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Combining ability for yield and oil quality traits in Indian mustard [*Brassica juncea* (L.) Czern & Coss] using line × tester analysis

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ABSTRACT : Ten lines and four testers of Indian mustard [*Brassica juncea* (L.) Czern & Coss.] genotypes were used to estimate general combining ability (GCA) and specific combining ability (SCA) effects estimate for yield and oil quality traits. For all the quantitative and quality traits, the mean sum of squares due to line/tester was highly significant, proving that the parental lines used in present investigation are comprising the diverse genetic background. Among the lines and testers, good general combiner RH-30, RAURD 214, EC 401574 and Rajendra Sufalam have exhibited desirable negative and significant GCA effect for days to 50 per cent flowering and days to maturity, whereas positive and significant GCA effect for number of primary and secondary branches per plant, siliqua per plant, siliqua length, 1000 seed weight, biological yield per plant, oleic acid, oil content and seed yield per plant, indicating the presence of additive gene action or additive x additive interaction effects. On the basis of desirable SCA effects for yield, oil and its component traits were found best cross combinations RAURD 153/JD-6, EC 401574/Rajendra Sufalam, RAURD 170/JD-6 and RAURD 214/Rajendra Sufalam. The cross combinations EC 401574/Rajendra Sufalam, RAURD 214/Pusa Bold and RAURD 172/Pusa Bold with highly significant economic heterosis and SCA effects, reflected presence of both additive and non-additive gene effects responsible for increase in grain yield over economic parents.

KEY WORDS : Combining ability, GCA, SCA, Seed yield, Oil quality, *Brassica juncea* L.

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Many authors applied different tactics for improving both quality and quantity of seed yield through its component traits to brassica oil crops (Singh, 2003 and Singh *et al.*, 2003). Hence, it has become necessary to enhance the present production by developing superior varieties in terms of quality and productivity in crop *Brassicas*. 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). Improvement of superior varieties could be done by reshuffling the genes through hybridization from proper parents. Moreover, it is also necessary to know about the nature and magnitude of gene action responsible for controlling the inheritance of various yield attributes along with combining ability of the parents and their cross combinations in order to make use of them in further crop improvement programme.Seed yield being quantitative trait, is largely influenced by the different environmental effects (Diepenbrock, 2000 and Rameeh, 2012). The value amount of heterosis as well as the GCA and SCA effects is important consideration for hybrid breeding. Knowledge about the type and amount of genetic effects is required for an efficient use of genetic variability of crops. The concept of good combining ability refers to the potential of a parental form of producing by its crossing with another parent superior offspring for the breeding process and it is widely used in the breeding of cross-pollinated plants. Information and exact study of combining ability can be useful in regard to selection of breeding methods and selection of lines for hybrid combination.The present study was, therefore, undertaken with a view to estimate general and specific combining ability variances and effects in Indian mustard for seed yield and oil quality traits.

RESEARCH PROCEDURE

The experimental material comprising the selected parents (10 lines and 4 testers) are involved in hybridization and generate the 40 F_1s materials during *Rabi* 2011-12. The generated 40 F_1s and 14 parents along with one check of Indian mustard were grown in Randomized Block Design with three replications during *Rabi* season of 2012-13 at the research farm of Tirhut College of Agriculture, Dholi, Muzaffarpur (Rajendra Agricultural University-Pusa) Bihar located at to 25.5^0N latitude, 35.4^0E longitude and an altitude 52.2 m average sea level. Entries were sown in a plot consisting of three rows of 5 m length in three replications with inter and intra row spacing of 30cm x 10cm. Recommended package of practices for Indian mustard ware followed to raise a healthy crop. Data were recorded on five randomly selected competitive plants of each genotype in all the replications for twenty one characters *viz.*, days to 50 per cent flowering, days to maturity, plant height (cm), primary branches per plant, secondary branches per plant, number of siliqua per plant, siliqua length (cm), number of seeds per siliqua, length of main raceme (cm), number of siliqua on main raceme, siliqua density (siliqua/ cm^2), 1000 seed weight (g), biological yield per plant (g), harvest index (%), fatty acid (%) *viz.*, palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, erucic acid, oil content (%) and seed yield per plant (g) and their mean values were subjected to various statistical and biometrical analyses. Combining ability analysis was done using line x tester method (Kempthorne, 1957). The variances for general combining ability and specific combining ability were tested against their respective error variances derived from ANOVA reduced to mean level. Significance test for GCA and SCA effects were performed using t-test.

RESEARCH ANALYSIS AND REASONING

The analysis of variance (Table 1) showed highly significant differences among the crosses for all the yield and oil quality traits except days to maturity. The mean

Table 1 : Analysis of variance for combining ability of twenty one quantitative and quality traits in Indian mustard

