Electronic Journal of Plant Breeding, 6(2): 445-453 (June 2015)
ISSN 0975-928X

Research Article

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

Gideon J. Synrem*, N. R. Rangare[1], Anil K. Choudhari, Sujeet Kumar and Ibadaiahun Myrthong[2]
Department of Genetics and Plant Breeding, SHIATS, Allahabad-211007, Uttar Pradesh.
[1]Indira Gandhi Krishi Vishwavidhyalay, Raipur – 492006, CG
[2]Department of Environmental Science, SHIATS, Allahabad-211007, Uttar Pradesh.
Email:synrem.gideon@gmail.com

(Received:30 Sep 2014; Accepted:05 Nov 2014)

Abstract
Combining ability of eight quantitative traits was studied in 12 lines, 4 testers and 48 F_1's in Line x Tester mating design to know the inheritance pattern of yield attributes of Indian mustard [*Brassica juncea* (L.) Czern & Coss]. The estimates of *gca* and *sca* variances showed the preponderance of non-additive gene action for all the traits studied. Data revealed that variances due Line x Tester effect were significant for seed yield and all the traits studied. Among the lines and testers, good general combining parents BASANTI, CS 54, VARUNA, DURGAMANI, GM 1 and PM 67 exhibited desirable negative and highly significant *gca* effect for days to 50% flowering and days to maturity and the parents RL-1359, KRISHNA, RH-819 and JM-2 were good general combiners as they showed positive and highly significant gca effect for seed yield plant^{-1}, plant height, primary branches plant^{-1}, secondary branches plant^{-1}, number of seeds siliqua^{-1}, length of siliqua and days to maturity indicating the presence of additive gene action or additive x additive interaction effects. Hybrids RL 1359 x JM 2, KRISHNA x JM 2, GM 2 x JM 2 and CS 54 X LAXMI exhibited significant and positive specific combining ability effects for seed yield plant^{-1}, days to 50 % flowering, secondary branches plant^{-1} and number of seeds siliqua-^{1}. However, on the basis of *per se* performance and significant specific combining ability effect for seed yield plant^{-1} hybrids RL 1359 x JM 2 and KRISHNA x JM 2 were considered to be most promising for further exploitation in breeding programme.

Key words
Indian mustard, general combining ability, specific combining ability and traits.

Introduction

Among the major oilseed producing countries India contributes about 7% at the global level. Oilseed crops hold an important position in Indian economy also. Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is the second important oilseed crop at national level after groundnut and contributes nearly 27% to edible oil pool of the country. Major mustard growing states are UP, Rajasthan, M.P., Punjab, Haryana, West Bengal, Assam and Bihar. It has its wider adaptability and comparative tolerance to biotic and abiotic stresses as compared to other *Brassica* species grown as oilseeds (Yadava et al., 2010). It is well established that heterosis breeding approach produces desired crop varieties. 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 (Allard, 1960). In order to incorporate desirable characters to maximize economic yields, the knowledge of combining ability is useful to get information on selection of parents and nature of gene actions involved. Variability for economic traits must exist in the working germplasm for profitable exploitation following recombination breeding and selection. Combining ability analysis is one of the powerful tools to test the value of parental lines to produce superior hybrids and for recombinants. Indian mustard being a self pollinated crop, the technique of line x tester of Kempthorne (1957) for combing ability analysis is very important for screening lines with rapidity. Keeping this background in view, the present investigation was undertaken to study combining ability in Indian mustard parents.

Material and method

Twelve female lines of Indian mustard *viz.*, (L_1- GM-1, L_2- RL-1359, L_3- KRISHNA, L_4- PUSABOLD, L_5- JD-6, L_6- JM-3, L_7- BASANTI, L_8- PM-67, L_9- LAHI, L_{10}-CS 54, L_{11}- RH-819 and L_{12}- GM-2) were crossed with 4 testers (T_1- DURGAMANI, T_2- VARUNA, T_3- LAXMI and T_4- JM-2) during *rabi*-2008-09. A set of 64 genotypes consisting of twelve female lines, four testers and their 48 resultant F_1 crosses were evaluated following randomized block design with two replications during *rabi* 2009-10 at Field Experimentation Centre, Allahabad School of Agriculture, SHIATS, Allahabad. Row to row and plant to plant distance was kept at 45 and 10

