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Line x Tester Analysis in Indian Mustard (*Brassica juncea* L.) Czern and Coss

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A B S T R A C T

Diallel analysis was done using 60 F_1s obtained from 15 lines x 4 testers in line x tester mating design. Highly significant gca and sca various were observed. Non additive genetic variances were predominant for most of the characters. Based on gca effects DRB 20004-3, KMR 10-1, NDR-8501, Kargil selection, Basanti and Parashmani in timely sown condition whereas DRB 2004-3, RH-58, Kargil selection, KM-9201 and KMR-10-2 under late sown condition were identified superior donors for seed yield. Best five crosses combinations based on durable sca effects for seed yield were RH 58 x CS-54, NDR-8501 x CS-54, Basanti x Urvashi, PRB-2004-3 x NDRE-4 and RMM-09-3 x Urvashi under timely sown and Kargil selection x Urvashi, KMR-10-1 x NDRE-4, Kargil selection x RGN-73, Narendra Swarna Rai-8 x CS-54 and Basanti x Urvashi in late sown condition.

Introduction

India is one of the largest rapeseed mustard growing country in the world occupying the third position in area and production after Canada and China. Brassica (rapeseed-mustard) is the most important edible oilseeds crop in India after soyabean and accounts 30% of the total oilseeds product in the country. When compared to other edible oils it has lowest amount of harmful saturated fatty acids. Mustard seed is the second largest produced oil seeds in the world with an area of 37.0 mha. With the production of 63.09 m tones and productivity of 18.50 q/ha. In India it had the area of 6.3 m ha. With the production of 7.6 m tones and productivity of 11.90 q/ha. Indian mustard {*Brassica juncea* (L.) Czern and Coss.}, which is cultivated throughout the world belong to family Cruciferae (Brassicaceae). It has 38 to 42% of oil and 24% protein. Since oilseeds account for nearly 14% of gross national product and 7% of the value of all agriculture products, therefore, Indian mustard assumes as an important crop.

Combining ability is the capacity of an individual to transmit superior performance to its offsprings. Combining ability of line or inbred is the important factor in determining future usefulness of the lines for developing

hybrids. Studies on combining ability are useful to understand the nature of genetic variances. It helps the breeder to choose suitable parents for developing hybrids or varieties.

Materials and Methods

The material for present investigation comprised of 60 F_1's (developed by crossing 15 lines *viz.*, NPJ 141, RH-0735, KMR-10-2, Parasmani-33, KMR-10-1, RRN-702, CAN-83, NDR-8501, Kargil Selection, Basanti, Narendra Swarna Rai-8, RMM-09-3, RH-58, KM-9201, PRB-2004-3 with 4 testers (NDRE-4, CS-54, RGN-73, Urvashi) in line x tester design. A total of 79 treatments (60F_1's + 15 lines+ 4 testers) were used for investigation. All the treatments were sown in randomized block design with three replications under two environments (timely sown 24 October-E_1 and late sown 19 November-E_2) during *Rabi*-2013. The entries were sown in a single row plot of 3m with inter and intra- row spacing of 45 cm and 15 cm respectively. Recommended agronomic practices were adopted to raise a good crop. The mean value of 5 randomly selected plants in F_1's and parental lines were employed for Line x tester analysis and combining ability estimation as out lined by Kempthorne 1957. Observations were recorded on eleven different qualitative characters, days to 50% flowering, days to maturity, primary branches/ plant, secondary branches/ plant, length of main raceme (cm), no. of silique on main raceme, seeds per siliqua, 1000 seed weight (g), seed yield/ plant (g), harvest index % and oil content (%). The data in days to 50% flowering, and days to maturity were taken as plot basis.

Results and Discussion

The analysis of variance of combining ability for different characters has been presented in table 1. The mean sum of squares due to lines were significant for days to 50% flowering, 100 seed weight and oil content under E_1 environment whereas it was non-significant for all the traits under late sown condition (E_2). The mean sum of squares due to testers was significant for days to 50% flowering, days to maturity, plant height, number of primary branches/ plant and 1000 seed weight under both the environment where as it was significant for no. of secondary branches/ plant only under timely sown condition (E_2). Interaction effect for lines and testers was found to be significant for all the characters under both the environments. Estimates of sca variances were higher than gca variance for all the traits studied indicating that dominance variance was more than the additive variance. Thus, for the improvement of these traits, biparental mating and recurrent selection is advocated. These results are in agreement with the findings of Thakral *et al.,* (2000), Lalita *et al.,* (2002) and Singh *et al.,* (2005). The estimates of general combining ability effects of lines and testers are presented in table 3. Estimates of GCA effects showed that it was not possible to pick out a good general combiner for all the characters because the combining ability effects of the parents were not consistent for all the yield components.