Sources	df	DFF	DM	MSL	PBP	SBP	SPP	SMR	SL	SS	SD
Replicates	2	1.23	5.63	4.32	1.42	4.57	1.63	3.19	0.02	7.08	0.00
Crosses	39	99.68**	28.17	675.94**	5.62**	112.94**	221245.28**	133.76**	0.51**	4.34**	0.07**
Line effect	9	321.45**	76.56	1191.38**	6.38	144.19	208197.75	177.53	1.09*	5.17	0.14**
Tester effect	3	56.39	23.34	1891.23**	8.13	79.89	216335.41	156.57	0.25	2.15	0.24**
Line * tester effect	27	30.57**	12.57**	369.10**	5.09**	106.20**	226140.00**	116.64**	0.35**	4.31**	0.03**
Error	78	2.40	3.39	11.91	1.24	3.93	11.75	5.11	0.06	0.89	0.01
Total	119	34.26	11.55	229.41	2.68	39.67	72516.69	47.24	0.20	2.13	0.03
Var. GCA		8.89**	2.21**	72.87**	0.28**	5.14	10107.39**	7.70*	0.03**	0.13	0.008**
Var. SCA		9.48**	3.03**	119.39**	1.26**	34.07**	75376.21**	37.11**	0.09**	1.15**	0.008**
GCA/SCA		0.94	0.73	0.61	0.22	0.15	0.14	0.21	0.30	0.12	1.01
Degree of dominance		1.03	1.17	1.28	2.11	2.57	2.73	2.19	1.82	2.94	0.99

Table 1 : Contd..…

Table 1 : Contd…………….

Sources	df	TSW	BYP	HI	OC	PA	SA	OA	LA	LNA	EA	SYP
Replicates	2	0.11	13.44	0.36	0.04	0.01	0.02	0.02	0.01	0.03	0.06	2.05
Crosses	39	1.56**	1171.30**	38.91**	1.37**	0.55**	0.21**	4.49**	8.80**	10.91**	50.53**	112.48**
Line effect	9	4.28**	2084.64*	28.90	1.59	0.41	0.15	4.39	8.57	17.26**	72.82	94.28
Tester effect	3	2.64**	985.84	0.44	0.43	0.24	0.13	9.32	29.44*	44.48**	104.57	65.65
Line * tester effect	27	0.53**	887.45**	46.52**	1.40**	0.63**	0.24**	3.99**	6.58**	5.06**	37.10**	123.74**
Error	78	0.06	16.69	1.60	0.02	0.03	0.04	0.02	0.02	0.04	0.04	3.04
Total	119	0.55	395.04	13.81	0.46	0.18	0.07	1.47	2.88	3.57	16.59	38.89
Var. GCA		0.16**	72.34**	0.61	0.05	0.02	0.007	0.33*	0.90*	1.47**	4.22**	3.68
Var. SCA		0.15**	29.05**	14.90**	0.46**	0.21**	0.801**	1.33**	2.19**	1.68**	12.36**	40.35
GCA/SCA		1.05	0.25	0.04	0.10	0.07	0.08	0.25	0.41	0.87	0.34	0.09
Degree of dominance		0.98	2.00	4.93	3.12	3.70	3.44	2.02	1.56	1.07	1.71	3.31

* and ** indicate significance of values at P=0.05 and 0.01, respectively

sum of squares due to lines were observed highly significant for days to 50 per cent flowering, main shoot length, siliqua length, siliqua density, 1000 seed weight, biological yield per plant and linolenic acid; whereas due to testers found highly significant for main shoot length, siliqua density, 1000 seed weight, linoleic acid and linolenic acid; for all the quantitative and quality traits, the mean sum of squares due to line/tester were highly significant, proving that the parental lines used in present investigation are comprising the diverse genetic background. The magnitude of additive variance (GCA) was highly significant for days to 50 per cent flowering, days to maturity, main shoot length, primary branches per plant, number of siliqua per plant, number of siliqua on main raceme, siliqua length, siliqua density, 1000 seed weight, biological yield per plant, oleic acid, linoleic acid, linolenic acid and erucic acid and of non-additive variance (SCA) observed highly significant for all the characters except seed yield per plant. Preponderance of additive as well as non-additive gene effects as reflected in the present investigation for the expression of characters under study was similar to the findings by Vaghela *et al.* (2011) and Azizinia (2012). The ratio of GCA and SCA variance as less than one and degree of dominance more than one for days to 50 per cent flowering, days to maturity, main shoot length, primary branches per plant, secondary branches per plant, number of siliqua per plant, number of siliqua on main raceme, siliqua length, number of seeds per siliqua, biological yield per plant, harvest index, palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, erucic acid, oil content and seed yield per plant, whereas more than one and degree of dominance less than one for siliqua density and 1000 seed weight, indicated greater role of non-additive component in the inheritance of these characters. The presence of predominantly large amount of non-additive gene action would be necessitating the

Table 2 : Proportional contribution of lines, testers and L x T interaction to total variance in Indian mustard

Sources	DFF	DM	MSL	PBP	SBP	SPP	SMR	SL	SS	SD
Lines	74.42	62.72	40.67	26.19	29.46	74.42	30.63	49.13	27.48	43.66
Testers	4.35	6.37	21.52	11.12	5.44	4.35	9.00	3.72	3.80	24.31
Line * Tester	21.23	30.90	37.80	62.69	65.09	21.23	60.37	47.14	68.71	32.02

Continued……..

