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Research Article

Combining ability and economic heterosis for yield and oil quality traits in Indian mustard (*Brassica juncea* L. Czern & Coss)

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Abstract
The estimates of *gca* and *sca* variances showed the preponderance of non-additive gene action for all the traits studied except siliqua density and 1000 seed weight. Among the lines and testers, good general combiner RH-30, RAURD 214, EC 401574 and Rajendra Sufalam have exhibited desirable negative and highly significant gca effect for days to 50% flowering and days to maturity and positive and highly significant for number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, siliqua length, siliqua density, 1000 seed weight, biological yield per plant, stearic acid, oleic acid, oil content and seed yield per plant indicating the presence of additive gene action or additive x additive interaction effects. Heterotic cross combinations were more frequently observed in crosses involving H x H, L x H and L x L *gca* of the parents.

Key words: Indian mustard, Genetic divergence, combining ability, quantitative traits.

Introduction

Cultivated oilseeds *brassica* shows considerable diversity, which can be suitability exploited through focused breeding programme. The future thrust areas of research in rapeseed-mustard *inter-alia* include exploitation of available heterosis in Indian mustard for yield targeting low and high input situations. 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 program. 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. Information and exact study of combining ability can be useful in regard to selection of breeding methods and selection of lines for hybrid combination. Thus, the present investigation on genetic divergence and combining ability in relation to economic heterosis for yield and oil quality traits in Indian mustard was taken up.

Material and Methods

Ten lines *viz.*, RAURD-172, RAURD-32, RAURD-78, RAURD-34, RAURD-214, RAURD-153, RAURD-170, RH -30, EC 399788, EC 401574 and 4 testers namely, JD-6, Pusa Bold, Vardan and Rajendra Suflam were crossed in line x tester (Kempthorne, 1957) design during 2011-12 and to obtain 40 F_1 crosses, evaluating these 40 F_1s and 14 parents along with check (Varuna) in Randomized Block Design with three replications during the crop season 2012-13 at the research farm of Tirhut College of Agriculture, Dholi, Muzaffarpur (Rajendra Agricultural University-Pusa), Bihar. This site is located at to 25.5^0 N latitude, 35.4^{0}E longitude and an altitude 52.2 m average sea level. All the entries were grown in Randomized Block Design with three replications. Each entries was sown in a plot consisting of three rows of 5m length in three replications with inter and intra row spacing of 30cm x 10cm. Recommended package of practices for Indian mustard were followed to raise a healthy crop. Data was recorded on five randomly selected competitive plants of each genotype in all the replications for twenty one characters *viz.*, days to 50% 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, 1000 seed weight (g), biological yield per plant (g), harvest index (%), 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. Heterosis expressed as percent increase or decrease of hybrids (F_1) over standard heterosis (Hc) was determined as outlined by (Meredith and Bridges, 1972). The degree of dominance was also calculated as $((\sigma^2D/\sigma^2A)0.5$.

Results and Discussion

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 sum of squares due to lines were observed highly significant for days to 50% flowering, main shoot length, siliqua length, siliqua density, 1000 seed weight, biological yield per plant and linolenic acid. Variances 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% 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. 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 Gupta *et al.* (2010), Vaghela *et al.* (2011) and Azzinia (2012). The ratio of gca and sca variance as less than one and degree of dominance more than one for days to 50% 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. It 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 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 reported by Singh *et al.* (2007), Akbar *et al.* (2008) and Vaghela *et al.* (2011). EC401574 was identified as best general combiner for yield and oil content; whereas RH-30 and RAURD 214 for number of primary branches per plant, number of secondary branches per plant, biological yield per plant, stearic acid; RAURD 34 for early flowering, early maturity, short stature plant, siliqua on main raceme, 1000 seed weight, harvest index, linoleic acid and highest negative significant gca effect for erucic acid can be included in the breeding programme for accumulation of favorable alleles in a single genetic background. The good general combiners generally possess high additive effects. Thus, it can be inferred that high sca effects of crosses involving H x H and H x L combiner might have resulted due to the interaction of additive type of epistasis and that of L x L combiners might be due to non-additive type of gene action. In case of H x H crosses there was possibility of complementary epistatic effects acting in the direction of additive effects of good combiners and L x L combiners might be due to dominance x recessive interaction expected to produce desirable segregates (Gupta *et al.*, 1991). It may not always be necessary to attempt crosses between H x H *gca* parents. Crosses with low or average gca parents can also manifest high sca in suitable cross combinations and attributable to interaction effects (Singh and Sachan, 2003). Hybrids between lines of diverse origin generally display a greater heterosis than those between closely related parents, but maximum heterosis generally occurs at an optimal or intermediate level of diversity. Further crosses involving one high/ average and another low general combiner displayed high *sca* effects there by producing more heterotic effects in Indian mustard (Sutariya *et al.*, 2011).