Among the parents, NDRE-4, recorded significant by negative gca effects (desirable direction) only for days to 50% flowering and days to maturity in E_1 and positive significant gca effects for number of secondary branches per plant under late sown condition (E_2). PRB-2004-3 was found to be a good general combiner for seed yield per plant, biological yield/plant, harvest index and oil content in E_1 and only for seed yield per plant, 1000 seed weight, harvest index and oil content in E_2. For seed yield good general combiners were PRB 2004-3, KMR-10-1, NDR-8501, Kargil selection and Basanti in E_1 and PRB-2004-3, RH-58, Kargil selection, KM-9201 and KMR-10-2 in E_2.

Table.1 Analysis of variance for combing ability for 13 characters in Line x Tester mating design in Indian mustard

Characters	Source of Variation							
	Lines		Testers		Lines x Testers		Errors	
d.f.	14		3		42		118	
	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
Days to 50% flowering	62.74**	103.37	184.13**	424.99*	18.60**	115.81**	1.05	3.46
Days to maturity	19.07	17.74	106.91**	152.78**	16.49**	23.47**	1.49	1.70
Plant Height	710.03	230.87	5018.33**	7089.36**	385.64**	264.89**	21.89	24.68
No. of primary branches /plant	1.03	1.69	5.98*	4.13*	1.63**	1.08**	0.29	0.33
No. of Secondary branches/ plant	13.67	10.56	54.32*	29.18	13.08**	17.45**	0.75	0.90
Length of main raceme (cm)	173.87	132.97	163.54	351.24	110.47**	130.13**	16.20	10.43
No. of Siliquae on main raceme	31.06	69.54	33.60	126.64	36.78**	61.68**	5.32	9.64
No. of seeds per siliqua	4.89	2.84	3.31	2.13	3.19**	1.93**	0.59	0.78
1000- seed weight (g)	178**	1.24	8.84**	8.23**	0.66**	0.74**	0.01	0.02
Seed Yield/ Plant (g)	15.35	8.12	15.45	8.26	144.67**	8.40**	0.99	0.32
Biological Yield	311.07	102.47	223.84	530.47	324.28**	206.27**	11.81	7.33
Harvest Index (%)	22.65	28.56	21.54	42.62	26.10**	18.50**	1.29	1.41
Oil content (%)	0.81*	1.53	1.39	1.05	0.41**	0.61**	0.00	0.00

*, ** significant at 5% and 1% probability levels, respectively.

Note –E_1= timely sown, E_2= late sown.

Table.2 Components of variance, degree of dominance, additive and dominance components and heritability in narrow sense for 13 characters in Indian mustard

Characters	gca variance (σ^2g)		sca variance (σ^2s)		Average degree of dominance $\sqrt{\sigma^2s/2\sigma^2g}$		Predictability ratio 2 σ^2g/2 σ^2g+ σ^2s		σ^2A		σ^2D		Heritability (h^2n) %	
	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
Days to 50% flowering	3.62	5.20	5.85	37.57	0.90	5.51	1.81	4.61	5.85	10.41	23.42	37.57	53.90	21.24
Days to maturity	1.63	2.16	4.99	7.20	1.24	2.96	2.53	2.67	3.26	4.33	4.99	7.20	37.24	35.65
Plant Height	86.96	119.13	122.15	79.61	0.84	0.91	1.70	1.33	173.93	238.26	122.15	79.61	57.50	72.96
No. of primary branches /plant	0.06	0.06	0.46	0.22	0.20	3.19	1.04	2.83	0.13	0.12	0.46	0.22	19.41	26.31
No. of Secondary branches/ plant	0.73	0.08	4.13	5.52	1.68	40.37	3.83	35.50	1.46	0.16	4.13	5.52	25.16	2.83
Length of main raceme (cm)	2.03	3.92	32.33	39.55	2.82	7.29	8.96	6.04	4.06	7.85	32.33	39.52	9.92	15.33
No. of Siliquae on main raceme	-0.15	1.27	10.59	17.37	@	9.45	@	7.84	-0.31	2.55	10.59	17.37	@	11.05
No. of seeds per siliqua	0.03	0.01	0.87	0.37	3.81	22.80	15.50	19.50	0.06	0.03	0.87	0.37	5.65	5.71
1000- seed weight (g)	0.16	0.14	0.004	0.24	0.11	1.78	1.01	1.86	0.32	0.28	0.21	0.24	59.35	52.95
Seed Yield/ Plant (g)	0.02	-0.007	4.61	2.68	10.74	@	116.25	-190.43	0.05	-0.01	4.61	2.68	1.04	-0.51
Biological Yield	-1.99	3.86	104.94	66.28	@	11.52	@	9.56	-3.98	7.73	104.94	66.28	@	10.11
Harvest Index (%)	-0.14	0.59	8.32	5.76	@	7.09	@	5.88	-0.28	1.19	8.32	5.76	@	16.27
Oil content (%)	0.24	0.02	0.13	0.20	0.52	7.24	1.27	6.00	0.04	0.04	0.13	0.20	26.27	19.13