Sources	TSW	BYP	HI	OC	PA	SA	OA	LA	LNA	EA	SYP
Lines	63.44	41.07	17.14	26.80	17.32	16.48	22.56	22.48	36.53	33.25	19.34
Testers	13.04	6.47	0.09	2.42	3.30	4.85	15.96	25.73	31.37	15.92	4.49
Line * Tester	23.52	52.45	82.77	70.77	79.37	78.66	61.48	51.78	32.09	50.82	76.16

DF=Days to flowering, DM= Days to maturity, PBP= Primary branches/ plant, SBP= Secondary branches/ plant , SPP= No. of siliqua/ plant, SL= Siliqua length, SS= No. of seeds/ siliqua , MSL= Main shoot length, SMR= No. of siliqua on main raceme, SD= Siliqua density
TSW= 1000 seed weight, BYP= Biological yield/ plant, HI= Harvest index, PA= Palmitic acid, SA= Stearic acid, OA= oleic acid, LA= Linoleic acid, LNA=Linolenic acid, EA= Erucic acid, OC= Oil content and SYP= Seed yield/ plant

maintenance of heterozygosity in the population. Breeding methods *i.e*. biparental mating followed by one/two cycle of reciprocal recurrent selection may increase frequency of genetic recombination and hasten the rate of genetic improvement as earlier reported by Akbar *et al.* (2008) and Vaghela *et al.* (2011).The contribution of lines, tester and their interaction towards total variances are presented in Table 2. The contribution of lines was higher than corresponding contribution of testers for all the traits under study except for linoleic acid. The proportional contribution of line/tester interaction was higher than the testers for all the traits under study; whereas the line/tester interaction was higher than the lines for primary branches per plant, secondary branches per plant, siliqua on main raceme, number of seeds per siliqua, biological yield per plant, harvest index, palmitic acid, stearic acid, oleic acid, linoleic acid, erucic acid, oil content and seed yield per plant, indicating that heterosis breeding may be effective using diverse parental lines for the improvement of Indian mustard.

General combining ability effects :

Among the lines and testers, good general combiner RH-30, RAURD 214, EC 401574, Pusa Bold and Rajendra Sufalam (Table 3) have exhibited positive and significant GCA effect for seed yield per plant, indicating the presence of additive gene action or additive x additive interaction effects. Among these RH-30, RAURD 214 and Rajendra Sufalam exhibited desirable negative and significant GCA effect for days to 50 per cent flowering and days to maturity along with desirable positive and significant GCA effect with higher magnitude for the traits *viz*., number of primary and secondary branches per plant, number of siliqua per plant, siliqua length, siliqua density, 1000 seed weight, biological yield per plant, stearic acid, oleic acid and oil content; suggesting that to develop the early maturing genotype with higher grain yield with superiority in component traits, these parental lines may be used as one of the parent in improvement programme to enhance the production and productivity of mustard. Based on higher positive and significant GCA effects along with high *per se* performance EC401574 was identified

Table 3 : General combining ability effect of parents for twenty one characters in Indian mustard

Sr.No.	Parents	DFF	DM	MSL	PBP	SBP	SPP	SMR	SL	SS	SD	TSW
1.	RH -30	-1.84**	-0.17	-9.72**	0.80*	4.21**	148.87**	-3.87**	0.04	-0.60*	0.18**	-0.02
2.	RAURD-172	-0.43	2.83**	-8.71**	-0.58	-2.39**	-117.60**	-2.75**	-0.22**	1.02**	-0.04	-0.34**
3.	RAURD-32	-2.51**	-3.67**	-2.51*	-0.83*	-2.79**	162.00**	-4.50**	0.14	0.57*	0.11**	0.18*
4.	RAURD-78	-0.84*	-1.08*	-1.11	0.20	0.43	31.00**	5.32**	0.16*	-0.36	-0.09**	0.50**
5.	RAURD-34	-3.76**	-4.75**	-7.09**	-1.40**	-6.47**	-276.96**	5.72**	0.07	-0.28	0.02	0.48**
6.	RAURD-214	-3.92**	1.67**	-4.98**	0.69*	3.32**	45.52**	-1.90**	0.37**	0.22	0.10**	0.37**
7.	RAURD-153	-4.93**	0.08	-3.61**	0.42	-2.66**	-71.69**	-1.80**	0.40**	0.47	0.04	0.68**
8.	EC 401574	0.74	2.33**	2.50*	0.15	1.58**	92.75**	3.95**	-0.59**	-1.16**	-0.08**	-0.17*
9.	EC 399788	12.16**	1.67**	18.44**	0.65	3.59**	5.92**	-1.95**	-0.25**	0.45	-0.12**	-1.36**
10.	RAURD-170	5.32**	1.08*	16.78**	-0.10	1.18*	-19.81**	1.78**	-0.10	-0.35	-0.13**	-0.33**
11.	Vardan	0.69*	0.62	-0.85	0.11	-0.14	-58.67**	-1.95**	0.11*	-0.01	0.03	0.11*
12.	Pusa bold	1.56**	0.68*	10.31**	0.67**	1.00**	102.76**	0.86*	-0.1*1	-0.20	-0.13**	-0.41**
13.	Rajendra Sufalam	-0.81**	-0.08	-0.40	-0.56**	-2.25**	-79.75**	2.84**	-0.02	-0.16	0.03	0.29**
14.	JD-6 (Pusa Mahak)	-1.44**	-1.22**	-9.06**	-0.22	1.38**	35.66**	-1.75**	0.02	0.38*	0.08**	0.00
	CD 95% GCA(Line)	0.84	1.07	1.90	0.66	1.15	1.94	1.33	0.14	0.54	0.06	0.15
	CD 95% GCA(Tester)	0.53	0.68	1.20	0.42	0.73	1.23	0.84	0.09	0.34	0.03	0.09