cm, respectively. The recommended fertilizer dose was followed for N: P_2O_5: K_2O @ 80: 40: 40 kg ha^{-1}. The recommended agricultural package of practices was followed to raise a healthy crop. A total of eight quantitative traits was studied in the experiment for which five randomly selected plants were selected to record the data for six quantitative characters *viz.* plant height (cm), number of primary branches $plant^{-1}$, number of secondary branches $plant^{-1}$, length of siliquae (cm), number of seeds $siliqua^{-1}$ and seed yield plant $(g)^{-1}$ while the two characters *viz.*, days to 50% flowering and days to maturity were recorded on plot basis. The analysis of variance was carried out for nine characters as per the procedure described by Panse and Sukhatame (1967). The combining ability analysis was carried out as suggested by Kempthorne (1957).The estimate of heterosis over mid parent was followed by the procedure of Turner (1953), heterosis over better parent was calculated by the formula suggested by Fonesca & Patterson (1968).

Result and discussion

The analysis of variance revealed considerable genetic variation among parents and hybrids for almost all the traits under study (Table 1). The average performance of hybrids differed significantly from the average performance of parents indicating the presence of overall heterosis, which was also evident from the significance of parents vs. hybrids comparison for all the traits except for seed yield $plant^{-1}$. Highly significant differences were recorded among the treatments for all the characters namely, days to 50% flowering, plant height (cm), number of primary branches $plant^{-1}$, number of secondary branches $plant^{-1}$, length of siliquae (cm), number of seeds $siliqua^{-1}$, days to maturity and seed yield plant $(g)^{-1}$. Vaghela et al. (2011) earlier reported the analysis of variance for the experimental design revealed that highly significant differences existed among genotypes for all the characters studied. Arifullah et al. (2013) revealed that there was highly significant differences among the treatments for all the characters studied also supports the experimental results of analysis of variance. Synrem et al. (2014) earlier reported the results of analysis of variance revealed that there were highly significant differences among the crosses for all characters studied.

The analysis of variance for combining ability shows that the mean sum of square due to lines and tester were significant for days to maturity and primary branches per plant respectively (Table 2). The mean sum of square due to line x tester effect were significant for days to 50 % flowering, plant height (cm), number of primary branches $plant^{-1}$, number of secondary branches $plant^{-1}$, length of siliquae (cm), number of seeds $siliqua^{-1}$, days to maturity and seed yield plant $(g)^{-1}$. Kumar et al. (2014*)* also reported that the mean sum of square due to line x tester effect was significant for days to 50 % flowering, number of siliquae main $branch^{-1}$, number of primary branches $plant^{-1}$, number of secondary branches $plant^{-1}$, length of siliquae, number of seeds $siliqua^{-1}$, days to maturity and seed yield $plant^{-1}$.

Estimates of general combining ability (gca) effects of sixteen parents (twelve lines and four testers) for nine characters is shown in Table 3. For days to 50 % flowering among the lines BASANTI (-2.78**) was found to be the best combining line followed by GM 2 (-1.78**) and CS 54 (-1.28 **). The poorest general combining line was PUSABOLD (1.84**). The best general combining tester was LAXMI (-0.53**) followed by VARUNA (-0.32**) and the poorest combining tester was DURGAMANI (0.47**).

For plant height, gca effect values for 16 parents the best general combining line was CS 54 (**-9.21****) followed by LAHI (**-7.62****)** and PM 67 (-3.28**). The best general combining tester was VARUNA (-2.52**) followed by DURGAMANI (-1.57**). The above results were supported by similar findings of Singh et al. (2010) reported parent Varuna was found to be a good general combiner for days to 50% flowering, plant height, length of main raceme, number of siliquae and parent DURGAMANI showed significant negative gca effect for plant height.

The range of gca effect for primary branches $plant^{-1}$ for 16 parents was from 0.83** (LAHI) to -1.24** (BASANTI). The best general combining line was LAHI (0.83**) followed by RL-1359 (0.41*) and GM-1 (0.39*), while the poorest was BASANTI (-1.24**). The best general combining tester was JM-2 (0.63**) followed by LAXMI (0.39**) and VARUNA (0.16*). The poorest general combiner was DURGAMANI (-1.19**). For secondary branches $plant^{-1}$ the best general combining line was RL-1359 (2.96**) followed by RH-819 (2.41**) and KRISHNA (1.37*) as these showed high and positive gca values for this trait. The poorest general combining line was GM 1 (-3.09**). The best general combining tester was JM-2 (1.17**) and the poorest was DURGAMANI (-0.78**).

