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Genetics of yield components and oil content in Indian mustard

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SUMMARY

Indian mustard [*Brassica juncea* (L.) Czern and Coss.] is an important *Rabi* oilseed crop. India is the second largest rapeseed-mustard growing country in the world and ranks third next to Canada and China in production. Ten genetically diverse genotypes of Indian mustard were crossed following diallel mating design to generate basic material to know the general combining ability (gca) of the parents and suggested the crosses with specific combining ability (sca). The 10 genotypes along with 45 F_1s and their F_2s were evaluated in completely randomized block design (CRBD) at CSAUA and T., Kanpur (India) during 2003-04 for yield and other agronomic traits. The parent Rohini was found good general combiner for maximum characters, *viz*., length of main raceme, number of siliquae on main raceme, number of seeds per siliquae, seed yield per plant and oil content followed by parent Varuna for four characters days to maturity, 1000-seed weight, seed yield per plant and oil content. RK 01-3 was found as a good general combiner for four characters, *viz*., days to 50 per cent flower, plant height, number of secondary branches per plant and days to maturity. Considering sca effects of crosses over the generations, the crosses Rohini x RK 02-5, Rohini x RK 02-3 and Varuna x RK 02-4 for seed yield per plant and RK 02-4 X SEJ-2 for oil content were found as good specific combiners.

Key words : Indian mustard, Diallel, Combining ability analysis

Among major oilseeds crops of the world, the oleiferous *Brassicae*, comprising rapeseed-mustard, occupies third position in production after soybean and cottonseed. In India, rapeseed-mustard ranks second after groundnut and is grown in an area of 5.1mha.. Indian mustard is a naturally evolved from secondary balanced polyploid of two monogenomics [*Brassica campestris* (L.) 2n=AA=20 and *Brassica nigra* (L.) Koch, 2n=BB=16] due to autosyndetic pairing. Being often cross-pollinated crop, the knowledge of combining ability is useful to assess nicking ability of parents and to elucidate the nature and magnitude of gene action involved. The concept of combining ability has assumed greater importance in plant breeding as it permits the prediction of the efficiency of parents based on early generation performance besides enabling to study the comparative performance of genotypes/lines in hybrid combination. The gca effect is primarily a function of additive gene effects and additive x additive interaction. The additive effects are mainly due to polygenes, which act in additive manner, expressing fixable effects, while sca effects represent non-additive type of gene action (Griffing, 1956). Non-additive gene action results from the effect of dominance, epistasis and various other interactions, which are non-fixable. The present investigation was carried out to know the gene action for certain quantitative characters and to identify certain parents/crosses for their utilization in further breeding programme.

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MATERIALS AND METHODS

The present study comprised of ten diverse genotypes of Indian mustard, *viz*., Varuna, Rohini, RK 02-3, RK 02-4, RK 02-5, RK 02-6, RK 03-1, RK 03-2, RK 01-3 and SEJ-2 and their F_1s and F_2s (excluding reciprocals). These genotypes were crossed in all possible combinations in winter 2003-04 and advanced to F_2 in off-season nursery during summer season of 2004. Forty-five F_1s and F_2s along with ten parents were grown in a randomized block design with three replications during winter 2004-05 at Oilseed Research Farm, Kalayanpur, C.S.Azad University of Agriculture and Technology, Kanpur. Each progeny was represented by a single row of parents and F_1s and two rows of F_2s having five meter length with inter and intra row spacing of 45 cm and 20 cm, respectively. The standard agronomic practices were followed to raise the crop.