Table 3 : Contd……

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Sr.No.	Parents	BYP	HI	OC	PA	SA	OA	LA	LNA	EA	SYP
1.	RH -30	2.97*	1.01*	-0.29**	-0.25**	0.20**	0.08**	-0.06**	-0.93**	0.29**	1.34**
2.	RAURD-172	-10.98**	-0.16	0.37**	-0.35**	0.06**	0.73**	0.79**	-1.00**	-0.71**	-2.34**
3.	RAURD-32	-8.25**	-1.19**	0.18**	0.20**	0.04**	0.99**	0.54**	0.05**	-0.74**	-2.86**
4.	RAURD-78	0.87	0.25	-0.29**	0.02	-0.06**	-0.49**	-0.76**	0.13**	0.19**	0.85
5.	RAURD-34	-19.78**	3.69**	0.21**	0.07**	-0.15**	-0.39**	1.05**	0.02**	-3.26**	-0.69
6.	RAURD-214	21.99**	-1.02*	-0.59**	-0.06**	0.15**	-0.33**	-0.06**	1.93**	-0.08	3.43**
7.	RAURD-153	-2.46*	0.07	-0.41**	0.18**	-0.03**	0.26**	-0.25**	1.45**	-2.50**	-0.80
8.	EC 401574	19.32**	0.28	0.48**	-0.04*	-0.09**	0.00	0.01	0.85**	1.73**	5.38**
9.	EC 399788	5.40**	-1.69**	0.13**	0.20**	-0.10**	-1.07**	-1.85**	-2.08**	5.75**	-0.87
10.	RAURD-170	-9.07**	-1.24**	0.21**	0.03	-0.01**	0.23**	0.58**	-0.42**	-0.68**	-3.46**
11.	Vardan	-7.74**	-0.15	-0.05**	-0.01	-0.09**	-0.52**	0.31**	0.71**	-0.08**	-2.10**
12.	Pusa bold	5.69**	-0.04	0.04	-0.11**	0.07**	-0.35**	-1.28**	-1.72**	2.23**	1.19**
13.	Rajendra Sufalam	2.48**	0.13	0.14**	0.00	0.02**	0.72**	1.09**	0.98**	0.18**	0.84**
14.	JD-6 (Pusa Mahak)	-0.43	0.06	-0.13**	0.11**	-0.01**	0.15**	-0.11**	0.03**	-2.33**	0.07
	CD 95% GCA(Line)	2.30	0.77	0.07	0.04	0.01	0.03	0.02	0.01	0.10	0.94
	CD 95% GCA(Tester)	1.45	0.49	0.04	0.02	0.01	0.02	0.01	0.01	0.06	0.60

* and ** indicate significance of values at P=0.05 and 0.01, respectively

as best general combiner for yield and oil content, whereas RH-30 followed by RAURD 214 for number of primary and secondary branches per plant, biological yield per plant and stearic acid; RAURD 153 for early flowering, short statured main shoot length, 1000 seed weight and siliqua length; RAURD 34 for early flowering, early maturity, short stature plant, siliqua on main raceme, 1000 seed weight, harvest index and linoleic acid shall be included in the breeding programme for accumulation of favourable alleles in a single genetic background. It suggested that these parental lines may be used in hybridization programme to have the superior recombinants for respective traits. These outcomes clearly reflected that there is scope for combining the component traits of the parents, which would ultimately improve the seed yield and oil quantity of resulting genotypes. In accordance to these observations, Singh and Dixit (2007) reported negative significant GCA effect for days to 50 per cent flowering, positive and significant GCA effect for number of primary branches and secondary branches per plant, siliqua on main raceme and seed yield per plant; Rameeh (2012) reported negative significant GCA effect for main shoot length; Turi *et al.* (2010) reported positive and significant GCA effect for number of siliqua per plant, Siliqua length, number of seeds per siliqua and seed yield per plant; Gupta *et al*. (2010) recorded high value of positive and significant GCA effect for 1000 seed weight, biological yield per plant and harvest index and Verma *et al.* (2011) reported high value of positive and significant GCA effect for oil content and seed yield per plant. Although all these, namely JD-6, EC 399788, Rajendra Sufalam, RAURD 214, RAURD 32, RAURD 34 and RAURD 153, general combiners identified have shown significant superiority for more attributes on the basis of their *per se* performance and rated as good general combiners (Table 4) but on overall basis, JD-6 was the only good general combiner common for earliness in flowering coupled with early maturity and shorter main shoot length; EC 399788 were general combiners common for two attributes namely high palmitic acid and low linolenic acid; one genotype each for number of siliqua on main raceme and seed yield per plant (Rajendra Sufalam); early flowering and more number of siliqua per plant (RAURD 214); high siliqua density and palmitic acid (RAURD 32); low erucic acid and early flowering (RAURD 34); days to 50 per cent flowering and 1000 seed weight (RAURD 153). As flowering initiation is first important phenological stage just after completion of vegetative phase and earliness provides sufficient time for the expression of other phenological stages in sequence this might be the probable reason two good general combiners namely, RAURD 214 and RAURD 153 along with their superiority for above mentioned component characters, also exhibited superiority for high number of siliqua per plant, 1000 seed weight, earliest flowering and maturity coupled with short plant stature, JD-6 clearly indicated its importance as short stature, early flowering, early maturity released variety for Eastern Zone including Bihar state.