The results for length of siliquae revealed that the range for gca effect for 16 parents was from (0.27**) GM-2 to -0.31** (BASANTI). Among the lines the best general combiner was GM-2 (0.27**) followed by PUSABOLD (0.23**) and LAHI (0.18**) while the poorest general combining line was BASANTI (-

0.31**). The best general combining tester was JM-2 (0.11**) and the poorest was VARUNA (-0.09**). The range of gca effect for 16 parents for number of seeds siliqua^{-1} was from (0.75*) (BASANTI) to (-1.09**) JD-6. The best line for gca was BASANTI (0.75*), followed by KRISHNA (0.69*). The poorest general combining line was JD-6 (-1.09**) followed by RL-1359 (-0.81**). The best general combining tester was JM-2 (0.92**) and the poorest was LAXMI (-0.90**). The gca effect for days to maturity varied from 1.96** (RH-819) to -2.79** (BASANTI). The best general combining line was BASANTI (-2.79**) followed by RL 1359 (-1.54**) while the poorest general combining line was RH 819 (1.96**). The best general combining tester was JM 2 (-0.46**) and the poorest combining tester was VARUNA (0.63**). For seed yield plant^{-1} for 16 parents the gca effect ranged from 2.30** (RL-1359) to -2.18** (JM 3). The best general combining line was RL-1359 (2.30**) followed by KRISHNA (2.07**) and RH-819 (1.15**) as these showed high and positive gca values for this trait, while the poorest general combiner was JM-3 (-2.18**). The best general combining tester was JM-2 (1.06**) followed by VARUNA (0.28*) and the poorest general combiner was LAXMI (-0.71**). The parents *viz.*, RL-1359, KRISHNA, RH-819 and JM-2 can be considered as superior parents in the present study as they recorded high *per se* with positive significance gca effect for seed yield per plant. The above results were supported by similar findings of Parmar et al. (2011) who reported that parent RH 819 used as female was a good general combiner for days to maturity, days to 50 % flowering and seed yield plant^{-1} and parent GM 2 as female was a good general combiner for days to maturity.

Estimates of specific combining ability for 48 crosses are presented in Table 4. None of the cross combination was found to be a common combiner for all the characters under study. Cross combination JD-6 x DURGAMANI showed highly significant desirable negative specific combining ability (sca) effects for days to 50% flowering and cross combination BASANTI x JM-2 exhibited highly significant negative sca effect for days to maturity. These cross combinations can be exploited to isolate early maturing genotype in later generations. Cross combination BASANTI x DURGAMANI was good specific combiner for plant height. Cross combination PM-67 x LAXMI was good specific combiner number of primary branches, while cross combination RL-1359 x JM-2 was good specific combiner number of secondary branches. The cross RH-819 x VARUNA was found to be good specific combiner for length of siliquae. Cross combination LAHI x VARUNA was found to be good specific combiner for number of seeds siliqua^{-1}. Cross combination RL-1359 x JM-2 followed by KRISHNA x JM-2, GM-2 x JM-2 and PM-67 x DURGAMANI showed significant positive sca effects for seed yield plant $^{-1}$. The above results were supported by similar findings by Singh et al. (2007) who reported that cross combination Durgamani x RH-30 showed significant positive sca effects for seed yield plant and cross combination RH-30 x Pusa Basant and RLM-198 x Pusa Basant showed highly significant desirable negative specific combining ability (sca) effects for days to 50% flowering and for days to maturity respectively.

