Index	Protein content(%)	Oil content (%)	Erucic acid content(%)	Glucosinolate content (µ mol/g)
Parents (GCA)	9	4.50**	2.46**	71.70**	68.29**	0.43**	1.53**	123.07**	1432.79**
Hybrids (SCA)	45	3.67**	0.48**	29.34**	53.42**	0.78**	1.66**	31.86**	164.84**
Error	108	0.12	0.014	0.41	1.38	0.05	0.07	0.11	1.17
Estimates									
σ^2gca (Σg_i^2)		0.07	0.17**	3.53**	1.2**	-0.03	-0.01	7.60**	105.66**
σ^2sca ($\Sigma\Sigma s_{ij}^2$)		3.55**	0.47**	28.93**	52.05**	0.73**	1.59**	31.75**	163.67**
Potence ratio		-	1.77	0.61	0.12	-	-	1.20	3.23
Predictability ratio		-	0.41	0.20	0.05	-	-	0.32	0.56
σ^2A		0.14	0.33	7.06	2.48	-0.06	-0.02	15.20	211.33
σ^2D		3.55	0.47	28.93	52.05	0.73	1.59	31.75	163.67
$[\sigma^2D / \sigma^2A]^{0.5}$		5.07	1.19	2.02	4.58	3.49	8.92	1.45	0.88

*, ** Significant at 5 % and 1 % levels of probability, respectively.

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Table 2. Estimates of general combining ability (GCA) effect of parents for various characters in Indian mustard

Parents	Days to 50 % flowering	Days to 80 % siliquae maturity	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Effective length of main branch (cm)	Number of siliquae per plant	Average siliqua length (cm)
Varuna	0.18	0.88*	0.33	-0.17**	-0.34	-4.12**	-46.68**	0.25**
Pusa Bold	-0.82*	-1.29**	1.52*	-0.78**	-0.54**	0.84**	-31.00**	-0.05
GM-2	1.21**	2.29**	-7.92**	-0.09	-0.37	-1.35**	-2.33	0.10*
SEJ-2	-1.49**	-2.34**	-8.98**	0.07	-0.59**	-3.04**	-28.47**	0.09*
BIO-902	-1.16**	-2.01**	-4.00**	0.47**	0.61**	-2.61**	32.89**	0.19**
TM-2	-0.57	-1.04**	4.43**	-0.27**	0.50**	3.30**	32.25**	-0.09*
GM-3	1.48**	2.57**	1.87**	0.20**	0.61**	1.57**	-27.86**	0.00
JM-3	-0.66*	-1.12**	-1.36*	-0.02	0.01	-0.88**	-34.58**	-0.03
EC-287711	2.76**	3.85**	8.28**	0.34**	0.33	3.81**	64.39**	-0.21**
NUDHYJ-3	-0.93**	-1.79**	5.83**	0.24**	-0.22	2.49**	41.41**	-0.26**
S.E. (g_i) ±	0.34	0.35	0.61	0.05	0.20	0.24	3.61	0.04

*, ** Significant at 5 % and 1 % levels of probability, respectively.

Table 2 Contd.

Parents	Number of seeds per siliquae	Test weight (g)	Seed yield per plant (g)	Harvest index	Protein content(%)	Oil content (%)	Erucic acid content(%)	Glucosinolate content (µ mol/g)
Varuna	-1.17**	-0.24**	-5.70**	-3.04**	0.17**	0.48**	2.15**	4.65**
Pusa Bold	0.21 *	0.76**	1.80**	-0.08	0.45**	0.26**	1.97**	14.07**
GM-2	0.13	0.28**	0.12	-2.97**	-0.06	0.33**	0.37**	2.67**
SEJ-2	0.12	-0.02	-1.72**	-0.85**	0.06	-0.38**	-0.13	3.70**
BIO-902	-0.93**	0.45**	1.85**	-1.19**	-0.06	-0.04	2.31**	5.31**
TM-2	0.10	-0.32**	2.22**	3.68**	-0.07	-0.09	1.98**	5.52**
GM-3	0.00	0.43**	0.59**	1.70**	-0.22**	0.31**	0.12	-3.06**
JM-3	0.46**	-0.27**	-1.75**	-1.90**	-0.03	-0.03	2.34**	2.59**
EC-287711	0.18	-0.54**	1.20**	2.63**	-0.13*	-0.67**	-3.68**	-9.63**
NUDHYJ-3	0.90**	-0.53**	1.39**	2.01**	-0.11	-0.18*	-7.44**	-25.82**
S.E. (g_i) ±	0.09	0.03	0.18	0.32	0.06	0.07	0.09	0.30

*, ** Significant at 5 % and 1 % levels of probability, respectively.