Specific combining ability :

The negative and significant estimates of SCA effects for days to 50 per cent flowering, were obtained (Table 5) in the crosses RAURD 170/Vardan, RAURD 153/ JD-6 and EC 399788/Pusa Bold; whereas, for earliness in days to maturity, best two cross combinations were RAURD 153/JD-6 and RAURD 32/Rajendra Sufalam, suggesting that RAURD 153/JD-6 was best cross combinations for flowering maturity traits and could be further exploited to develop early flowering/early maturing mustard genotypes. Rameeh (2012) similarly found negative and significant SCA effect for days to 50 per cent flowering in most of the crosses studied. The crosses involving EC399788/Pusa Bold, RAURD 153/JD-6 and RAURD 172/JD-6 exhibited negative and significant SCA effects for main shoot length, suggesting there usefulness in developing genotypes with shorter main shoot length. Three crosses RAURD 153/Pusa Bold, RAURD 78/Pusa Bold and RAURD 214/Rajendra Sufalam showed significant and positive SCA effects for primary and secondary branches per plant as also earlier observed and reported by Arifullah *et al.* (2012) and Verma *et al.* (2011).After subsequent selection in advanced generations, the suggested crosses may be utilized to develop the inbred comprising the higher number of primary and secondary branches per plant subsequently contributed towards seed yield. EC 401574/Rajendra Sufalam for siliqua per plant and siliqua on main raceme and RAURD 214/ Rajendra Sufalam for siliqua length and number of seeds per siliqua exhibited positive and

Table 4 : Ranking of desirable parents on the basis of *per se* performance and GCA effects for 21 characters

Characters	Best parents on the basis of *per se* performance	Best general combiner	Common parent
DFF	JD-6, Rajendra Sufalam, Vardan , EC 399788, RAURD-34, RAURD-214, RAURD-153	RAURD-34, RAURD-214 , JD-6, RAURD-153	RAURD-34, RAURD-214 , JD-6, RAURD-153
DM	JD-6, EC 399788	RAURD-34, RAURD-32, JD-6	JD-6
MSL	JD-6, Rajendra Sufalam, RAURD-153	RH-30, JD-6, RAURD-34, RAURD-172,	JD-6
PBP	RAURD-34	RH-30, RAURD 214, Pusa Bold	-
SBP	RAURD-34, RAURD-32, RAURD-214	RH-30, RAURD 214, EC 399788	RAURD 214
SPP	RAURD 78, RAURD-34, RAURD-172, RAURD-214	RH-30, RAURD 32, Pusa Bold, EC 401574	-
SMR	RAURD-214, RAURD-153, Rajendra Sufalam	RAURD-34, RAURD-78, EC 401574, Rajendra Sufalam	Rajendra Sufalam
SL	EC 399788, RAURD 32	RAURD-214, RAURD-153	-
SS	RAURD 78	RAURD 32, RAURD 172	-
SD	EC 399788, RAURD 32, Rajendra Sufalam, RAURD 153	RAURD 32, RAURD 214, RH-30	RAURD 32
TSW	Rajendra Sufalam, RAURD 153	RAURD 78, RAURD 34, RAURD 153	RAURD 153
BYP	RAURD 153	RAURD 214, EC 401574, Pusa Bold	-
HI	Rajendra Sufalam, RAURD 78, EC 401574	RH-30, RAURD 34	-
PA	RAURD 214, RH-30, EC 399788, RAURD 32	EC 399788, RAURD 32	EC 399788, RAURD 32
SA	Rajendra Sufalam, RAURD 78, EC 401574	RH-30, RAURD 214	-
OA	RAURD 214, EC 399788,	RAURD 32, RAURD 172, Rajendra Sufalam,	-
LA	RAURD 153, RAURD 170, EC 401574, RH-30, RAURD 214	RAURD 172, Rajendra Sufalam, RAURD 34, RAURD 170	RAURD 170
LNA	EC 399788, EC 401574, RAURD 214, RAURD 153, RAURD-34	EC 399788, RAURD 172, Pusa Bold	EC 399788
EA	RAURD-34, RH-30	RAURD-34, RAURD 153, JD-6	RAURD 34
OC	JD-6	RAURD 172, EC 401574	-
SYP	RAURD 153, Rajendra Sufalam, RAURD 78,	Rajendra Sufalam, EC 401574, RH-30, Pusa Bold	Rajendra Sufalam

Table 5 : Specific combining ability effect of crosses for twenty one characters in Indian mustard

