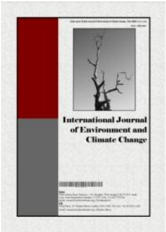

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Gene Action of Seed Yield and Its Contributing Attributes in Indian Mustard [*Brassica juncea* (L) Czern & Coss]

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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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 specific combing ability 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.

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1. 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," [1]. 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 general combing ability coupled with high performance indicates an outstanding parents will reservoir genes due to additive genetic variance. Hence both mean performance and general combing ability (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 epistatic components of variation that are non-fixable in nature thus it would be worthy for commercial exploitation as hybrids.

2. 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 F1,s were evaluated in a double row with 4.0 m row length and spacing at 45x20 cm^2 in a randomized block design (RBD) under three different environments created by three dates of sowing [1^{st} October (E_1), 15^{th} October (E_2) and 30^{th} October (E_3)] 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, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, siliqua length, number of seed per siliqua and leaf area index 1000 seed weight, oil content, biological yield per plant, harvest index and seed yield per plant.

The combining ability analysis of data for individual environment was carried out for all the three environments separately, using Griffing's method II, [2]. The following statistical model was employed:

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

3. RESULTS AND DISCUSSION

The analysis of variance for combining ability in the individual environment separately revealed that mean squares due to general combing ability and specific combing ability were significant for all the characters except oil content for general combing ability [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. [3] and Ramandeep et al. [4] 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. [5], Shrimali et al. [6] and Singh et al. [7]. 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 ENVS were significant for almost all characters with the except 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_1; PBR-378, RGN-303 and RGN-229 in E_2 PBR-378, RGN-298 and RH-406 in E_3 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 $E_{1,}$ E_2 E_3 and pooled basis; RGN-298 in E_1, E_3 and pooled environment; RGN-229 in $E_{1,}$ E_2 and pooled environment ; RGN-303 in E_2 and RGN-406 in E_1 emerged as good general combiners for seed yield with simultaneous consideration of other characters. Earlier, Choudhary et al. [8] and Singh et al. [9], provided similar information on combining ability in Indian mustard.

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_1	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_2	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_3	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_1	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_2	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_3	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_1	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_2	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_3	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_1	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_2	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_3	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_1	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_2	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_3	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_1	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_2	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_3	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 combing 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	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	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 **
SCA	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 **
Environments	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 **
GCA X ENVS	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 **
SCA X ENVS	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 **
ERROR	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_1	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_2	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_3	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_1	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_2	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_3	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*

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_1; RGN-303 x RGN-229, RGN-298 x PBR-378 and RGN-13 x RH-406 in E_2; RGN-236 x RB-50, RGN-298 x PBR-378 and RGN-13 x RB-50 in E_3 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_1 (very early sown) , E_2 (early sown) 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, E_3 (timely sown) and pooled environment as good specific cross combinations. 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 [10] and Singh et al. [11]. It is interesting to note that GCA effects of best crosses like RGN-303 x RGN-229 (good × good), RGN-13 x RH-406 (poor × good), RGN-298 x PBR-378 (good × good), RH-30 x RB-50 (poor × poor) and RGN-13 x RB-50 (poor × 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 [12] and Nigan and Alka [13], is expected to throw desirable segregants in the segregating generations.

4. CONCLUSION

Over all concluded that 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 three environment with over the environment. The crosses like RH-30 × RB-50, RGN-303 × RGN-229, RGN-13 × RH-406, RGN-298 × PBR-378 and RGN-236 × RB-50 emerged as good specific combiner for seed yield and related traits. These best crosses were the results of good x good, poor x poor and good x poor general combiners. Thus, these parents and crosses may be used in making an appropriate choice of the crosses in multiple crossing programmes of Indian mustard.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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