@ Negative estimates; Note: E_1= timely sown, E_2= Late sown

Table.3 Estimates of GCA effects of parents (females and males) for 13 characters in Indian mustard

S. No.	Lines	Days to 50% flowering		Days to maturity		Plant height		No. of primary branches per plant	
		GCA		GCA		GCA		GCA	
		E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
1.	NPJ 141	1.45**	-2.77**	-0.83	-1.43**	-12.42**	4.85**	-0.08	-0.18
2.	**RH 0735**	1.45**	0.40	-0.66	0.91*	0.36	-4.31**	-0.43*	-0.08
3.	**KMR 10-2**	1.70**	0.90	-0.99**	2.16**	3.37**	7.12**	-0.02	0.29
4.	**Parashmani 33**	2.20**	1.07*	-1.83**	0.99*	-1.31	0.63	0.52*	0.66**
5.	**KMR 10-1**	0.45	4.82**	-1.99**	2.07**	8.64**	5.63**	0.10	0.48*
6.	**RRN 702**	1.20**	-0.27	-0.91*	-0.01	4.23**	-4.45**	-0.06	-0.03
7.	**ACN 83**	-1.05**	-1.52**	1.26**	-1.26**	-14.78**	0.37	0.32*	-0.57**
8.	**NDR 8501**	1.95**	-0.10	0.01	0.32	7.01**	-0.62	-0.46**	-0.23
9.	**Kargil Selection**	0.78**	-3.60**	1.51**	-0.01	2.51*	-2.14	0.21	0.48*
10.	**Basanti**	1.70**	4.65**	0.01	-0.26	10.04**	0.40	0.04	0.04
11.	**Narendra Swarna Rai 8**	1.70**	-1.27*	0.51	-1.01*	-10.04**	4.32**	0.18	-0.09
12.	**RMM 09-3**	-3.55**	-3.18**	0.09	-0.18	2.21	2.23	0.23	0.19
13.	**RH- 58**	-4.13**	2.40**	1.67**	-2.26**	0.37	-2.43	-0.12	-0.51**
14.	**KM 9201**	-3.80**	3.23**	-0.08	-0.01	-6.71**	-9.15**	-0.52**	0.05
15.	**PR09, B 2004-3**	-2.05**	-4.77**	2.26**	-0.01	6.54**	-2.47	0.09	-0.51**
	SE(gi) lines	0.41	0.71	0.50	0.55	1.78	2.08	0.20	0.26
Testers									
1.	NDRE 4	-2.99**	3.98**	-1.96**	-2.09**	-15.24**	-16.26**	0.53**	0.18
2.	CS 54	0.72**	-2.73**	-0.51**	2.18**	5.86**	9.19**	-0.21**	-0.29**
3.	RGN 73	1.12**	0.83**	1.22**	0.69**	8.14**	10.57**	-0.06	0.33**
4.	Uravshi	1.16**	-2.08**	1.24**	-0.78*	1.24	-3.50**	-0.26**	-0.22*
	SE(gi) tester	0.21	0.37	0.25	0.28	0.92	1.07	0.10	0.13