RESULTS AND DISCUSSION

Analysis of variance for combining ability revealed that variances due to gca and sca were highly significant for all the characters in both the generations (Table 1). This indicated existence of genetic variability among parents included in the present study and role of both additive and non-additive gene effects in the inheritance

Table 1 : Analysis of variance for combining ability and related statistics, their ratios and average degree of dominance for 11 characters in Indian mustard

Source	Generation	d.f.	Days to 50per cent flower	Plant height	Number of primary branches per plant	Number of secondary branches per plant	Days to maturity	Length of main raceme	Number of siliquae on main raceme	Number of seeds per siliqua	1000-seed weight	Seed yield per plant	Oil content
gca													
	F_1	9	302.60**	1362.63**	0.72**	5.38**	273.37**	173.80**	67.60**	11.08**	2.94**	34.85**	1.40**
	F_2	9	255.31**	1073.37**	0.98**	1.57**	161.44**	371.63**	196.80**	6.65**	2.75**	45.10**	3.00**
sca													
	F_1	45	10.16**	52.09**	0.96**	3.47**	11.57**	42.93**	48.63**	1.91**	0.16**	2.66**	0.74**
	F_2	45	13.46**	72.13**	0.52**	3.00**	13.34**	33.37**	97.93**	2.20**	0.14**	2.29**	0.82**
Error													
	F_1	108	0.48	1.66	0.22	0.54	0.40	6.15	1.80	0.22	0.008	0.04	0.13
	F_2	108	0.59	2.63	0.16	0.71	0.42	3.14	1.43	0.24	0.004	0.02	0.09
$\delta^2 g$													
	F_1		24.37	109.21	-0.02	0.16	21.82	10.90	1.58	0.76	0.23	2.15	0.05
	F_2		20.15	83.44	0.04	-0.12	12.34	28.19	8.24	0.37	0.22	2.27	0.18
$\delta^2 s$													
	F_1		9.68	50.43	0.73	2.93	11.17	36.78	46.83	1.69	0.16	2.68	0.61
	F_2		12.87	69.50	0.35	2.29	12.91	30.23	96.5	1.96	0.14	3.57	0.74
$\delta^2 g/ \delta^2 s$													
	F_1		2.52	2.16	0.03	0.05	1.95	0.29	0.03	0.45	1.44	0.80	0.08
	F_2		1.56	1.20	0.11	0.05	0.95	0.93	0.08	0.19	1.57	0.64	0.24
$(\delta^2 s/ \delta^2 g)^{0.5}$													
	F_1		0.63	0.68	6.04	4.28	0.71	1.84	5.44	1.49	0.83	1.12	3.49
	F_2		0.79	0.91	2.95	4.36	1.02	1.03	3.42	2.30	0.79	1.25	2.03

** indicates significant of value at P=0.01

gca = general combining ability; sca = specific combining ability;

$\delta^2 g/ \delta^2 s$ = ratio of gca variance to sca variance; $(\delta^2 s/ \delta^2 g)^{0.5}$ = degree of dominance of these traits. These findings were in accordance with those of Singh and Srivastava (1986), Gupta *et al.* (1987), Jain *et al.* (1988) and Monalisa *et al.* (2005).

So far as nature of gene action is concerned, the estimates of δ^2g and δ^2s and their ratio (δ^2g/ δ^2s) with value less than unity indicated a predominant role of non-additive gene action for the characters number of primary branches per plant, number of secondary branches per plant, length of main raceme, number of siliquae on main raceme, number of seeds per siliquae, seed yield per plant and oil content in both the generations and days to maturity in F_2. On the other hand additive gene action was predominant for characters days to 50 per cent flower, plant height, 1000-seed weight in both the generations and days to maturity in F_1.

In addition to other genetic parameters, the average degree of dominance is also of interest to plant breeders (Gardner, 1963). The degree of dominance through combining ability has been estimated as $(\delta^2 s/ \delta^2 g)^{0.5}$. This formula is based on assumptions that the genes are iso-directionally distributed among the parents and all the increments have the same sign (Kempthorne and Curnow, 1961).

Character number of primary and secondary branches per plant, length of main raceme, number of siliquae on main raceme, number of seeds per siliqua, seed yield per plant and oil content in both the generations and days to maturity in F_2 with estimated value more than unity exhibited over dominance. These results are in agreement of genetic analysis, which indicated non-additive gene action for the above traits.

Days to 50 per cent flower, plant height, 1000-seed weight in both the generations and days to maturity in F_1 with value less than unity exhibited partial dominance.