The information regarding six best performing parents as good general combiners, best performing hybrids along with their per cent heterosis over mid parent as well as better parent and sca effects for seed yield plant^{-1} is presented in Table 5. The estimates of sca effects revealed that four cross combinations namely, RL 1359 x JM 2, KRISHNA x JM 2, GM 2 x JM 2 and CS 54 X LAXMI exhibited significant and positive sca effects for seed yield per plant. It was observed that at least one good general combining parent was involved in heterotic hybrids having desirable sca effects. The performance of hybrids with respect to heterosis over mid parent (MP) and better parent (BP) for seed yield per plant revealed that, out of 48 crosses the above mentioned four crosses namely, RL 1359 x JM 2, KRISHNA x JM 2, GM 2 x JM 2 and CS 54 X LAXMI also showed high positive significant heterosis. This suggested that information on gca effects of the parents should be considered along with sca effect and *per se* performance of hybrid for predicting the value of any hybrid. These results were supported by similar findings of Singh et al. (2000); Rao and Gulati (2001); Singh et al. (2002). Significant positive sca effects for seed yield and its important yield component traits have also been reported by Singh et al. (2003), Srivastava et al. (2009), Tripathy and Lenka (2010) and Singh et al. (2013)**.** From the above discussion, that hybrids RL 1359 x JM 2, KRISHNA x JM 2, GM 2 x JM 2 and CS 54 X LAXMI having high mean value, high heterosis over mid parent as well as better parent and desirable sca effects for seed yield per plant, can be further exploited in practical plant breeding. These highly significant heterotic hybrids could be utilized to exploit non-additive gene action by heterosis breeding.

References

Allard, R.W. 1960. Principles of plant breeding. *John Wiley and Sons*. New York.

Arifullah, M., Munir, M., Mahmood, A., Ajmal K. S., and Hassan, U. F. 2013. Genetic analysis of some yield attributes in Indian mustard (*Brassica juncea L.) Afri. J. Pl. Sci*., **7** (6): 219-226.

Fonesca, S. and Patterson, P. 1968. Hybrid vigor in a seven parent diallel cross in common winter wheat. *Crop Sci*., **8**: 85-88.

Kempthorne, O. 1957. An Introduction to Genetic Statistics, (John Willy and Sons. Inc. New York, Pp.545.

Kumar, B., Pandey, A. and Singh, S.K. 2014. Combining ability and economic heterosis for yield and oil quality traits in Indian mustard (*Brassica juncea* L. Czern & Coss) *Electron J. Plant Breed.,* **5** (2): 203-207.

Panse, V. G. and Sukhatme, P. V. 1967. Statistical method for agricultural workers (2nd Ed. ICAR, New Delhi: Pp. 381

Parmar A. S., Jaimini, S. N. and Ram, B. 2011. Combining ability analysis for seed yield and its components over environments in Indian mustard (*Brassica juncea* L.) *J. Oilseed Brassica,* **2** (2): 61-66.

Rao, N.V.P. R. and Gulati, S.C. 2001. Comparison of gene action in F1 and F2 diallel of Indian mustard [*Brassica juncea* (L.) Czern & Coss]. *Crop Res.*, **21** (1): 72-76.

Singh, M., Singh, S.P. and Singh, D. 2000. Genetic analysis for yield and it's components
in yellow sarson. *Indian J. Agric. Sci.*, **70** (9): 624-626.

Singh, M., Srivastava, L., R.K. Dixit and Singh M. 2002.Combining ability studies for seed yield, it's component characters and oil content in Indian mustard [*Brassica juncea* (L.) Czern & Coss]. *Progressive Agric.,* **2** (2): 125-128.

Singh, K.H., Gupta, M.C., Shrivastava, K.K. and Kumar P.R. 2003. Combining ability and heterosis in Indian mustard. *J. Oilseeds Res.*, **20** (1): 35-39.

Singh, R.A., Yadav, R. and Pahuja, S.K. 2007. Evaluation of Egyptian clover germplasm using multivariate analysis. *Indian J. Genet.*, **67** (2):135-139.

Singh, M., Ranjeet and Srivastava, S.B.L. 2009. Heterosis and combining ability estimates in Indian mustard (*Brassica juncea* (L.) Czern and Coss. *J. Oilseed Res.*, **26**: 61-63.

Singh, M., Singh, L. and Srivastava, S.B.L. 2010. Combining ability analysis in Indian mustard (*Brassica juncea* L. Czern & Coss) *J. Oilseed Brassica,* **1** (1): 23-27.

Singh, A., Avtar, R., Singh, D., Sangwan, O., Thakral, N. K., Malik, V.S., Goyat, B. and Dalal, U. 2013. Combining ability analysis for seed yield and component traits in Indian mustard [*Brassica juncea* (L.) Czern & Coss.] *Res. in Plant Biol.*, **3** (2): 26-31.