Cont.…

S. No.	Lines	No. of secondary branches per plant		Length of main raceme (cm)		No. of siliquae on main raceme		No. of seeds per siliqua	
		GCA		GCA		GCA		GCA	
		E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
1.	NPJ 141	1.15**	0.46	5.27**	2.89**	-0.86	1.08	0.53*	0.60*
2.	RH 0735	-1.28**	-1.09**	-1.89	0.91	-2.29**	0.44	-0.23	-0.43
3.	KMR 10-2	-2.04**	1.83**	-2.76*	-0.54	-1.42*	-0.70	-0.20	-0.09
4.	Parashmani 33	0.76**	0.64*	-3.27**	3.91**	-1.15	2.92**	0.05	0.21
5.	KMR 10-1	-0.44	1.08**	0.29	2.95**	0.35	3.28**	0.00	0.01
6.	RRN 702	-0.73**	-0.63*	-1.53	-4.90**	-0.66	-1.82*	-0.74**	0.16
7.	ACN 83	1.27**	-0.40	-7.80**	5.44**	0.40	1.09	-1.30**	-0.29
8.	NDR 8501	-1.13**	0.87*	3.16**	-0.78	0.80	0.77	-0.63**	-0.82**
9.	Kargil Selection	1.47**	0.35	2.14*	-2.55*	3.56**	1.21	0.85**	0.56*
10.	Basanti	0.15	0.09	3.14**	-0.70	2.44**	1.69	1.32**	1.14**
11.	Narendra Swarna Rai 8	1.25**	0.22	-1.41	-0.48	-0.75	2.09*	-0.20	-0.15
12.	RMM 09-3	0.63**	-1.46**	-3.34**	-5.38**	0.31	-2.08*	0.32	-0.11
13.	RH- 58	-0.08	0.18	3.15**	4.26**	0.50	-0.99	0.09	-0.51
14.	KM 9201	-0.51*	-1.24**	-1.50	-2.07*	-2.23**	-3.96**	-0.17	-0.15
15.	PR09, B 2004-3	-0.46	-0.90**	6.34**	-2.96**	1.02	-5.02**	0.28	-0.12
	SE(gi) lines	0.34	0.38	1.51	1.38	0.47	1.26	0.30	0.36
Testers									

1.	NDRE 4	1.60**	1.14**	-2.78**	-3.11**	-1.19**	-0.96*	-0.25*	0.00
2.	CS 54	-0.74**	-0.68**	0.43	3.14**	0.64	0.42	0.06	-0.14
3.	RGN 73	-0.14	-0.04	0.86	1.39**	-0.09	2.17**	0.36**	0.31*
4.	Uravshi	-0.72**	-0.42	1.50**	-1.42**	0.64	-1.63**	-0.17	-0.17
	SE(gi) tester	0.17	0.19	0.78	0.71	1.82	0.65	0.15	0.18