The information regarding gca effect of the parents is of prime importance as it helps in successful prediction of genetic potentiality of crosses, which produce desirable individuals in segregating generations as the choice of the parents for hybridization is normally based on the *per se* performance

While considering the gca effects of parents, it was observed that none of the parents was found as good general combiner for all the eleven characters studied in both the generations. However, parent Rohini showed desirable gca effects for five characters length of main raceme, number of siliquae on main raceme, number of seeds per siliqua, seed yield per plant and oil content, whereas Varuna showed desirable effects for four

Table 2 : Ranking of desirable parents with respect to their superiority on the basis of *per se* performance and general combining ability for 11 characters in Indian mustard

Characters	Superior parents on the basis of *per se* performance	Good general combiner			
		F_1	F_2	Common in F_1 and F_2	Common in *per se*, F_1 and F_2
Days to 50 per cent flower	SEJ-2, RK 01-03, RK 02-6	SEJ-2, RK 01-3, RK 02-6	SEJ-2, RK 01-3, Varuna	SEJ-2, RK 01-3	SEJ-2, RK 01-3
Plant height	SEJ-2, RK 01-3, RK 02-6	SEJ-2, RK 01-3, RK 02-6	SEJ-2, RK 01-3, Varuna	SEJ-2, RK 01-3	SEJ-2, RK 01-3
Number of primary branches per plant	RK 03-2, Varuna, RK 02-6	RK 02-5, RK 03-1, RK 02-6	RK 03-1, RK 02-6, Varuna	RK 03-1, RK 02-6	RK 02-6
Number of secondary branches per plant	RK 01-3, Varuna, RK 02-3	RK 01-3, RK 02-3, RK 02-5	RK 01-3, SEJ-2, Varuna	RK 01-3	RK 01-3
Days to maturity	SEJ-2, RK 01-3, Varuna	SEJ-2, RK 01-3, Varuna	SEJ-2, RK 01-3, Varuna	SEJ-2, RK 01-3, Varuna	SEJ-2, RK 01-3, Varuna
Length of main raceme	Rohini, RK02-5, RK 02-3	Rohini, RK 02-4, RK 02-5	Rohini, RK 02-4, Varuna	Rohini, RK 02-4	Rohini
Number of siliquae on main raceme	RK 02-4, Rohini, RK 02-5	Rohini, RK 02-4, RK 02-5	Rohini, RK 02-3, RK 02-5	RK 02-5, Rohini	Rohini, RK 02-5
Number of seeds per siliqua	RK 03-2, RK 02-4, RK 02-5	RK 03-2, Rohini, RK 02-5	RK 03-2, Rohini, Varuna	RK 03-2, Rohini	RK 03-2
1000-seed weight	RK 02-3, Varuna, Rohini	Varuna, RK 02-3, RK 02-4	Varuna, RK 02-3, RK 02-4	Varuna, RK 02-3, RK 02-4	RK 03-2, Varuna
Seed yield per plant	Rohini, Varuna, RK 02-5	Rohini, Varuna, RK 02-3	Rohini, Varuna, RK 02-5	Varuna, Rohini	Rohini, Varuna
Oil content	Rohini, Varuna, R 02-5	Rohini, Varuna, RK 02-6	Varuna, RK 02-6, Rohini	RK 02-6, Varuna, Rohini	Rohini, Varuna

Table 3 : The crosses with high sca effect in F_1 and F_2 generations and gca effect of parents involved for 11 characters in Indian mustard