Srivastava, S. B. L., Shekhar, R., Singh, M., and Mahesh, R. 2009. Combining ability analysis for yield and yield contributing characters in Indian mustard, (*Brassica juncea* (L.) Czern and Coss. *J. Oilseeds Res.*, **26** (special issue): 58-60.

Synrem, G. J., Rangare, N. R., Myrthong, I., and Bahadure, D.M. (2014).Variability studies in Intra specific crosses of Indian mustard [*Brassica juncea* (L.) Czern and Coss.] genotypes. *IOSR J. Agric. and Veterinary Sci.*, 7 (9): 29-32.

Tripathy, S. K. and Lenka, D. 2010. Combining ability and heterosis in rapeseed (*Brassica compastris*) var. toria. *J. Oilseeds Res.*, **27** (1): 52-54.

Turner, J.H. 1953. A study of heterosis in upland cotton, combining ability and inbreeding effects. *Agron. J.*, **43:** 478-490.

Vaghela, P. O., Thakkar, D. A., Bhadauria, H. S., Sutariya, D. A., Parmar, S. K. and Prajapati, D.V. 2011. Heterosis and combining ability for yield and its component traits in Indian mustard [*Brassica juncea* (L.)] *J. Oilseed Brassica,* **2** (1): 39-43.

Yadava , D K., Giri, S C., Sujata, V., Yadav, Kumar, A. Das, B., Raje, R. S., Vignesh, M., Singh, Mohapatra, R, and Prabhu, K.V. 2010. Stability analysis in Indian mustard (*Brassica juncea* L.) varieties. *Indian J. Agril. Sci.,* **80** (9): 761-765.

Table 1. Analysis of variance of parents and hybrids for yield and its component characters in Indian mustard (*Brassica juncea* L.).

Source of variation	D f.	Characters							
		Days to 50 % flowering	Plant height (cm)	Primary branches per Plant	Secondary branch per Plant	Length of Siliquae (cm)	No. of seeds per siliqua	Days to Maturity	Seed yield per plant (cm)
Replicate	1	0.87	3.64	1.95	2.79	2.79	10.46**	10.69**	16.10**
Treatment	63	33.18**	206.39**	4.64**	28.33**	0.30**	6.84**	6.94**	13.70**
Parent	15	14.08**	157.64**	0.95	5.37**	0.28	5.02**	4.68**	8.31**
Hybrid	47	27.54**	209.24**	5.48**	33.47**	0.26	5.98**	7.11**	15.67**
Parent Vs Hybrid	1	585.09**	803.88**	20.25**	131.48**	2.48**	74.73**	33.25**	2.16
Error	63	1.70	2.96	2.10	1.63	0.15	1.14	1.45	0.98

***and**= 0.05 and 0.01 level of significance, respectively.**

Table 2. Analysis of variance for combining ability in L x T crosses for different traits in Indian mustard (*Brassica juncea* L.)

S. N.	Sources	df.	Characters							
			Days to 50 % flowering	Plant height (cm)	Primary branches per plant	Secondary branch per plant	Length of siliquae (cm)	No. of seeds per siliqua	Days to maturity	Seed yield per plant (g)
1.	Replicates	1	3.01	5.27	0.02	0.92	0.54	1.45	1.04	8.94**
2.	Crosses	47	27.54**	209.24**	5.49**	33.47**	0.27*	5.98**	7.11**	15.60 **
3.	Line effect	11	18.71	227.50	2.74	25.56	0.26	3.18	12.60*	16.63
4.	Tester effect	3	6.04	164.34	15.97*	16.57	0.17	13.28	6.28	16.64
5.	Line x Tester effect	33	32.44**	207.23**	5.45**	37.64**	0.28*	6.26**	5.36**	15.27**
4.	Error	47	1.82	3.38	0.58	1.58	0.16	1.29	1.62	1.19
5.	Total	95	14.56	105.25	3.00	17.35	0.22	3.61	4.33	8.44
	Var. gca		0.67	12.06	0.55	1.21	0.00	0.44	0.50	0.98
	Var. sca		15.37	102.14	2.45	18.01	0.06	2.55	1.95	7.14
	gca/sca		0.04	0.11	0.22	0.06	0.00	0.17	0.25	0.13
	Degree of dominance		3.39	2.06	1.49	2.72	3.02	1.70	1.40	1.91

***and**= 0.05 and 0.01 level of significance, respectively.**

Electronic Journal of Plant Breeding, 6(2): 445-453 (June 2015)
ISSN 0975-928X

Table 3. Estimates of general combining ability for lines and tester parents for 8 characters in Indian mustard (*Brassica juncea* L.).