Cont……

S. No.	Lines	1000-seed weight (g)		Seed yield per plant (g)		Biological yield (g)per plant		Harvest Index (%)		Oil content (%)	
		GCA		GCA		GCA		GCA		GCA	
		E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
1.	NPJ 141	0.08*	0.32**	-0.32	-0.55**	-2.99**	-1.95*	1.01**	-0.39	-0.45**	-0.49**
2.	RH 0735	0.63**	0.37**	-0.53*	-0.78**	-2.73**	-1.23	0.28	-1.30**	0.03	0.11**
3.	KMR 10-2	-0.08*	-0.05	-2.15**	0.44*	-10.18**	2.57**	0.60	-0.18	0.06	0.01
4.	Parashmani 33	0.54**	-0.03	-0.12	0.23	-1.13	0.91	0.43	0.36	0.39**	0.48**
5.	KMR 10-1	0.05	-0.01	1.23**	0.21	5.03**	3.10**	-0.02	-1.14**	0.11**	0.01
6.	RRN 702	-0.17**	0.09	-0.56*	-0.86**	-3.06**	-3.01**	0.63*	-0.11	0.07	0.02
7.	ACN 83	-0.70**	0.05	-0.58*	-0.47**	-4.38**	1.52	1.67**	-2.04**	-0.24**	-0.23**
8.	NDR 8501	0.38**	0.52**	1.03**	-1.05**	1.27	-4.90**	1.90**	-0.15	0.03	0.43**
9.	Kargil Selection	-0.09**	0.30**	0.91**	1.15**	6.92**	4.67**	-1.71**	0.21	0.29**	0.12**
10.	Basanti	-0.54**	-0.63**	0.41	-0.58**	6.20**	-3.85**	-2.62**	0.66*	0.15**	0.29**
11.	Narendra Swarna Rai 8	-0.24**	-0.40**	-0.16	-0.29	0.09	-2.69**	-0.99**	0.62	-0.54**	-0.91**
12.	RMM 09-3	-0.44**	-0.40**	-0.62*	-0.76**	-0.77	1.14	-1.54**	-2.44**	-0.05	-0.03
13.	RH- 58	-0.04	0.04	-0.23	1.29**	2.62**	1.74*	-1.51**	1.94**	0.22**	0.24**
14.	KM 9201	0.58**	-0.31**	-0.99**	0.71**	-5.05**	3.41**	0.26	0.08	-0.24**	-0.23**
15.	PR09, B 2004-3	0.04	0.15**	2.69**	1.31**	8.17**	-1.43	1.58**	3.90**	0.17**	0.18**
	SE(gi) lines	0.04	0.06	0.37	0.24	1.25	1.11	0.43	0.44	0.05	0.03
Testers											
1.	NDRE 4	-0.63**	-0.22**	-0.67**	-0.53**	-3.09**	-2.13**	-0.07	-0.15	-0.13**	-0.07**
2.	CS 54	0.38**	0.60**	-0.04	0.07	1.26**	-0.53	-0.71**	0.23	0.26**	0.23**
3.	RGN 73	0.02	0.00	0.76**	0.52**	1.95**	5.01**	0.95*	-1.22**	-0.06**	-0.05**
4.	Uravshi	0.22**	-0.03**	-0.06	-0.06	-0.12	-2.34**	-0.17	1.13**	-0.07	-0.10**
	SE(gi) tester	0.02	0.03	0.19	0.12	0.64	0.57	0.22	0.23	0.02	0.01

*, ** significant at 5 and 1 percent probability levels, respectively; Note: E_1= timely sown, E_2= late sown

Table.4 Five best crosses on the basis of sca and per se performance (E_1)

S. No.	Seed yield per plant (g)			Biological yield per plant(g)			1000 seed weight (g)			Harvest Index (%)			Oil Content (%)		
	Crosses	***per se***	**sca**	**Crosses**	***per se***	**sca**	**Crosses**	***per se***	**Sca**	**Crosses**	***per se***	**sca**	**Crosses**	***per se***	**sca**
1.	RH58x CS-54	14.33	4.54	RH58x CS-54	71.70	24.78	KM9201 x RGN73	5.83	0.932	Parasmani x CS54	28.54	5.20	KMR10-2 x RGN73	41.91	0.86
2.	NDR8501x CS54	15.43	4.38	NDR8501x CS54	68.00	22.42	RH58 x CS54	5.53	0.885	RH0737 x RGN73	29.39	4.54	KMR10-1 x Urvasi	41.96	0.59
3.	Bsanti x Urvasi	14.00	3.58	NPJ141 x RGN73	56.73	14.73	RRN 702x Urvasi	5.03	0.687	KM9201 x NDRE4	27.87	4.07	ACH83 x CS54	41.90	0.56
4.	PBR 2004-3x NDRE-4	15.50	3.40	ACH83x CS54	54.33	14.40	RH0737 x RGN73	5.61	0.670	RH58 x Urvasi	25.59	3.66	NDR8501 x CS54	42.18	0.56
5.	RMM09-3 x Urvasi	12.20	2.82	KM9201Xrgn73	50.73	10.79	RMM09-3 x CS54	4.76	0.522	RMM09-3 x Urvasi	25.41	3.50	NDR 8501 x RGN73	41.72	0.42

Table.5 Five best crosses on the basis of gca and per se performance (E_2)

