

## Gene Action of Seed Yield And Its Contributing Attributes in Indian Mustard ( *Brassica juncea* )

Comment [dc1]: *Brassica juncea* (L.)

### Abstract

Comment [dc2]: Write full forms instead of abbreviations in abstract

Ten genetically diverse parents along with 45  $F_1$ 's were evaluated in randomized block design with three replications under three different environments. Data were recorded for seed yield and important yield attributes. The parents, RH-406, RGN-303, RGN-229, RGN-298 and PBR-378 were found to be good general combiners for seed yield and other yield contributing traits in which the parent, PBR-378 performed well in all the environment while, RGN-298 in  $E_1$ ,  $E_3$  and pooled environments and RGN-229 in  $E_1$ ,  $E_2$  and pooled environment were found as good combiners for seed yield and other yield contributing traits. Crosses, RH-30 X RB-50, RGN-303 X RGN-229, RGN-13 X RH-406, RGN-298 X PBR-378 and RGN-236 X RB-50 emerged as good specific combiner for seed yield and one or more related traits. On the basis of SCA effects and *per se* performance an overall appraisal revealed that the cross combination RGN-303 X RGN-229 in  $E_1$ ,  $E_2$  and pooled environment, RGN-13 X RH-406 in  $E_1$  and  $E_2$ , RH-30 X RB-50 in  $E_1$  and combined environment while, RGN-298 X PBR-378 in  $E_2$  and  $E_3$  were found most desirable for seed yield and its contributing characters. These best crosses were the results of good x good, poor x poor and good x poor general combiners.

Comment [dc3]: Replace X with x symbol in whole manuscript

**Key Words:** Indian Mustard, Diallel, Combining Ability, Yield Attributes, Environment, Genotype, Gene Action, GCA, SCA

Comment [dc4]: Do not replicate the words which already present in the title; rearrange key words in alphabetical order

### INTRODUCTION

Indian mustard [*Brassica juncea* (L) Czern & Coss] is an important oilseed crop of Brassicaceae family which accounts more than 70 % under rapeseed and mustard. The term mustard is thought to come from an early European tradition of combining the sweet "must" of old wine with crushed seeds to make a fiery paste called "hot must" or "mustum ardens," ( Hemingway, 1976 ). The combining ability studies are used by plant breeders to select parents with maximum capacity of transmitting desirable genes to the progenies and evolution of parental line of good combining makes the pathways easy, towards the success identify the best specific crosses for yield and various quality parameters. High GCA coupled with high performance indicates an outstanding parents will reservoir genes due to additive genetic variance. Hence both mean performance and GCA effect may be taken into account for parental selection. Specific combining ability (SCA) is associated with interaction effects which may be due to dominance and

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epistatic components of variation that are non-fixable in nature thus it would be worthy for commercial exploitation as hybrids.

## MATERIALS AND METHODS

Ten genetically diverse parents namely, RGN-303, RGN-13, RGN-229, RGN-298, RGN-236, RH-30, RH-406, RB-50, RLM-619 and PBR-378 were crossed in diallel mating design excluding reciprocals. During Rabi 2019-20, ten parents and their 45 F<sub>1</sub>s were evaluated in a double row with 4.0 m row length and spacing at 45x20 cm<sup>2</sup> in a randomized block design (RBD) under three different environments created by three dates of sowing [1<sup>st</sup> October (E<sub>1</sub>), 15<sup>th</sup> October (E<sub>2</sub>) and 30<sup>th</sup> October (E<sub>3</sub>)] during Rabi 2019-2020 at Research farm, College of Agriculture, SKRAU, Bikaner. Observations were recorded for the characters namely, days to 50% flowering and days to maturity, plant height, no. of primary branches per plant, no. of secondary branches per plant, no. of siliquae per plant, siliqua length, no. of seed per siliqua and leaf area index, 1000 seed weight, oil content, biological yield per plant, harvest index and seed yield per plant.