S. N.	Parents		Days to 50 % flowering	Plant height (cm)	Primary branches plant^{-1}	Secondary branches plant^{-1}	Length of Siliquae (cm)	Number of seeds siliqua^{-1}	Days to Maturity	Seed yield plant^{-1} (g)
Lines										
1.	L1	GM-1	-0.4100**	-1.0000**	0.3937*	-3.099**	0.1100*	-0.2800**	0.7100	-0.9200**
2.	L2	RL-1359	0.4700	-0.6593**	0.4187*	2.9624**	-0.0100**	-0.8145**	-1.5416**	2.3000**
3.	L3	KRISHNA	1.7200**	10.0406**	0.0937	1.3749*	-0.1937**	0.6900*	-0.1700**	2.0718**
4.	L4	PUSABOLD	1.8437**	5.0881**	-0.9138**	-1.6499**	0.2312**	0.4604	-0.0416**	1.0000**
5.	L5	JD 6	0.7200	1.7531*	-0.1187**	-0.3124**	-0.0812**	-1.0900**	-0.0416**	0.0718
6.	L6	JM-3	1.5937**	3.2281**	-0.2312**	-0.4000**	-0.0437**	0.4000	-0.1700**	-2.1800**
7.	L7	BASANTI	-2.7812**	-1.0718**	-1.2437**	1.3625*	-0.3100**	0.7500*	-2.7916**	-1.8300**
8.	L8	PM 67	-0.7812**	-3.2843**	0.1562	-0.8125**	-0.0312**	0.2104	-0.5416**	-1.0800**
9.	L9	LAHI	-0.7812**	-7.6218**	0.8312**	-1.7000**	0.1812**	0.5604	0.7100	-0.9031**
10.	L10	CS 54	-1.2812**	-9.2123**	0.3687*	0.5000	-0.1937**	-0.5900**	0.7100	0.0500
11.	L11	RH-819	1.4687*	-1.1468**	0.3312*	2.4124**	0.0700	0.2400	1.9600**	1.1500**
12.	L12	GM-2	-1.7812**	3.8906**	-0.0812**	-0.6374**	0.2700**	-0.5300**	1.2100*	0.2718
S E. (Female)			0.4612	0.6087	0.2638	0.4517	0.1405	0.3789	0.4268	0.3512
Testers										
13.	T1	DURGAMANI	0.4700*	-1.5718**	-1.1905**	-0.7834**	-0.0229**	-0.0400**	0.2100	-0.6200**
14.	T2	VARUNA	-0.3229**	-2.5260**	0.1645*	-0.3000**	-0.0937**	0.0104	0.6300**	0.2800*
15.	T3	LAXMI	-0.5312**	0.7706*	0.3937**	-0.0834**	0.0104	-0.9000**	-0.3800**	-0.7114**
16.	T4	JM 2	0.3900*	3.3322**	0.6312**	1.1700**	0.1100**	0.9229**	-0.4600**	1.0600**
S E. (Male)			0.2663	0.3514	0.1523	0.2608	0.0811	0.2188	0.2464	0.2028

*and**= 0.05 and 0.01 level of significance, respectively

Table 4. Estimates of sca effects of top five cross combinations for eight characters in Indian mustard (*Brassica juncea* L.).