Sr.No.	Crosses	DFF	DM	MSL	PBP	SBP	SPP	SMR	SL	SS	SD	TSW
1.	RH -30 / Vardan	1.48	1.97	-5.38**	1.49 *	2.47 *	481.92**	-14.70**	-0.05	-0.91	0.07	0.38 *
2.	RH -30 / Pusa Bold	-2.39**	1.90	7.48**	0.60	4.66**	51.22**	1.15	-0.13	1.15 *	-0.04	-0.06
3.	RH -30 / Rajendra Sufalam	-1.69 *	-2.00	-6.38**	-1.51 *	-2.95*	-48.40**	9.58 **	0.18	0.98	0.12*	-0.11
4.	RH -30 /JD-6	2.61 **	-1.87	4.28 *	-0.58	-4.18 **	-48.74**	3.97 **	0.00	-1.23*	-0.15 *	-0.21
5.	RAURD-172 / Vardan	2.06 *	0.63	8.64**	0.68	4.20***	-43.42**	-0.95	-0.10	-0.59	-0.15**	-0.25
6.	RAURD-172 / Pusa Bold	-0.14	-0.43	11.58**	-2.35**	-8.67 ***	144.35**	1.90	-0.11	-0.86	-0.03	0.03
7.	RAURD-172 / Rajendra Sufalam	-1.11	0.33	-7.71**	0.34	3.85**	-177.07**	0.13	0.02	0.10	-0.05	0.33*
8.	RAURD-172 / JD-6	-0.81	-0.53	-12.51**	1.34*	0.62	76.13**	-1.08	0.19	1.35 *	0.23**	-0.11
9.	RAURD-32 / Vardan	0.14	-1.87	6.87**	-1.87**	-2.53*	-445.68**	4.27**	0.40**	1.40*	0.10	0.04
10.	RAURD-32 / Pusa Bold	-2.39 **	1.07	-8.18**	0.90	5.66**	-56.25**	3.39*	-0.11	0.32	-0.22**	0.67**
11.	RAURD-32 / Rajendra Sufalam	1.98 *	-2.50 *	7.74**	1.19	-5.08 **	-140.73**	-5.72**	-0.30*	-2.32**	0.04	-0.84**
12.	RAURD-32 / JD-6	0.28	3.30**	-6.43**	-0.21	1.95	642.66**	-1.93	0.02	0.60	0.08	0.12
13.	RAURD-78 / Vardan	0.47	-0.12	-2.97	-0.24	-0.68	136.52**	10.32**	-0.36*	-1.00	0.02	-0.09
14.	RAURD-78 / Pusa Bold	2.28**	-0.18	5.55 **	1.67 *	8.38**	205.59**	-8.16**	0.10	-0.21	-0.15**	-0.89**
15.	RAURD-78 / Rajendra Sufalam	-0.36	1.58	-4.66 *	-1.11	-3.77**	-108.30**	-1.80	-0.20	1.08*	0.10	0.89**
16.	RAURD-78 / JD-6	-2.39**	-1.28	2.08	-0.31	-3.93 **	-233.81**	-0.35	0.47 **	0.13	0.03	0.08
17.	RAURD-34 / Vardan	-2.61**	-1.78	-9.34**	0.76	1.15	176.28**	1.58	0.34*	2.05**	0.01	-0.50**
18.	RAURD-34 / Pusa Bold	1.52	-1.52	2.18	-0.80	-7.05**	-255.81**	-1.16	-0.39**	-0.43	0.10	-0.12
19.	RAURD-34 / Rajendra Sufalam	-0.11	-0.42	7.98 **	-0.31	3.40 **	14.03**	-1.07	0.00	-0.93	-0.02	0.24
20.	RAURD-34 / JD-6	1.19	3.72**	-0.82	0.35	2.50*	65.49**	0.65	0.05	-0.68	-0.09	0.38*
21.	RAURD-214 / Vardan	-0.44	-0.20	0.22	-0.40	-5.24 **	-238.67**	-2.07	-0.19	-0.19	0.01	0.24
22.	RAURD-214 / Pusa Bold	-0.64	-1.60	-12.72**	-0.49	-6.38 **	-68.36**	8.65**	0.11	-0.59	0.04	0.04
23.	RAURD-214 / Rajendra Sufalam	0.06	0.17	-11.01**	1.50 *	8.68 **	302.68**	-5.45**	0.61 **	1.70**	-0.08	-0.50**
24.	RAURD-214 / JD-6	1.02	1.63	23.51**	-0.61	2.94*	4.34*	-1.13	-0.53**	-0.92	0.04	0.22
25.	RAURD-153 / Vardan	1.23	2.72*	-3.93*	-1.79 **	-3.13**	3.81	5.17 **	0.59 **	-1.24 *	-0.04	0.34 *
26.	RAURD-153 / Pusa Bold	1.36	0.98	5.14**	1.78**	2.13	283.91**	-3.65**	-0.35*	-0.51	0.10	-0.05
27.	RAURD-153 / Rajendra Sufalam	4.06**	1.42	15.95**	0.41	-0.55	-74.37**	-0.75	-0.09	0.91	-0.06	-0.41**
28.	RAURD-153 / JD-6	-6.64**	-5.12**	-17.16**	-0.40	1.55	-213.35**	-0.77	-0.14	0.83	0.00	0.12
29.	EC 401574 / Vardan	-0.11	-1.87	9.30**	0.28	5.04**	-33.90**	-1.58	-0.43**	0.86	0.04	-0.07
30.	EC 401574 / Pusa Bold	-0.31	-0.27	2.13	-1.75**	-4.17**	-183.46**	-5.00 **	0.64**	0.26	0.00	0.13
31.	EC 401574 / Rajendra Sufalam	0.73	1.50	-12.49**	1.07	1.95	326.58**	12.03 **	-0.24	-1.59**	-0.07	0.31*
32.	EC 401574 / JD-6	-0.31	0.63	1.05	0.40	-2.81*	-109.22**	-5.45**	0.02	0.47	0.03	-0.37*
33.	EC 399788 / Vardan	5.47**	1.13	-3.08	1.38*	-4.51 **	-54.67**	2.85 *	-0.06	0.78	-0.01	-0.13
34.	EC 399788 / Pusa Bold	-3.39 **	0.40	-18.26**	0.68	9.95**	-38.90**	-1.76	-0.10	-0.56	0.10	0.29
35.	EC 399788 / Rajendra Sufalam	-1.69 *	-0.83	14.44 **	-0.76	1.80	156.15**	-1.67	0.21	-0.07	0.03	0.13
36.	EC 399788 / JD-6	-0.39	-0.70	6.90**	-1.30	-7.23**	-62.59**	0.58	-0.05	-0.15	-0.12*	-0.29
37.	RAURD-170 / Vardan	-7.69**	-0.62	-0.32	-0.27	3.24**	17.80**	-4.88**	-0.13	-1.15 *	-0.04	0.04
38.	RAURD-170 / Pusa Bold	4.11 **	-0.35	5.10**	-0.23	-4.50**	-82.30**	4.64 **	0.34*	1.44 **	0.11	-0.04
39.	RAURD-170 / Rajendra Sufalam	-1.86 *	0.75	-3.87*	-0.81	-7.32**	-250.58**	-5.27**	-0.19	0.13	-0.02	-0.06
40.	RAURD-170 / JD-6	5.44**	0.22	-0.91	1.32*	8.59**	315.08**	5.52**	-0.03	-0.42	-0.05	0.06

Table 5 : Contd…………

Table 5 : Contd…..