Characters	Cross	sca effect	gca effect		Reaction
			P_1	P_2	
Days to 50 per	F_1				
cent flower	RK 02-3 x RK 01-3	-5.29**	-0.28	-6.28**	L x L
	RK 02-3 x SEJ-2	-4.12**	-0.28	-9.12**	L x L
	RK 02-4 x RK 02-6	-4.04**	4.47**	-2.28**	H x L
	Varuna x SEJ-2	-4.01**	0.39*	9.12**	L x H
	RK 02-4 x RK 03-2	-3.93**	4.47**	1.94**	H x H
	F_2				
	RK 02-3 x RK 01-3	-9.24**	0.77**	-4.92**	L x L
	Varuna x Rohini	-7.13**	-2.17**	3.02**	L x H
	RK 02-3 x SEJ-2	-6.49**	-0.78**	-8.67**	L x L
	Varuna x SEJ-2	-5.10**	-2.17**	-8.67**	L x L
	RK 02-6 x RK 03-1	-4.74**	-1.37**	7.16**	L x H
Plant height	F_1				
	RK 02-5 x RK 03-2	-19.59**	7.49**	4.91**	H x H
	RK 02-4 x SEJ-2	-6.12**	9.11**	-17.17**	H x L
	RK 02-3 x RK 03-2	-6.12**	-2.64**	4.91**	L x H
	Varuna x RK 02-6	-5.90**	-2.12**	-5.17**	L x L
	Rohini x RK 02-5	-5.32**	5.97**	7.49**	H x H
	F_2				
	RK 02-4 x SEJ-2	-19.14**	6.28**	-18.74**	H x L
	RK 02-5 x RK 03-1	-12.89**	5.26**	12.70**	H x H
	RK 02-3 x RK 02-5	-10.92**	-0.27	5.26**	L x H
	RK 02-4 x RK 02-5	-9.81**	6.28**	5.26**	H x H
	RK 02-5 x RK 03-2	-9.53**	5.26**	6.67**	H x H
Number of	F_1				
primary branches	Rohini x SEJ-2	1.38**	-0.28*	-0.25	L x L
per plant	Rohini x RK 01-3	1.29**	-0.28*	-0.17	L x L
	RK 02-3 x SEJ-2	1.15**	-0.06	-0.25	L x L
	Rohini x RK 03-2	1.02**	-0.28*	0.11	L x L
	RK 02-4 x RK 03-1	0.90*	0.06	0.22	L x L
	F_2				
	RK 02-4 x RK 02-6	1.14**	-0.09	0.27	L x H
	Rohini x RK 01-3	1.12**	0.05	-0.51**	L x L
	RK 02-4 x RK 03-2	1.09**	-0.09	-0.01	L x L
	Rohini x RK 02-4	1.03**	0.05	-0.09	L x L
	Rohini x RK 03-1	0.98**	0.05	0.30**	L x H
Number of	F_1				
secondary	RK 02-5 x RK 03-2	3.45**	0.30	-0.03	L x L
branches per	Varuna x RK 03-2	3.29**	-0.20	-0.03	L x L
plant	Rohini x RK 03-2	2.79**	-0.70**	-0.03	L x L
	RK 02-6 x RK 03-1	2.48**	-0.26	-1.17**	L x L
	RK 02-3 x RK 01-3	2.12**	0.88**	1.05**	H x H
	F_2				
	Varuna x RK 03-1	2.79**	0.20	-0.44	L x L
	Rohini x SEJ-2	2.79**	-0.33	0.42	L x L
	RK 02-3 x RK 01-3	2.15**	0.09	0.64**	L x H
	RK 02-3 x RK 02-6	1.76*	0.09	-0.30	L x L
	RK 02-3 x SEJ-2	1.71*	0.09	0.42	L x L

Contd..... Table 3

Table 3 contd....

