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Combining ability and heterosis for seed yield and its components in Indian mustard (*Brassica juncea* (L.) Czern & Coss)

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Abstract

A line × tester analysis involving 29 promising female and seven male parents were carried out for 10 quantitative traits in Indian mustard. Among the parents, SKM 93-28, VSL-5, YSRL-10, STRAIN-26, AD-2041, DBS-10 and KBJ-3 were found to be significantly superior general combiners for seed yield and yield components. The cross YSRL-10 × Pusa Bold, DBS-10 × Pusa Bold showed high heterosis for seed yield and some of the yield contributing traits. For most the major characters including seed yield both additive and non-additive gene action were of prime importance.

Key words : *Brassica juncea*, Indian mustard, combining ability, seed yield, gca, sca

Introduction

Indian mustard is one of the most important oilseed crops grown during *rabi* season. The relisable yield potential in this crop based on various observations is repored to be much more than what has been achieved so far. The increase in productivity through breeding efforts has not been adequate because of traditional selection methods following hybridization. Heterosis breeding could be a potential alternative for achiving quantum jumps in production and productivity. Since, commercial exploitation of heterosis in several crop plants has caused a majr breakthrough in yield levels. The magnitude of heterosis particularly for yield is of paramount importance and if the heterosis is practically and economically feasible it can help to reach high yield levels and thereby higher out put of oil in mustard.

The heterosis component is largely dependent on diverse parents with good general combining ability (gca). In practical heterosis breeding, it is necessary to select combinations with high degree of specific combining ability (sca) as well as parents with high gca. The present study was undertaken to select parents for effective hybridization programme as well as rapid selection advance in segregating generations.

Materials and methods

The materials consisted of 29 lines, 7 testers and their possible 203 F_1 cross combinations. These were grown in randomized block design with three replications at Indian Agricultural Research Institute, New Delhi during *rabi* season 1996-97. The observations were recorded on 10 quantitative characters [days to 50% flowering (DF), days to maturity (DM) plant height (PH), main shoot length (MSL), number of primary branches (PB), number of secondary branches (SB), number of siliqua on main shoot (Sq/MS), number of seeds per siliqua (S/Sq), seed yield (SY) and oil content per cent (OC)] from five competitive plants selected randomly from each plot. The mean values of each genotype were subjected to combining ability analysis by line × tester method of Kempthorne [1].

Results and discussion

The analysis of variance (Table 1) revealed significant differences for all the characters studied in case of lines, which indicated the existence of genetic diversity in the parental materials. On the other hand, among testers highly significant differences were observed for days to 50% flowering, plant height, main shoot length and number of primary and secondary branches. The mean squares due to females were found to be smaller than those due to males except for DM, Sq/MS, S/Sq and OC (Table 1). Variations among line × tester interactions were significant for all the characters except DM. This indicated the manifestation of parental genetic variability in their crosses and presence of uniformity among the hybrids. The variance due to sca was found to be considerably higher than that of gca for all characters except days to 50% flowering, indicating greater importance of non-additive gene action for exploitation of heterosis. Similar findings have also been

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Table 1. Analysis of variance of combining ability for 12 characters in Indian mustard

Source	df	Mean squares											
		DF	DM	PH	MSL	PB	SB	Sq/MS	S/Sq	HI	SY	SW	OC
Replication	2	68.41	299.5	639.16	15.55	0.21	14.97	274.44	2.10	0.0006	11.22	0.46	9.20
Lines	28	180.33*	370.29*	835.89*	537.39*	4.56*	57.29*	916.99*	13.15*	0.0081*	532.43*	0.41	107.58*
Testers	6	305.48*	10.17	2938.37	660.0*	8.23*	133.82*	258.9	8.28	0.015*	1117.73	0.84	33.20
Lines × Testers	168	16.61*	13.57	221.16*	111.97*	1.14*	19.68*	317.1*	2.91*	0.003*	85.78*	0.28*	7.84*
Error	4040	4.72	24.26	97.87	33.79	0.39	4.69	278.23	0.92	0.00024	24.59	0.24	2.12

*Significant at 5% level

reported by Singh *et al.* [2] and Bhateria *et al.* [3] in Indian mustard.

General combining effects of all the lines and testers are presented in Table 2. For seed yield the genotypes appeared as best general combiners were SKM 93-28, VSL-5, YSRL-10, DLM-55, Strain-26, AD-2041, RCC-462, PSMT-34, DBS-10 and KBJ-3 (Table 3). Among the parents, SKM 93-28 was found

Table 2. General combining ability effects of lines and testers for 12 characters in Indian mustard