S. No.	Seed yield per plant (g)			Biological yield per plant(g)			1000 seed weight (g)			Harvest Index (%)			Oil Content (%)		
	Crosses	***per se***	**gca**	**Crosses**	***per se***	**gca**	**Crosses**	***per se***	**Gca**	**Crosses**	***per se***	**gca**	**Crosses**	***per se***	**gca**
1.	Kargil Sel x Urvasi	13.53	3.32	Kargil Sel x RGN 73	69.00	16.90	RMM 09-3 x Urvasi	3.70	0.83	RRN 702 x Urvasi	28.59	5.87	Swarna Rai x NDRE 4	39.64	0.79
2.	KMR 10-1 x NDRE 4	11.43	2.63	KMR10-1x NDRE 4	57.00	13.61	Swarna Rai x CS 54	4.55	0.71	Kargil Sel x Urvasi	28.26	5.22	KMR 10-1 x Urvasi	40.39	0.65
3.	Kargil Sel x RGN 73	13.20	2.42	RH 0735 x Urvasi	51.07	12.21	RH 58 x CS 54	4.85	0.58	KMR 10-2 x RGN 73	25.43	5.12	KMR 10-2 x RGN 73	40.42	0.63
4.	Swarna Rai x CS 54	11.10	2.21	NPJ 141 x Urvasi	47.67	9.53	KMR 10-1 x Urvasi	3.76	0.51	Swarna Rai x CS 54	26.55	4.01	ACN 83x CS 54	40.44	0.60
5.	Basanti x Urvasi	10.53	2.06	KMR 10-2 x NDRE 4	51.00	8.13	KMR 10-2 x Urvasi	3.71	0.49	PRB 2004-3 x NDRE 4	28.48	3.03	RH 0735 x RGN 73	40.48	0.57

Table.6 Best specific combiners in relation to mean performance of the cross and general combining ability

Sr. No.	Character	Cross with significant effects		Mean performance of crosses		gca effects of parents	
		E_1	**E_2**	**E_1**	**E_2**	**E_1**	**E_2**
1.	Days to 50 % flowering	RMM 09-3 x CS 54	RRN 702 x CS- 54	43.00	55.33	L x H	A x L
		RMM 09-3 x RGN 73	ACN 83 x Urvashi	44.00	56.33	L x H	L x L
		RH 58 x NDRE 4	KARGIL SEL x CS54	41.00	52.33	L x L	H x H
		RH 58 x RGN 73	RMM 09-3 x Urvashi	44.00	52.33	L x H	H x H
		RH 58 x Urvashi	PRB-2004-3 x RGN-73	44.67	48.33	L x H	H x L
2.	Days to maturity	NPJ 141 x NDRE 4	NPJ-141 x CS-54	121.00	116.33	L x L	L x H
		RH 0737 x NDRE 4	ACN-83 x NDRE-4	121.00	117.00	A x L	L x L
		KMR 10-1 x NDRE 4	N SWARNA RAI 8 x NDRE-4	122.00	115.00	L x L	L x L
		Parasmani 33 x NDRE 4	RH 58 x NDRE-4	121.00	115.33	L x L	L x L
		RRN 702 x NDRE 4	RH 58 x Urvashi	121.00	115.33	L x L	L x L
3.	Plant Height	RH 0735 x RGN 73	NPJ-141 x RGN-73	191.00	175.73	A x H	H x H
		KMR10-2 x CS-54	KMR-10-2 x Urvashi	181.60	166.27	H x H	H x L
		NDR -85-01x CS-54	Parasmani-33 x CS-54	188.10	166.67	H x H	A x H
		RH-58 x CS-54	BASANTI x RGN-73	190.97	170.10	A x H	A x H
		PRB-2004-3 x RGN-73	RH-58 x CS-54	188.83	170.83	H x H	A x H
4.	No. of primary branches per plant	Parasmani 33 x NDRE 4	NPJ-141 x RGN-73	7.93	6.20	H x A	A x H
		KMR-10-1 x RGN 73	KMR-10-1 x NDRE-4	5.70	6.20	A x A	H x A
		ACN-83 x CS-54	RRN-702 x RGN-73	5.73	6.90	H x L	A x H
		RMM 09-3 x NDRE-4	KARGIL SEL x NDRE-4	6.10	6.80	A x A	H x A
		PRB 2004-3 x NDRE-4	BASANTI x RGN-73	5.80	6.43	A x A	A x H
5.	No. of secondary branches per plant	NPJ-141 x RGN-73	NPJ-141 x NDRE-4	10.40	13.40	H x A	A x H
		PARASHMANI 33 x NDRE-4	KMR-10-2 x NDRE-4	13.10	15.40	H x A	H x H
		ACN 83 x CS-54	KMR-10-2 x CS-54	10.60	13.40	H x L	H x L
		BASANTI x NDRE-4	KMR-10-1 x CS-54	10.80	13.80	A x A	H x L