Length of main raceme	F_1				
	RK 02-4 x RK 01-3	10.52**	4.09**	-5.27**	H x L
	RK 02-3 x RK 03-2	10.44**	2.17**	-0.94	H x L
	RK 03-2 x RK 01-3	10.22**	-0.94	-5.27**	L x L
	Varuna x RK 03-1	9.91**	1.39*	-1.97*	H x L
	Varuna x RK 02-3	7.44**	1.39*	2.17**	H x H
	F_2				
	RK 01-3 x SEJ-2	10.43**	-8.01**	-5.34**	L x L
	Varuna x RK 02-4	9.46**	5.49**	0.79	H x L
	RK 02-6 x RK 03-2	9.21**	-1.96**	-2.18**	L x L
	Varuna x RK 02-3	6.60**	5.49**	5.66**	H x H
	RK 02-3 x RK 03-2	5.27**	5.66**	-2.18**	H x L
Number of siliquae on main raceme	F_1				
	Varuna x RK 02-4	12.84**	-2.06**	2.55**	L x H
	Rohini x RK 02-5	11.34**	3.16**	2.16**	H x H
	RK 03-2 x SEJ-2	9.06**	1.33**	-2.06**	H x L
	RK 03-2 x RK 01-3	8.70**	1.33**	-2.37**	H x L
	RK 02-3 x RK 03-2	8.17**	1.83**	1.33**	H x H
	F_2				
	Varuna x RK 02-4	14.18**	1.11**	0.47	H x L
	Rohini x RK 02-5	14.10**	6.24**	2.74**	H x H
	RK 02-3 x RK 02-5	12.46**	4.88**	2.74**	H x H
	RK 01-3 x SEJ-2	9.71**	-5.53**	-4.76**	L x L
	RK 02-3 x RK 03-1	9.26**	4.88**	-4.73**	H x L
Number of seeds per siliqua	F_1				
	Varuna x RK 01-3	3.06**	0.64**	-0.55*	H x L
	RK 02-6 x RK 03-2	2.45**	-1.02**	2.06**	L x H
	RK 02-3 x RK 03-2	2.01**	-0.24	2.06**	L x H
	RK 02-3 x RK 01-3	1.95**	-0.24	-0.55*	L x L
	Rohini x RK 03-2	1.92**	0.17	2.06**	L x H
	F_2				
	RK 02-6 x RK 03-2	2.85**	0.07	1.46**	L x H
	Varuna x SEJ-2	2.58**	0.37**	-0.57**	H x L
	RK 02-4 x RK 02-5	2.24**	-0.13	-0.07**	L x L
	Varuna x RK 03-2	2.21**	0.37**	1.46**	H x H
	Rohini x RK 02-4	2.10**	0.73**	-0.13	H x L
1000- seed weight	F_1				
	Rohini x RK 02-6	0.82**	0.26**	0.01	H x L
	Varuna x RK 01-3	0.66**	0.89**	-0.58**	H x L
	RK 02-5 x RK 03-1	0.66**	0.03	-0.48**	L x L
	RK 02-4 x SEJ-2	0.64**	0.28**	-0.56**	H x L
	RK 02-3 x RK 03-2	0.58**	0.51**	-0.36**	H x L
	F_2				
	RK 02-3 x RK 02-4 Varuna	0.73**	0.61**	0.27**	H x H
	x RK 03-2 Varuna x RK	0.65**	0.63**	-0.13**	H x L
	02-4 Varuna x Rohini	0.53**	0.63**	0.27**	H x H
	Varuna x RK 02-5	0.50**	0.63**	0.17**	H x H
		0.49**	0.63**	0.11**	H x H

Contd.. Table 3

Table 3 contd....

Seed yield per	F_1				
plant	Varuna x Rohini	3.70**	1.47**	2.16**	H x H
	Rohini x RK 02-5	3.54**	2.16**	1.24**	H x H
	Rohini x RK 02-3	3.17**	2.16**	1.30**	H x H
	Varuna x RK 02-4	2.98**	1.47**	0.88**	H x H
	RK 02-6 x RK 03-2	2.51**	-0.70**	0.19**	L x H
	F_2				
	Varuna x Rohini	2.99**	1.58**	2.33**	H x H
	Rohini x RK 02-3	2.65**	2.33**	1.47**	H x H
	Rohini x RK 02-5	2.62**	2.33**	1.56**	H x H
	Varuna x RK 02-4	2.58**	1.58**	0.75**	H x H
	RK 02-3 x RK 02-	2.21**	1.47**	1.56**	H x H
Oil content	F_1				
	RK 03-1 x RK 01-3	1.34**	-0.33**	-0.31**	L x L
	RK 02-3 x SEJ-2	1.22**	-0.14	-0.39**	L x L
	RK 03-1 x SEJ-2	1.09**	-0.33**	-0.39**	L x L
	RK 03-2 x RK 01-3	1.06**	-0.06	-0.31**	L x L
	RK 02-4 x SEJ-2	1.03**	0.06	-0.39**	L x L
	F_2				
	RK 02-4 x SEJ-2	1.55**	0.02	-0.52**	L x L
	RK 02-3 x RK 01-3	1.47**	0.20**	-0.66**	H x L
	RK 02-3 x RK 03-1	1.38**	0.20**	-0.58**	H x L
	RK 02-4 x RK 01-3	1.36**	-0.02	-0.66**	L x L
	RK 02-5 x RK 03-1	1.33**	0.26**	-0.58**	H x L