Genotypes	DF	DM	PH	MSL	PB	SB	Sq/MS	S/Sq	HI	SY	SW	OC
PSR-18	−1.75**	0.72	−3.42	5.33**	0.26*	0.56	−1.34	0.35	0.00	0.18	0.01	0.32
SKM-9328	−1.66**	−0.38	6.60**	2.88*	0.31**	2.56**	5.80	0.68**	0.00	4.97**	−0.01	−1.05**
VSL-5	−3.37**	2.29*	−0.77	1.51	−0.12	0.51	1.56	−0.22	0.01	5.66**	0.09	0.95**
NPJ-30	−3.13**	1.43	−3.02	4.38**	−0.31**	−0.58	−1.39	−0.75**	0.01	0.95	0.08	0.48
RH-9303	−0.23	1.77	2.02	0.01	0.31**	0.47	0.04	−0.60**	−0.01	0.97	0.06	0.66*
NDR-8208	0.77	1.96*	14.67**	3.90**	0.50**	1.18**	1.42	0.44*	−0.02*	0.87	0.01	−0.55
TM-38	0.82	2.48*	3.55	0.78	−0.31**	−0.06	2.04	−0.65**	0.02*	0.87	0.01	−0.55
YSRL-10	1.44**	1.62	2.96	0.66	0.11	1.70**	−1.67	0.25	0.00	2.36*	−0.05	1.50**
NPJ-35	−1.18**	1.91*	−3.97*	−0.60	−0.46**	−2.44**	−0.34	−0.60**	0.01	1.79	0.05	1.69**
DLM-55	−0.27	2.91**	3.46	−4.49**	0.11	−0.20	2.04	−0.89**	0.01	5.14**	0.13	0.41
Strain-26	−1.75**	0.43	0.66	2.02	0.50**	1.61**	3.47	0.21	0.03**	4.16**	0.03	0.68*
AD-2041	−4.4**	−0.95	−11.74**	−1.09	−0.08	−0.39	3.66	−0.75**	0.03**	3.39**	−0.09	1.82**
PSMT-40	−2.94**	2.00*	−8.63**	−0.08	−0.84**	−3.82**	−2.58	−0.70**	−0,01	−5.72**	−0.03	1.03**
RL-1359	−0.70	0.34	−1.05	3.60**	0.11	−0.11	0.75	−0.08	0.00	−0.59	−0.07	1.90**
RCC-462	−1.18**	−2.19*	−2.66	−4.94**	0.11	0.23	−2.53	0.30	0.01	3.38**	−0.05	0.17
NKG-207	1.62**	−8.76**	−5.46**	−2.47*	−0.12	−0.01	−2.15	0.40*	0.00	0.35	−0.02	1.27**
IB-618	1.63**	−14.00**	3.16	0.06	0.69**	−0.30	−3.25	0.25	−0.01	1.27	−0.14	0.06
NIC-11703	−0.27	−11.38**	−3.77	5.73**	−0.69**	−0.30	−3.25	−0.03	−0.01	0.17	0.03	−1.34**
BEC-201AB	1.30**	−0.47	−2.67	−1.33	−0.08	0.42	−0.82	0.06	0.00	−1.47	−0.05	−0.25
SKM-92-66	−1.18**	1.20	−6.09**	−7.02**	−0.17	−0.96*	0.47	0.49**	0.00	−2.41*	0.06	−0.42
PSMT-34	−0.66	1.34	3.77	0.72	−0.08	−0.34	2.28	0.11	0.04**	1.98*	0.03	0.35
Strain-23	−0.51	4.29**	0.60	−2.46*	0.07	−1.20**	−1.58	0.54**	0.01	−1.25	0.10	0.45
IB-642	−0.32	1.86	0.28	−0.91	−0.03	0.23	30.53	0.01	0.00	−2.07*	−0.07	−0.71*
PRG-904	−0.61	0.86	14.17**	10.01**	−0.31**	−1.15**	0.66	1.59**	−0.02**	−2.59**	−0.15	0.84**
RCG-5	1.49**	1.24	6.51**	−4.04**	0.02	−0.20	−0.10	1.16**	−0.01	−2.99**	−0.17	−0.28
DBS-10	−0.66	0.67	5.93**	4.74**	0.35**	2.32**	5.75	−0.32	0.00	3.26**	−0.13	2.28**
KBJ-3	1.06*	1.15	2.27	4.79**	0.16	3.04**	0.13	1.01**	−0.01	3.46**	−0.13	−0.20
B. oxyrrhina A	4.06**	2.20**	−11.66**	−4.32**	−0.89**	−3.91**	−3.34	0.40*	−0.01	−10.97**	0.58	−1.48**
Prakash A	12.20**	3.43**	−6.09**	−17.35**	0.88**	−1.39**	−6.00	−2.65**	−0.07**	−18.58**	−0.17	−10.67**
TESTERS												
Varuna	−1.78**	−0.17	−6.83**	0.70	−0.35**	−1.38**	1.94	−0.25**	0.02*	−0.63	0.01	0.24
Kranti	−1.90**	−0.57	−4.97**	3.16**	−0.10	−0.02	0.88	0.11	0.01	0.35	−0.08	−0.36**
Pusa Bold	−1.16**	0.11	−4.86**	−0.74	−0.26*	−0.98**	−3.46*	0.02	0.00	−0.54	0.04	1.00**
BIO-772	−0.77	0.25	−1.20	1.11*	−0.05	−0.14	0.70	−0.17	0.00	−0.33	−0.03	0.40**
RH-30	2.05**	0.12	6.02**	0.91	0.07	−0.54**	0.50	−0.44**	−0.02*	−1.66**	0.18**	−0.91**
PR-45	0.83	0.47	5.76**	0.54	0.10	0.71**	−0.76	0.40**	0.00	0.90	0.00	−0.33*
Prakash	2.74**	−0.21	6.07**	−5.67**	0.59**	2.35**	0.20	0.30**	−0.01	1.91**	−0.12*	−0.04