Sr.No.	Crosses	BYP	HI	OC	PA	SA	OA	LA	LNA	EA	SYP
1.	RH -30 / Vardan	38.90 **	-6.01 **	-1.57**	0.40**	0.05 **	-1.13**	0.24 **	0.30**	0.18	0.61
2.	RH -30 / Pusa Bold	-15.12 **	-0.16	0.09	-0.49**	-0.18**	-1.22 **	1.09**	1.22**	0.01	-2.99 **
3.	RH -30 / Rajendra Sufalam	-10.78**	5.18**	1.17 **	0.42 **	0.06 **	1.84 **	-0.38**	-0.46**	-1.62**	3.87**
4.	RH -30 /JD-6	-13.00**	0.99	0.32**	-0.33**	0.07**	0.51**	-0.94**	-1.06**	1.44**	-1.49
5.	RAURD-172 / Vardan	8.26**	2.90**	-0.35**	0.10**	-0.20**	-0.36 **	1.51**	1.36**	-0.79 **	4.97**
6.	RAURD-172 / Pusa Bold	0.96	2.74**	0.17 *	-0.35**	-0.16**	0.14**	-0.91**	0.29**	1.11**	3.11**
7.	RAURD-172 / Rajendra Sufalam	-18.50 **	-4.87**	-0.30**	-0.36**	0.21**	-1.05 **	0.01	-0.47**	1.24**	-8.96**
8.	RAURD-172 / JD-6	9.28**	-0.77	0.48**	0.61**	0.15**	1.27**	-0.62**	-1.18 **	-1.55**	0.88
9.	RAURD-32 / Vardan	-18.21**	-1.10	0.71 **	-0.03	0.02*	-0.25**	-1.21**	0.48**	1.37 **	-4.68**
10.	RAURD-32 / Pusa Bold	-0.97	0.97	0.01	-0.05	0.14 **	-1.17**	-1.54 **	0.65 **	-4.86**	0.65
11.	RAURD-32 / Rajendra Sufalam	-0.83	-2.67**	0.35**	-0.20**	-0.07 **	0.67**	2.19**	0.54**	-0.03	-3.56**
12.	RAURD-32 / JD-6	20.01**	2.80**	-1.07**	0.28**	-0.09**	0.75**	0.56**	-1.67**	3.51**	7.59 **
13.	RAURD-78 / Vardan	-9.06**	-1.95*	0.05	-0.07	0.23 **	-0.65**	-0.27 **	-1.85 **	-4.70**	-4.14**
14.	RAURD-78 / Pusa Bold	9.78**	5.45**	0.61**	0.52 **	-0.07**	0.55 **	0.34**	1.11**	3.69 **	9.31 **
15.	RAURD-78 / Rajendra Sufalam	-2.01	-1.50	-1.17**	-0.11**	-0.31**	0.98**	1.78**	1.06**	-1.40**	-2.68**
16.	RAURD-78 / JD-6	1.30	-2.00 *	0.51**	-0.34 **	0.15**	-0.88 **	-1.84**	-0.32**	2.41**	-2.49 *
17.	RAURD-34 / Vardan	-2.81	0.65	0.15 *	-0.18**	0.00	1.83**	1.69**	-1.49**	3.25**	-0.20
18.	RAURD-34 / Pusa Bold	-27.91**	-0.41	0.13	-0.02	0.09**	0.62**	0.21**	0.15**	-8.62**	-7.36**
19.	RAURD-34 / Rajendra Sufalam	15.84**	0.61	-0.07	-0.50**	0.12**	-2.12 **	-3.18**	-0.89**	7.38**	4.78 **
20.	RAURD-34 / JD-6	14.88**	-0.86	-0.21 **	0.70**	-0.21**	-0.33**	1.28**	2.22**	-2.01**	2.78 **
21.	RAURD-214 / Vardan	-14.05 **	2.20 **	0.41 **	0.06	-0.05**	-0.68**	-1.69 **	1.10 **	2.26**	0.02
22.	RAURD-214 / Pusa Bold	7.40**	5.59**	0.33 **	0.32 **	0.05**	1.50**	0.00	-0.32**	0.42**	10.25**
23.	RAURD-214 / Rajendra Sufalam	11.87**	-5.93**	-0.44**	-0.66**	-0.09**	-1.19 **	0.20**	0.43 **	-0.29**	-6.69 **
24.	RAURD-214 / JD-6	-5.22 *	-1.85*	-0.29 **	0.28**	0.09**	0.36 **	1.50**	-1.21**	-2.40**	-3.57 **
25.	RAURD-153 / Vardan	-9.06 **	2.84**	-0.49**	-0.17 **	0.31 **	-0.09 **	-0.54**	-0.27**	0.26**	1.39
26.	RAURD-153 / Pusa Bold	23.38 **	-3.18 **	-0.49 **	-0.07*	-0.46**	-0.58**	-0.51**	-0.85**	2.95**	1.04
27.	RAURD-153 / Rajendra Sufalam	-14.22**	1.27	0.70 **	1.00 **	0.39 **	1.67 **	-0.12 **	-1.24**	-3.38 **	-1.64
28.	RAURD-153 / JD-6	-0.10	-0.93	0.29**	-0.75 **	-0.24**	-1.00**	1.17**	2.36**	0.17	-0.79
29.	EC 401574 / Vardan	-12.44**	-6.31**	0.15 *	0.37**	0.17 **	1.28**	2.47**	1.68**	-3.33**	-10.73**
30.	EC 401574 / Pusa Bold	-7.54**	-1.59*	-0.19 **	0.00	-0.24 **	0.09**	-0.61 **	-1.37**	4.16**	-4.49**
31.	EC 401574 / Rajendra Sufalam	26.60**	4.91**	0.32**	0.03	0.30**	-1.26**	-0.90**	-0.50**	1.32**	13.55**
32.	EC 401574 / JD-6	-6.62**	2.99**	-0.28**	-0.40**	-0.23 **	-0.12**	-0.97**	0.19**	-2.14**	1.67
33.	EC 399788 / Vardan	3.67	4.60**	0.83**	-0.14**	-0.19**	0.12 **	-1.12**	-1.54**	-1.12 **	6.65 **
34.	EC 399788 / Pusa Bold	9.11**	-3.45**	-1.05**	-0.18**	0.45**	0.15**	1.78**	0.36**	-1.10**	-2.92**
35.	EC 399788 / Rajendra Sufalam	8.05**	0.82	0.11	0.47 **	-0.13**	-0.47**	-0.80**	0.94**	-0.15	2.65**
36.	EC 399788 / JD-6	-20.83**	-1.98*	0.12	-0.15**	-0.13**	0.20**	0.14**	0.25**	2.37 **	-6.39 **
37.	RAURD-170 / Vardan	14.81**	2.17**	0.11	-0.35**	-0.33**	-0.08**	-1.08**	0.23**	2.62**	6.11**
38.	RAURD-170 / Pusa Bold	0.91	-5.96 **	0.40 **	0.33**	0.36**	-0.07*	0.15**	-1.24**	2.24**	-6.61**
39.	RAURD-170 / Rajendra Sufalam	-16.02**	2.18 **	-0.66 **	-0.08 *	-0.48**	0.92**	1.20**	0.59**	-3.07 **	-1.31
40.	RAURD-170 / JD-6	0.30	1.60 *	0.14*	0.10**	0.45**	-0.77**	-0.27**	0.42**	-1.80**	1.81