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The combining ability analysis of data for individual environment was carried out for all the three environments separately, using Griffing's method II, (1956). The following statistical model was employed:

$$Y_{ijk} = \mu + g_i + g_j + S_{ij} + e_{ijk/r}$$

## RESULT AND DISCUSSION

The analysis of variance for combining ability in the individual environment separately revealed that mean squares due to GCA and SCA were significant for all the characters except oil content for GCA [Table1.] indicating that both additive and non-additive gene action controlled the genetic mechanism of these studied traits. These results were also confirmed by Malviya *et al.* (2019) and Ramandeep *et al.* (2019) in mustard crop. The GCA / SCA variance ratio (predictability ratio) was less than unity emphasizing the role of non-additive gene action for all the traits. Earlier, similar observations were obtained by Meena *et al.* (2015), Shrimali *et al.* (2018) and Singh *et al.* (2019). The mean squares due to environments were also found significant for all the attributes. Table 2 indicates that mean squares owing to GCA X ENVs and SCA X

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ENVS were significant for almost all characters with the exception of number of seeds per siliqua, 1000 seed weight, and oil content.

Perusal of Table 3 revealed that the parents, who showed desirable, GCA effects for seed yield per plant, also exhibited desirable GCA effects for one or more yield attributing traits. The parents PBR-378, RGN-298 and RGN-229 in E<sub>1</sub>; PBR-378, RGN-303 and RGN-229 in E<sub>2</sub> PBR-378, RGN-298 and RH-406 in E<sub>3</sub> and PBR-378, RGN-298 and RGN-229 over environments emerged as good general combiners for seed yield and some associated yield traits. An overall appraisal revealed that the parents PBR-378 in E<sub>1</sub>, E<sub>2</sub>, E<sub>3</sub> and pooled basis; RGN-298 in E<sub>1</sub>, E<sub>3</sub> and pooled environment; RGN-229 in E<sub>1</sub>, E<sub>2</sub> and pooled environment ; RGN-303 in E<sub>2</sub> and RGN-406 in E<sub>1</sub> emerged as good general combiners for seed yield with simultaneous consideration of other characters. Earlier, Choudhary *et al.* (2020) and Singh *et al.* (2020), provided similar information on combining ability in Indian mustard.

Perusal of Table 4 revealed that the crosses, which showed desirable significant SCA effects for seed yield per plant, also exhibited desirable SCA effects for one or more yield contributing traits. It has been informed from the present study that the crosses RH-30 X RB-50, RGN-303 X RGN-229 and RGN-13 X RH-406 in E<sub>1</sub>; RGN-303 X RGN-229, RGN-298 X PBR-378 and RGN-13 X RH-406 in E<sub>2</sub>; RGN-236 X RB-50, RGN-298 X PBR-378 and RGN-13 X RB-50 in E<sub>3</sub> and RGN-303 x RGN-229, RH-30 x RB-50 and RGN-298 x PBR-378 in pooled environment emerged as good specific cross combinations for seed yield per plant. An overall appraisal revealed that the crosses RGN-303 X RGN-229 in E<sub>1</sub> ( very early sown ) , E<sub>2</sub> ( early sown) and pooled environment , RGN-13 X RH-406 in E<sub>1</sub> and E<sub>2</sub>, RH-30 X RB-50 in E<sub>1</sub> and combined environment while, RGN-298 X PBR-378 in E<sub>2</sub>, E<sub>3</sub> ( timely sown) and pooled environment as good specific cross combinations.

## CONCLUSION

Overall concluded that the parents involved in best crosses, RH-406, RGN-303, RGN-229, RGN-298 and PBR-378 were good general combiners for seed yield and one or more yield contributing traits. Results of similar nature, where multiple number of parents having good GCA for several characters were also reported by Verma (2000) and Singh *et al.*( 2015). It is interesting to note that GCA effects of best crosses like

**Comment [dc9]:** Reframe the sentences and not include any reference in conclusion. Conclusion must be crisp and clear summary form and which should be easy to understand.

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RGN-303 X RGN-229 (good x good), RGN-13 X RH-406 (poor x good), RGN-298 X PBR-378 (good x good), RH-30 X RB-50 (poor x poor) and RGN-13 X RB-50 (poor x poor) indicated that the good specific cross combinations were the result of good x good, good x poor or poor x poor combinations. 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 as found by Lohia (2008) and Nilgan and Alka (2009), is expected to throw desirable segregants in the segregating generations.