SN.	Character	Specific combining ability effects	General combining ability effect of parents	
			P1	P2
1.	Days to 50 % flowering			
	JD-6 X DURGAMANI	-7.71**	0.72	0.47*
	JM-3 X LAXMI	-6.09**	1.59**	-0.53**
	LAHI X VARUNA	-5.42**	-0.78**	-0.32**
	KRISHNA X JM-2	-5.13**	1.72**	0.39*
	GM-2 X JM-2	-5.13**	-1.78**	0.39*
2.	Plant height (cm)			
	BASANTI X DURGAMANI	-15.32**	-1.07**	-1.57**
	KRISHNA X LAXMI	-14.47**	10.04**	0.77*
	PM 67 X JM 2	-14.02**	-3.28**	3.33**
	JM 3 X VARUNA	-12.77**	3.22**	-2.52**
	RH 819 X DURGAMANI	-12.75**	-1.14**	-1.57**
3.	Primary branches plant^{-1}			
	PM-67 X LAXMI	3.43**	0.1562	0.3937**
	GM-1 X JM-2	3.35**	0.3937*	0.6312**
	RL-1359 X JM-2	2.83**	0.4187*	0.6312**
	JD-6 X VARUNA	2.23**	-0.1187**	0.1645*
	LAHI X LAXMI	1.80*	0.8312**	0.3937**
	CS-54 X LAXMI	0.76	0.3687*	0.3937**
4.	Secondary branches plant^{-1}			
	RL-1359 X JM-2	12.48**	2.9624**	1.1700**
	KRISHNA X JM-2	9.27**	1.3749*	1.1700**
	JD-6 X VARUNA	7.77**	-0.3124**	-0.3000**
	JM-3 X LAXMI	3.14*	-0.4000**	-0.0834**
	GM-2 X LAXMI	2.88*	-0.6374**	-0.0834**
5.	Length of siliquae (cm)			
	RH-819 X VARUNA	0.49	0.0700	-0.0937**
	GM-2 X LAXMI	0.49	0.2700**	0.0104
	BASANTI X LAXMI	0.46	-0.3100**	0.0104
	GM-1X LAXMI	0.45	0.1100*	0.0104
	PUSA BOLD X JM-2	0.43	0.2312**	0.1100**
6.	Number of seeds siliqua^{-1}			
	LAHI X VARUNA	3.11**	0.5604	0.0104
	KRISHNA X JM-2	2.57*	0.6900*	0.9229**
	JM-3X LAXMI	2.18*	0.4000	-0.9000**
	JD-6 X LAXMI	2.17*	-1.0900**	-0.9000**
	PM-67X JM-2	2.05*	0.2104	0.9229**
	CS-54 X LAXMI	0.17	-0.5900**	-0.9000**
7.	Days to Maturity			
	BASANTI X JM-2	-3.16**	-2.7916**	-0.4600**
	RH-819 X VARUNA	-3.00**	1.9600**	0.6300**
	LAHI X JM-2	-2.16*	0.7100	-0.4600**
	PUSA BOLD X LAXMI	-2.00*	-0.0416**	-0.3800**
	LAHI X DURGAMANI	-1.83*	0.7100	0.2100
	CS-54 X LAXMI	-0.25	0.7100	-0.3800**
8.	Seed yield plant^{-1}(g)			
	RL-1359 X JM-2	9.29 **	2.3000**	1.0600**
	KRISHNA X JM-2	4.22 **	2.0718**	1.0600**
	GM-2 X JM-2	3.57**	0.2718	1.0600**
	PM-67 X DURGAMANI	2.94 **	-1.0800**	-0.6200**
	CS-54 X LAXMI	2.61**	0.0500	-0.7114**

***and**= 0.05 and 0.01 level of significance, respectively.**

Table 5.**Top ranking crosses for seed yield per plant in Indian mustard (*Brassica juncea* L.).**

S.N.	Cross Combination	*Per se* performance	Heterosis		SCA effect	Magnitude of GCA		Other characters with significant specific combining ability effect
			Mid parent (MP)	Better parent (BP)		P1	P2	
1.	RL 1359 x JM 2	25.30	62.95**	98.43**	9.30**	2.30**	1.06**	**Secondary branches plant^{-1}** **Number of seeds siliqua^{-1}**
2.	KRISHNA x JM 2	20.00	111.27**	53.26**	4.22**	2.07**	1.06**	**Secondary branches plant^{-1}** **Days to 50 % flowering**
3.	GM 2 x JM 2	17.55	41.53**	29.04**	3.57*	0.27	1.06**	**Days to 50 % flowering** **Primary branches**
4.	CS 54 x LAXMI	14.60	18.46*	14.96	2.61**	0.05	-0.71**	**Number of seeds siliqua^{-1}** **Days to maturity**

*** and ** significant at P = 0.05 and P = 0.01 levels, respectively. Where, P1= parent 1 and P2= parent 2.**