Table 3. Top ranking specific cross combinations for different traits on the basis of *per se*performance, *sca* and *gca* in Indian mustard.

Traits	Best cross combinations *per se*	*Per se* performance	*sca* effects	*gca* effect of parent
Days to 50% flowering	Pusa Bold x Bio-902	38.00	-2.98**	Good x Good
	Pusa Bold x SEJ-2	38.67	-1.98	Good x Good
	TM-2 x JM-3	39.00	-2.73**	AveragexGood
Days to 80 % siliquae maturity	Pusa Bold x Bio-902	98.00	-5.14**	Good x Good
	Pusa Bold x SEJ-2	98.67	-4.14**	Good x Good
	TM-2 x JM-3	99.00	-5.28**	Good x Good
	SEJ-2 x TM-2	100.00	-3.1**	Good x Good
Plant height (cm)	GM-2 x JM-3	151.80	-25.78**	Good x Good
	Pusa Bold x SEJ-2	167.77	-11.64**	PoorxGood
	Bio-902 x TM-2	169.40	-17.89**	GoodxPoor
Number of primary branches per plant	Bio-902 x EC-287711	7.50	2.55**	Good x Good
	Bio-902 x GM-3	6.97	2.15**	Good x Good
	SEJ-2 x JM-3	6.30	2.10**	AveragexAverage
Number of secondary branches per plant	GM-2 x Bio-902	16.57	3.41**	Average x Good
	Bio-902 x GM-3	16.50	2.37**	Good x Good
	Bio-902 x JM-3	16.47	2.93**	GoodxAverage
Effective length of main branch (cm)	EC-287711 x NUDHYJ-3	89.17	16.16**	Good x Good
	GM-3 x NUDHYJ-3	85.10	14.33**	Good x Good
	JM-3 x EC-287711	80.07	10.43**	PoorxGood
Number of siliquae per plant	Bio-902 x EC-287711	750.3	238.11**	GoodxAverage
	GM-2 x NUDHYJ-3	703.2	249.21**	AveragexAverage
	TM-2 x JM-3	610.7	198.03**	GoodxAverage
Average siliquae length (cm)	SEJ-2 x BIO-902	6.07	0.82**	Good x Good
	Varuna x Pusa Bold	5.99	0.82**	GoodxAverage
	GM-2 x SEJ-2	5.96	0.79**	Good x Good
Number of seeds per siliquae	SEJ-2 x EC-287711	17.40	3.73**	AveragexAverage
	GM-2 x TM-2	17.13	2.24**	Average x Good
	SEJ-2 x JM-3	16.50	2.86**	PoorxGood
Test weight (g)	Pusa Bold x Bio-902	7.57	1.08**	Good x Good
	Pusa Bold x SEJ-2	7.13	1.11**	GoodxAverage
	Bio-902 x GM-3	6.79	0.63**	Good x Good
Seed yield per plant (g)	Bio-902 x NUDHYJ-3	28.01	3.46**	Good x Good
	Pusa Bold x EC-287711	27.76	6.13**	Good x Good
	Pusa Bold x GM-3	27.60	3.93**	Good x Good
Harvest index (%)	TM-2 x NUDHYJ-3	39.94	7.46**	Good x Good
	SEJ-2 x NUDHYJ-3	39.60	6.37**	PoorxGood
	Varuna x TM-2	39.53	12.10**	PoorxGood
Protein content (%)	Pusa Bold x Bio-902	28.59	2.17**	GoodxAverage
	Varuna x SEJ-2	27.78	1.53**	GoodxAverage
	Varuna x Pusa Bold	27.62	0.97**	Good x Good
Oil content (%)	Varuna x JM-3	39.67	2.34**	GoodxAverage
	Pusa Bold x NUDHYJ-3	38.71	1.75**	GoodxPoor
	Varuna x TM-2	38.66	1.39*	GoodxAverage
Erucic acid content (%)	GM-3 x NUDHYJ-3	29.31	-4.41**	Average x Good
	SEJ-2 x GM-3	30.49	-10.54**	AveragexAverage
	GM-2 x NUDHYJ-3	30.92	-3.04**	Poor x Good
Glucosinolate content (μ mol/g)	SEJ-2 x NUDHYJ-3	75.50	-8.22**	PoorxGood
	EC-287711 x NUDHYJ-3	79.60	9.25**	Good x Good
	GM-3 x NUDHYJ-3	80.60	3.63**	Good x Good