* and ** indicate significance of values at P=0.05 and 0.01, respectively

significant SCA effects, may be exploited to develop inbreds having subsequent superiority in these important traits. Similarly Arifullah *et al.* (2012) reported significant positive SCA effect for siliqua per plant, siliqua length and seeds per siliqua, Verma *et al.* (2011) recorded high value of SCA effect for number of siliqua on main raceme. Highest positive and significant SCA effects for 1000 seed weight observed in four cross combination namely, RAURD 78/Rajendra Sufalam followed by RAURD 32/Pusa Bold, RAURD 34/JD-6 and RH-30/Vardan. So, to have the bolder seeded genotypes these cross combinations may be further advanced and exploited. Arifullah *et al.* (2012) also observed high positive and significant SCA effects for 100 seed weight. For biological yield per plant and harvest index the desirable cross combinations EC401574/Rajendra Sufalam and RAURD 153/Pusa Bold were best ones and may be utilized, to enhance the biomass of crop and harvest index, similar finding were reported by Gupta *et al.* (2010). Only one cross combination RAURD 153/Rajendra Sufalam exhibited positive and significant SCA effects for the palmitic acid, stearic acid and oleic acid, whereas RAURD 78/Vardan exhibited desirable negative and significant SCA effect for linolenic acid and erucic acid both; signifies importance of these crosses to develop the inbred in advanced generations comprising the high level of palmitic acid, stearic acid, oleic acid and linoleic acid whereas, low level of both the linolenic acid and erucic acid for improved oil quality, which corroborated with the earlier findings of Turi *et al.* (2010). RH-30/Rajendra Sufalam, EC399788/Vardan and RAURD 32/Vardan, were the best performing cross combinations for oil content, whereas for the yield best performing cross combinations were EC401574/Rajendra Sufalam, RAURD 214/Pusa Bold, RAURD 78/Pusa Bold and RAURD 32/JD-6 subsequently these cross combinations may be handeled to develop the superior inbreds for higher yield and oil content. Earlier reported by Verma *et al*. (2011) for oil content and Vaghela *et al*. (2011) for seed yield per plant also support the present phenomenon of crosses exhibiting superiority for the mentioned characters including yield and oil content discussed in this paper.

Conclusion:

The genetic improvement of a crop depends upon the correct choice of parents from available gene pool. Such a selection is not an easy task, since phenotypic expression is determined not only by the genotype but is also influenced by environment and interaction between genotype and environment. It, therefore, necessitates critical assessment of the material. In this respect, statistical tools are of immense importance in plant breeding programme based on a sound biometrical background. The improvement in the economic complex quantitative characters like yield, which is usually subjected to genotypic and environmental interactions, is the principal objective in any plant breeding programme. The understanding of gene action of such polygenic characters is essential for formulating effective procedure for the improvement of any crop species like Indian mustard. Thus, estimates of gene effects and genetic variance studied and explained in the present investigation may certainly help in understanding the genetic potential of the breeding material and their subsequent utilization in genetic enhancement of Indian mustard.

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