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**Table 1: Analysis of variance for combining ability for yield and its contributing characters of Indian mustard in different environments**

Source of variation	d.f.		Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches per plant	No. of Secondary branches per plant	No. of siliquae per plant	Siliqua length (cm)	No. of seeds per siliqua	1000-seed weight (g)	Biological yield per plant (g)	Oil content (%)	Leaf area index (LAI)	Harvest index (%)	Seed yield per plant (g)
GCA	9	E <sub>1</sub>	7.55**	6.95**	682.92**	0.65**	8.9**	1280.69**	0.86**	4.09**	0.66**	914.32**	0.36	0.24**	24.49**	67.81**
		E <sub>2</sub>	8.53**	5.97**	624.07**	0.64**	9.44**	6792.46**	0.94**	5.1**	0.53**	712.32**	0.4	0.29**	24.07**	69.41**
		E <sub>3</sub>	16.35**	16.96**	758.69**	1.14**	20.65**	6778.45**	0.39**	5.04**	0.63**	1154.77**	0.35	0.13**	22.61**	77.89**
SCA	45	E <sub>1</sub>	6.54**	7.42**	246.84**	1.07**	10.04**	767.27*	0.58**	3.98**	0.43**	527.25**	0.52**	0.3**	22.79**	96.62**
		E <sub>2</sub>	7**	6.03**	193.52**	1.09**	10.05**	9700.3**	0.57**	4**	0.41**	375.4**	0.6**	0.29**	23.36**	97.79**
		E <sub>3</sub>	9.34**	9.18**	191.89**	0.91**	13.46**	9788.77**	0.21*	3.97**	0.42**	438.23**	0.5**	0.25**	15.55**	82.09**
Error	108	E <sub>1</sub>	0.44	0.89	58.12	0.06	0.58	465.68	0.07	0.57	0.05	37.96	0.28	0.03	0.93	2.11
		E <sub>2</sub>	0.45	0.59	64.84	0.07	0.88	581.4	0.16	0.79	0.04	54.51	0.33	0.04	0.78	2.19
		E <sub>3</sub>	0.38	0.69	69.02	0.08	1.02	509.6	0.14	0.8	0.05	24.68	0.28	0.03	0.78	2.98
GCA Variance		E <sub>1</sub>	0.59	0.51	52.07	0.05	0.69	67.92	0.07	0.29	0.05	73.03	0.006	0.017	1.96	5.475
		E <sub>2</sub>	0.67	0.45	46.6	0.05	0.71	517.58	0.07	0.36	0.04	54.8175	0.005	0.02	1.94	5.6
		E <sub>3</sub>	1.33	1.36	57.47	0.09	1.64	522.4	0.02	0.35	0.05	94.17	0.01	0.01	1.81	6.24
SCA Variance		E <sub>1</sub>	6.1	6.53	188.72	1.01	9.46	301.59	0.51	3.41	0.38	489.29	0.24	0.27	21.86	94.51
		E <sub>2</sub>	6.55	5.44	128.68	1.02	9.17	9118.9	0.41	3.21	0.37	320.89	0.27	0.25	22.58	95.6
		E <sub>3</sub>	8.96	8.49	122.87	0.83	12.44	9279.17	0.07	3.17	0.37	413.55	0.22	0.22	14.77	79.11
GCA/SCA Variance ratio		E <sub>1</sub>	0.1	0.08	0.28	0.05	0.07	0.23	0.13	0.09	0.13	0.15	0.03	0.06	0.09	0.06
		E <sub>2</sub>	0.1	0.08	0.36	0.05	0.08	0.06	0.16	0.11	0.11	0.17	0.02	0.08	0.09	0.06
		E <sub>3</sub>	0.15	0.16	0.47	0.11	0.13	0.06	0.3	0.11	0.13	0.23	0.03	0.04	0.12	0.08

\* Significant at 5%, \*\* Significant at 1%

**Table-2 : Analysis of variance for combining ability for yield and its contributing characters of Indian mustard pooled over environments**