		RMM-09-3 x NDRE-4	Narendra Swarna Rai-8 x CS-54	10.90	15.37	H x A	A x L
6.	Length of main raceme	NPJ-141 x RGN-73	NPJ-141 x CS-54	81.20	69.67	H x A	H x H
		BASANTI x NDRE-4	RH-0735 x NDRE-4	80.70	65.60	H x L	A x L
		BASANTI x URVASHI	PARASHMANI-33 x CS-54	82.90	72.40	H x H	H x H
		RH-58 x CS 54	KMR-10-1 x CS-54	78.13	65.30	H x A	H x H
		PRB-2004-3 x RGN-73	ACN-83 x NDRE-4	78.93	68.80	H x A	H x L
7.	No. of siliquae on main raceme	PARASMANI-33 x CS-54	NPJ-141 x URVASHI	44.40	48.57	A x A	A x L
		NDR-8501 x CS-54	PARASHMANI-33 x CS-54	44.00	45.10	A x A	H x A
		KARGIL SEL x CS-54	ACN-83 x RGN-73	44.13	50.87	H x A	A x H
		KARGIL SEL x URVASHI	BASANTI x RGN-73	43.33	45.60	H x A	A x H
		BASANTI x URVASHI	Narendra Swarna Rai8 x RGN-73	47.83	43.50	H x A	A x L
8.	No. of seeds per siliqua	NPJ-141x URVASHI	PARASHMANI-33 x RGN-73	14.60	15.80	H x A	A x H
		RH-0735 x URVASHI	KARGIL SELECTION x NDRE-4	15.10	15.30	A x A	H x A
		PARASMANI-33 x RGN-73	BASANTI x CS-54	14.60	15.80	A x H	H x A
		KARGIL SEL x RGN-73	BASANTI x RGN-73	16.10	15.50	H x H	H x H
		BASANTI x CS-54	RMM-09-3 x URVASHI	15.73	15.40	H x A	H x A
9.	1000- seed weight (g)	KM-9201 x RGN-73	RMM-09-3 x URVASHI	5.83	3.70	H x A	L x A
		RH-58 x CS-54	Narendra Swarna Rai-8 x CS-54	5.53	4.55	A x H	L x H
		RRN-702 x URVASHI	RH-58 x CS-54	5.03	4.85	L x H	A x H
		RH-0735 x RGN-73	KMR-10-1 x URVASHI	5.61	3.76	H x A	A x A
		RMM x -09-3 x CS-54	KMR-10-2 x URVASHI	4.76	3.71	L x H	A x A
10.	Seed yield per plant (g)	RH-58 x CS-54	KARGIL SEL x URVASHI	14.33	13.53	A x A	L x L
		NDR-8501 x CS-54	KMR-10-1 x NDRE-4	15.43	11.43	H x A	A x L
		BASANTI x URVASHI	KARGIL SEL x RGN-73	14.00	13.20	A x A	L x H
		PRB-2004-3 x NDRE-4	NARENDRA SWARNA RAI x CS-54	15.50	15.50	H x A	A x A
		RMM-09-3 x URVASHI	BASANTI x URVASHI	12.20	12.20	L x A	L x L
11.	Biological yield (g)	RH-58 x CS-54	KARGIL SEL x RGN-73	71.70	69.00	H x H	H x H
		NDR-8501 x CS-54	KMR-10-1 x NDRE-4	68.00	57.00	A x H	H x L
		NPJ-141 x RGN-73	RH-0735 x URVASHI	56.73	51.07	L x H	A x L
		ACH-83 x CS-54	NPJ-141 x URVASHI	54.33	47.67	L x H	L x L
		KM-9201 x RGN-73	KMR-10-2 x NDRE-4	50.73	51.00	L x H	H x L
12.	Harvest Index (%)	PARASHMANI-33 xCS-54	RRN-702 x URVASHI	28.54	28.59	A x A	A x H
		RH-0737 x RGN-73	KARGIL SEL x URVASHI	29.39	28.26	A x L	A x H
		KM-9201 x NDRE-4	KMR-10-2 x RGN-73	27.87	25.43	A x L	A x L
		RH-58 x URVASHI	NARENRA SWARNA RAI x CS-54	25.59	26.55	L x H	A x A
		RMM-09-3 x URVASHI	PRB-2004-3 x NDRE-4	25.41	28.48	L x H	H x A
13.	Oil content (%)	KMR-10-2 x RGN-73	NARENDRA SWARNA RAI-8 x NDRE-4	41.91	39.64	H x L	L x L
		KMR-10-2 x URVASHI	KMR-10-1 x URVASHI	41.96	40.39	A x L	A x L
		CAN-83 x CS-54	KMR-10-2 x RGN-73	41.90	40.42	L x H	A x L
		NDR-8501 x CS-54	ACN-83 x CS-54	42.18	40.44	H x H	L x H
		NDR-8501 x RGN-73	RH-0735 x RGN-73	41.72	40.48	H x L	H x L