* and ** indicates significant of values at P=0.05 and 0.01, respectively. L = Low estimate; H = High estimate

characters days to maturity, 1000-seed weight, seed yield per plant and oil content. RK 01-3 was also found as a good general combiner for four characters, *viz*., days to 50 per cent flower, plant height, number of secondary branches per plant and days to maturity. SEJ-2 was good general combiner for three characters, namely, days to 50 per cent flower, plant height and days to maturity. Parent RK 02-4 for length of main raceme and 1000-seed weight; RK 02-6 for number of primary branches per plant and oil content.

The *per se* performance of the parents was also compared with their gca effects in F_1 and F_2 generations for all the characters under study. On the basis of *per se* performance and gca effects over the generations (Table 2) the good general combiners, were Rohini for length of main raceme, number of siliquae on main raceme, seed yield per plant and oil content; Varuna for days to maturity, 1000-seed weight, seed yield per plant and oil content; RK 01-3 for days to 50 per cent flower, plant height, number of secondary branches per plant and days to maturity; SEJ-2 for days to 50 per cent flower, plant height and days to maturity; RK 03-2 for number of seeds per siliqua and 1000-seed weight. This showed that *per se* performance of parents would provide only an indication of their general combining ability for utilizing them in hybridization programme. Similar observations on closer relationship between *per se* performance and gca effects has been reported by Wang and Wang (1986), Singh *et al.* (1986) and Singh *et al.* (2006) in Indian mustard.

It may be noted that, if that character is unidirectionally controlled by a set of alleles and additive effects are important, the choice of parents on the basis of *per se* performance in most of the cases may be adequate but the choice of parents on the basis of phenotypic performance alone is not a sound procedure, since phenotypically superior lines may yield poor recombinants in the segregating generations. It is, therefore, essential that the parents should be selected on the basis of their combining ability estimates, where non-allelic interactions are important.

Specific combining ability is associated with interaction effects, which may be due to dominance and epistatic component of variation that are non fixable in nature. The good cross combination and *per se* performers for different traits are given in Table 3. A perusal of the result indicated that none of the cross combinations was found superior for all the characters.

Considering sca effects of crosses over the generation, the crosses RK 02-3 x RK 01-3, RK 02-3 x SEJ-2 and Varuna x SEJ-2 for days to 50 per cent flower; RK 02-5 x RK 03-2 and RK 02-4 x SEJ-2 for plant height; Rohini x RK 01-3 for number of primary branches per plant; RK 02-3 x RK 01-3 for number of secondary branches per plant; RK 02-6 x RK 03-1 for days to maturity and Varuna x RK 02-3 for length of main raceme; Varuna x RK 02-4 and Rohini x RK 02-5 for number of siliquae on main raceme; RK 02-6 x RK 03-2 for number of seeds per siliqua; Varuna x RK 02-4, Rohini x RK 02-5 and Rohini x RK 02-3 for seed yield per plant and RK 02-4 x SEJ-2 for oil content were found as good specific combiners.

It is generally found that good cross combinations are resulted between high x high and poor ones between low x low general combiners. But in the present finding, best combinations involved high x high, high x low and low x low general combiners for the characters studied. Thus, it is evident that crosses with high sca are not always obtained between high x high, general combiners but may occur between low x low, general combiners. This might be probably due to the presence of dominant and epistatic gene interactions. In general, sca effects do not make any significant contribution in the improvement of self-pollinated crops except where there is possibility of commercial exploitation of heterosis. Breeders' interest normally, however, rests in obtaining transgressive segregants through crosses in order to produce homozygous line in self-pollinated crops. Therefore, crosses involving high x high general combiners in respect of some characters in the present study may be utilized for obtaining transgressive segregants in the segregating generation.

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