Source	d. f	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches per plant	No. of Secondary branches per plant	No. of siliquae per plant	Silique length (cm)	No. of seeds per siliqua	1000 - seed weight (g)	Biological yield per plant (g)	Oil content (%)	Leaf area index (LAI)	Harvest index (%)	Seed yield per plant (g)
<b>GCA</b>	9	24.759 **	21.395 **	1331.421 **	1.254 **	26.709 **	9679.281 **	1.416 **	14.030 **	1.808 **	2638.694 **	1.077 **	0.345 **	67.595 **	205.380 **
<b>SCA</b>	45	15.487 **	13.093 **	407.983 **	1.874 **	27.878 **	12838.310 **	0.868 **	11.808 **	1.248 **	1080.877 **	1.592 **	0.546 **	56.974 **	267.836 **
<b>Environments</b>	2	2706.836 **	2654.910 **	27375.830 **	53.002 **	381.794 **	3042564.000 **	56.406 **	689.212 **	29.971 **	39870.140 **	96.778 **	93.637 **	318.334 **	5841.211 **
<b>GCA X ENVS</b>	18	3.835 **	4.242 **	367.129 **	0.589 **	6.139 **	2586.161 **	0.391 **	0.099	0.005	71.359 *	0.014	0.161 **	1.790 **	4.863 **
<b>SCA X ENVS</b>	90	3.694 **	4.768 **	112.131 **	0.602 **	2.835 **	3709.019 **	0.245 **	0.069	0.004	129.995 **	0.015	0.143 **	2.362 **	4.334 **
<b>ERROR</b>	324	0.426	0.722	63.993	0.07	0.825	518.892	0.122	0.721	0.046	39.053	0.297	0.034	0.833	2.428

\* Significant at 5%, \*\* Significant at 1%

**Table 3: Best mustard parents possessing high GCA along with their *per se* performance and significant desirable GCA effects for other traits in over the environments.**

Environments	Best parent	GCA effect	Seed yield per plant	Other yield contributing traits with its GCA magnitude
E <sub>1</sub>	PBR-378	4.54**	34.97	Siliqua length , No. of seeds per siliqua, 1000-seed weight, Biological yield per plant and Harvest index
	RGN-298	2.29**	33.87	No. of seeds per siliqua, 1000-seed weight and Harvest index
	RGN-229	1.72**	34.67	Days to 50% flowering , Days to maturity , no. of primary branches per plant , no. of secondary branches per plant, no. of siliquae per plant, no. of seeds per siliqua, 1000-seed weight, biological yield per plant, leaf area index and harvest index
E <sub>2</sub>	PBR-378	3.93**	46.59	No. of seeds per siliqua, 1000-seed weight, biological yield per plant and harvest index
	RGN-303	2.03**	43.61	Days to 50% flowering, Days to maturity, plant height, no. of secondary branches per plant, 1000-seed weight and harvest index
	RGN-229	1.72**	43.6	Days to 50% flowering, no. of primary branches per plant, no. of secondary branches per plant, no. of seeds per siliqua, 1000-seed weight, leaf area index and harvest index
E <sub>3</sub>	PBR-378	4.74**	56.67	Siliqua length, no. of seeds per siliqua, 1000-seed weight, biological yield per plant and harvest index
	RGN-298	2.09**	57.92	Plant height, no. of primary branches per plant, Siliqua length, no. of seeds per siliqua, 1000-seed weight and harvest index
	RH-406	1.27	46.9	Days to maturity, no. of siliquae per plant and harvest index
Pooled	PBR-378	4.402**	46.08	Siliqua length, no. of seeds per siliqua, 1000-seed weight, Biological yield per plant and harvest index
	RGN-298	2.025**	44.89	No. of seeds per siliqua, 1000-seed weight and harvest index
	RGN-229	1.446**	45.20	No. of secondary branches per plant, no. of seeds per siliqua, 1000-seed weight, Biological yield per plant and leaf area index

\* and \*\* indicates significance of values at P< 0.05 and 0.01, respectively

**Table 4: Best mustard crosses possessing high SCA along with their *per se* performance and significant desirable SCA effects for other traits in individual and over the environments.**