H= High (significant and positive), L= Low (significant and negative), A= Average (non-significant)

For number of primary branches per plant, good general combiners were NDRE-4, Parasmani-33, and CAN-83 in E_1 and Parasmani-33 and Kargil selection and RGN-73 in E_2. KMR-10-2 was found a good for plant height, seed yield per plant and biological yield in E_1 and plant height, number of primary branches/ plant length of main raceme, number of siliquae in main raceme and biological yield in E_2. NDR-8501 was found a good general combiner for seed yield/ plant, biological yield, 100 seed weight and harvest index in E_1 and 1000 seed weight and oil content in E_2.

Kargil selection was found a good general combiner for number of siliquae on main raceme, number of seeds per siliqua, seed yield per plant, biological yield and oil content in E_1 and number of primary branches per plant, number of seeds per siliqua, number of siliquae on main raceme, seed yield per plant, biological yield, 1000 seed weight and oil content in E_2. Basanti was found good general combiner for plant height, length of main raceme, number of seed per siliqua, seed yield per plant, biological yield and oil content in E_1 and number of seed per siliqua, harvest-index and oil content in E_2. Parasmani -33 was found good general combiner for no. of primary branches per plant, no. of secondary branches per plant, 1000 seed weight and oil content in E_1 and no. of primary branches per plant, number of secondary branches per plant, length of main raceme, harvest index and oil content in E_2.

A number of crosses exhibited significant sca effects for various traits. The best five useful crosses with highly significant sca effects coupled with high mean performance for various characters both for timely sown condition (E_1) and for various characters both for timely sown condition (E_1) and late sown condition (E_2) have been given in tables 2, 3 and 4. For early maturity no single cross was promising both for E_1 and E_2 condition. However, the crosses NPJ-141 x NDRE-4 and NPJ-141 x CS-54 showed a high sca effects with early maturity for E_1 and E_2 condition. Best five cross combinations based on desirable sca effects for seed yield were RH-58 x CS-54, NDR-8501 x CS-54, Basanti x Urvashi, PRB-2004-3 x NDRE-4 and RMM-09-3 x Urvashi in E_1 and Kargil Selection x Urvashi, KMR-10-1 x NDRE-4, Kargil Selection x RGN-73, Narendra Swarna Rai-8 x CS-54 and Basanti x Urvashi in E_2. Narendra Swarna Rai-8 x NDRE-4, KMR-10-1 x Urvashi in E_1 and KMR-10-1 x Urvashi, KMR-10-2 x RGN-73 (0.63), AGN-83 x CS-54, RH-0737 x RGN-73 and Basanti x NDRE-4 in E_2 were good specific combinations for oil content.

In general maximum number of crosses which showed significant sca effects were invariably associated with better *per se* performance for respective trades (Table 4), good specific combinations involve parents of low x low, average x high, average x low, low x high and high x high general combining ability effects. From these findings it is obvious that best cross combination are not always resulted from high x high general combiners.

Best may also occurred in other type of parental combinations. However, in majority of crosses exhibiting high sca effects were found to have both or one of the parents as good general combiner for the character under study.

The result are in agreement with the findings of Yadava *et al.,* (1992), Chaudhary *et al.,* (1997), Sheikh and Singh (1998), Verma (2000), Lalta *et al.,* (2002), Monalisha *et al.,* (2005) and Yadava *et al.,* (2008). For the seed yield the crosses, Kargil Selection x Urvashi, KMR-10-1 x NDRE-4, Narendra Swarna Rai x CS-54, RMM-09-3 x Urvashi and Basanti x Urvashi may be utilized through hybrid breeding as both the parents in the crosses were high low gca effect or average gca effects. However the cross combination NDRE-8501 x CS-54 and PRB-2004-3 x NDRE-4 having high x low/ average gca with the expression of positive sca effects may be due to the dominant x recessive interaction expected to produce desirable segregants for seed yield in Indian mustard.

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