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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 Eff.	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

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 Eff.	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

DFF= Days to 50% flowering, **DM**= Days to maturity, **MSL**= Main shoot length, **PBP**= Primary branches per plant, **SBP**= Secondary branches per plant, **SPP**= Siliqua per plant, **SMR**= Siliqua on main raceme, **SL**= Siliqua length, **SS**= Seeds per siliqua, **SD**= Siliqua density, **TSW**=1000 seed weight, **BYP**= Biological yield per plant , **HI**= Harvest index, **OC**= Oil content, **PA**= Palmitic acid, **SA**= Stearic acid, **OA**= Oleic acid, **LA**= Linoleic acid, **LNA**= Linolenic acid, **EA**= Erucic acid, **SYP**= Seed yield per plant

Table 2. Combining ability effects, heterosis, clusters and *per se* performance over standard variety in Indian mustard

Characters	Best heterotic crosses	Economic heterosis (%)	gca	sca	*Per se* performance
Days to 50% flowering	RAURD 153/JD-6	-25.44	H x H	-6.64	42.00
	RAURD 34/Vardan	-12.43	H x L	-2.61	49.33
	RAURD 214/Rajendra Sufalam	-10.65	H x H	0.06	50.33
Days to maturity	-	-	-	-	-
Main shoot length	RAURD 172/JD-6	-19.89	H x H	-12.51	183.11
	RAURD 153/JD-6	-19.69	H x H	-17.16	183.56
	RAURD 32/JD-6	-14.51	H x H	-6.43	195.39
Primary branches per plant	RAURD 153/Pusa Bold	45.16	L x H	1.78	12.00
	RAURD 78/Pusa Bold	41.13	L x H	1.67	11.67
	RH-30/Vardan	39.52	H x L	1.49	11.53
Secondary branches per plant	EC399788/Pusa Bold	72.24	H x H	9.95	38.47
	RAURD 170/JD-6	57.01	H x H	8.59	35.07
	RH-30/Pusa Bold	51.34	H x H	4.66	33.80
Siliqua per plant	RAURD 32/JD-6	148.82	H x H	642.66	1724.33
	RH-30/Vardan	110.12	H x L	481.92	1456.13
	EC401574/Rajendra Sufalam	76.57	H x L	326.58	1223.60
Siliqua on main raceme	EC401574/Rajendra Sufalam	46.62	L x H	12.03	66.47
	RAURD 78/Vardan	35.29	H x L	10.32	61.33
	RAURD 214/Pusa Bold	21.91	L x H	8.65	55.27
Siliqua length	RAURD 153/Vardan	36.01	H x H	0.59	4.63
	RAURD 214/RAjendra Sufalam	32.29	H x L	0.61	4.51
	RAURD 78/JD-6	22.90	H x L	0.47	4.19
Seeds per siliqua	RAURD 172/JD-6	33.13	H x H	1.35	14.20
	RAURD 32/Vardan	25.63	H x L	1.40	13.40
	RAURD 34/Vardan	23.75	L x L	2.05	13.20
Siliqua density	RH-30/Rajendra Sufalam	36.17	H x L	0.12	1.49
	RH-30/Vardan	31.61	H x L	0.07	1.44
	RAURD 32/JD-6	31.61	H x H	0.08	1.44
1000 seed weight	RAURD 78/Rajendra Sufalam	30.35	H x H	0.89	6.03
	RAURD 34/Rajendra Sufalam	16.08	H x H	0.24	5.37
	RAURD 153/Vardan	18.67	H x H	0.34	5.49
Biological yield per plant	EC401574/Rajendra Sufalam	30.18	H x H	26.60	167.07
	RAURD 214/Rajendra Sufalam	20.78	H x H	11.87	155.00
	RH-30/Vardan	19.06	H x H	38.90	152.80
Harvest index	RH-30/Rajendra Sufalam	61.97	H x L	5.18	28.71
	RAURD 78/Pusa Bold	58.19	L x L	5.45	28.04
	EC401574/Rajendra Sufalam	56.31	L x L	1.59	27.70
Oil content	-	-	-	-	-
Palmitic acid	RAURD 153/Rajendra Sufalam	82.96	H x L	1.00	3.34
	RAURD 34/JD-6	66.27	H x H	0.70	3.04
	EC 399788/Rajendra Sufalam	55.45	H x L	0.47	2.84
Stearic acid	RAURD 170/JD-6	117.06	L x L	0.45	1.08
	EC 399788/Pusa Bold	116.39	L x H	0.45	1.07
	RAURD 170/Pusa Bold	116.19	L x H	0.36	1.07
Oleic acid	RAURD 153/Rajendra Sufalam	74.18	H x H	1.67	12.39
	RH-30/ Rajendra Sufalam	74.07	H x H	1.84	12.38
	RAURD 32/ Rajendra Sufalam	70.43	H x H	0.67	12.13
Linoleic acid	RAURD 32/ Rajendra Sufalam	50.94	H x H	2.19	20.25
	RAURD 34/Vardan	45.19	H x H	1.69	19.48
	RAURD 172/Vardan	41.95	H x H	-0.91	19.05
Linolenic acid	EC 399788/Pusa Bold	-13.19	L x L	0.36	9.92
	RAURD 170/Pusa Bold	-12.75	L x L	-1.24	9.97
	RAURD 172/Pusa Bold	-4.37	L x L	0.29	10.93
Erucic acid	RAURD 34/Pusa Bold	-6.59	L x H	-8.62	39.17
	RAURD 34/JD-6	-1.70	L x L	-2.01	41.22
Seed yield per plant	EC 401574/Rajendra Sufalam	103.76	L x H	13.55	46.27
	RAURD 214/Pusa Bold	82.22	H x H	10.35	41.38
	RAURD 78/Pusa Bold	66.71	L x H	9.31	37.85