Environments	Best parent	GCA effect	Seed yield per plant	Other yield contributing traits with its SCA magnitude
E <sub>1</sub>	RH-30 X RB-50	17.18**	46.36	Days to 50% flowering, Days to maturity, No. of primary branches per plant and Harvest index
	RGN-303 X RGN-229	16.82**	50.7	Days to 50% flowering, Plant height, No. of Secondary branches per plant, No. of seeds per siliqua, 1000-seed weight, Biological yield per plant and Harvest index
	RGN-13 X RH-406	12.91**	44.96	No. of Secondary branches per plant, 1000-seed weight, Biological yield per plant, Oil content, Leaf area index (LAI) and Harvest index
E <sub>2</sub>	RGN-303 X RGN-229	16.96**	63.71	Plant height, No. of siliquae per plant, No. of seeds per siliqua, 1000-seed weight and Harvest index
	RGN-298 X PBR-378	14.63**	63.26	1000-seed weight and Harvest index
	RGN-13 X RH-406	14.37**	56.75	No. of Secondary branches per plant, No. of siliquae per plant, 1000-seed weight, Oil content Leaf area index (LAI) and Harvest index
E <sub>3</sub>	RGN-236 X RB-50	14.83**	65.85	Harvest index
	RGN-298 X PBR-378	13.92**	73.98	Days to 50% flowering and Harvest index
	RGN-13 X RB-50	13.19**	63.01	No. of primary branches per plant, No. of Secondary branches per plant, No. of siliquae per plant, Mo. Of seeds per siliqua, Leaf area index (LAI) and Harvest index
Pooled	RGN-303 x RGN-229	14.983**	59.83	Days to 50% flowering, Days to maturity, Plant height, No. of Secondary branches per plant, No. of siliquae per plant, No. of seeds per siliqua, 1000-seed weight, Biological yield per plant, Oil content and Harvest index
	RH-30 x RB-50	14.264**	53.83	Days to 50% flowering, Days to maturity and Harvest index
	RGN-298 x PBR-378	13.429**	62.81	Siliqua length and Harvest index

\* and \*\* indicates significance of values at P < 0.05 and 0.01, respectively

## References

**Comment [dc12]:** Follow the guidelines properly some mistakes are there in references

- Choudhary, R. R., Sheoran, R. K., Avtar, A., Kumar, D. and Samita (2020). Heterosis studies based upon Mori CMS system in *Brassica juncea* L. *Journal of Oilseed Brassica*, **11**(2):116-120.
- Griffing, B. (1956b). A generalized treatment of the use of diallel crosses in quantitative inheritance. *Heredity*, **10** : 31-50.
- Hemingway, J.S. (1976). Mustards: *Brassica* spp., and *Sinapis alba* (Cruciferae). In: *Evolution of Crop Plants*. (Ed.): N. W. Simmonds, Longman, London, 56-59.
- Kaur, R., Kumar, R., Kaur, S., Singh, H. and Singh I. (2019). Combining ability analysis for yield and yield attributes in Indian mustard [*Brassica juncea* (L.) Czern&Coss.]. *Electronic Journal of Plant Breeding*, **10** (2): 778-784.
- Lohia, R. S. (2008). Combining ability analysis in Indian mustard (*Brassica juncea*) *Plant Archives*, **8**(1): 395-397.
- Malviya, N., Kumar, K. and Upadhyay, D.K. (2019). Combining ability and heterosis for seed yield, its component traits and oil content in Indian mustard [*Brassica juncea* (L.) Czern&Coss.]. *Journal of Pharmacognosy and Phytochemistry*, **8**(3): 696-699.
- Meena, H., Kumar, S. A., Ram, B., Singh, V. V., Meena, P. D., Singh, B. K. and Singh, D. (2015). Combining Ability and Heterosis for Seed Yield and Its Components in Indian Mustard (*Brassica juncea* L.). *J. Agr. Sci. Tech.*, **17**: 1861-1871.
- Nigam, R. and Alka (2009). Combining ability analysis for yield and its components in Indian mustard (*Brassica juncea*L.). *International Journal of Plant Sciences*, **4**(1): 109-111.
- Shrimali, T.M., Chauhan, R.M., Prajapati, K.P., Desai, S.A., Patel, J.R., Patel, P.T., Patel, P.J. and Chaudhary, B.K. (2018). Analysis of yield and its components based on heterosis and combining ability in Indian mustard (*Brassica juncea* L. Czern&Coss.). *Int. J. Pure App. Biosci.*, **6**(1): 219-224.
- 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]. *Research in Plant Biology*, **3** (2) : 26-31.
- Singh, H., Kumar, R., Kaur, S., Singh, I. and Kaur, R. (2019). Genetic analysis of Indian mustard for yield by calculating heterosis and combining ability. *J. Agri. Sci.*, **10**(1-2): 1-12.
- Singh, R. K., Singh, S. K. and Singh, A. (2020). Heterosis and combining ability analysis in indian mustard (*Brassica juncea*). *International Journal of All Research Education and Scientific Methods.*, **12**(8):1618-1623.
- Verma, S.K. and Sachan, J.N. (2000). Genetic divergence in Indian mustard (*Brassica juncea* (L.) Czern & Coss.). *Crop Res.*, **19**(2): 271-276.

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