*, ** Significant at 5% and 1% level, respectively

Table 3. Superior general combiners for different characters in Indian mustard

Characters	Lines	Testers
DF (Earliness)	PSR18, SKM 93-28, VSL 5, NPJ 30, NPJ 35, Strain-26, AD 2041, RCC 462, SKM 93-66	Varuna, Kranti, Pusa Bold
DM (Earliness)	RCC 462, NKG 207, IB 618, NIC 11703	-
PH (Dwarfness)	AD 2041, PSMT 40, SKB 93-66, NKG 207, *B. oxyhirrna* A, Prakash A, PSR 18, NPJ 30, NPJ 35, NIC 11703	Varuna, Kranti, Pusa Bold
MSL	PSR 18, SKM 93-28, NPJ 30, NDR 8208, RL 1359, NIC 11703, PRG 904, DBS 19, KBJ 3	Kranti, BIO 772
PB	Prakash A, IB 618, Strain 26, NDR 82082, DBS 10, VSL 5, RH 9303, PSR 18	Prakash
SB	KBJ 3, SKM 93-28, DBS 10, IB 618, YSRL 10, Strain 26, NDR 8208	Prakash, PR 45
SQ/MS	-, -	
S/SQ	SKM 93-28, NDR 8208, NKG 207, SKM 92-66, Strain 23, PRG 904, RCC 5, KBJ 3, *B. xyhirrna* A	PR45, Prakash
HI	Strain 26, TM 38, AD 2041, PSMT 34	Varuna
SY	VSL 5, DLM 55, SKN 93-28, NDR 8208, Strain 26, KBJ 3, AD 2041, RCC 462, DBS 10, YSRL 10, PSMT 34, NPJ 35	Prakash
SW	-	RH 30
OC	VSL 5, RH 9303, YSRL 10, NPJ 35, Strain 26, AD 2041, PSMT 40, RL 1359, NKG 207, PRG 904, DBS 10	Pusa Bold, BIO 772

to be good general combiner for other yield contributing traits like DF, MSL, PB, SB and S/Sq. The genotype AD-2041 was the best general combiner for early maturity and dwarfness. Other genotypes IB-618, NIC-11703, VSL-5 and NPJ-30 were also good general combiners for early maturity.

Specific combining ability effect estimates revealed a very wise range of variation for all characters. The crosses with significant desirable better parent heterosis (BHP) with their sca effects are presented in Table 4. Cross combinations SKM 93-28 × Kranti, NPJ-30 × PR-45, YSRL-10 × Pusa Bold, DBS-10 × Pusa Bold were the superior specific combiners for high seed yield. These crosses also had significant sca effects for other characters. Crosses like Strain-26 × Varuna and SKM 92-38 × PR-45 were the best specific combinations for earliness whereas, BEC-201 AB × Prakash and PSR-18 × Pusa Bold for dwarfness. Crosses KBJ-3 × Prakash, SKM-92-66 × Prakash, RCC-5 × RH-30 also performed as the best specific combiner for several yield contributing traits such as PB, SB and S/Sq, respectively. For the character Sq/MS, not a single cross either showed significant sca effects or heterosis.

Crosses with significant and desirable BPH along with their sca effects for different characters, were computed to identify the superior cross combinations for their potential use in hybrid breeding (Table 4). This experiment showed the presence of significant desirable BPH for a good number of crosses for different characters. For seed yield, YSRL-10 × Pusa Bold expressed the highest BPH of 73.75 per cent followed by AD-2041 × Pusa Bold (63.64%), DBS-10 ×Pusa Bold (53.31%), and KBJ3 × Prakash (50.42%). For top two hybrids YSRL-10 × Pusa Bold, DBS-10 × Pusa Bold had high significant sca effect for seed yield coupled with high gca of female parent for seed yield and major yield components. Therefore, both additive and non-additive type of gene action seemed to influence seed yield. On the other hand, the crosses AD-2041 × Pusa Bold and KBJ-3 × Prakash had very low sca effects but one of the parents had high gca. Hence, in these crosses heterosis for seed yield may be due to predominance of additive gene action and better selection advance can be expected in subsequent generations. DBS-10 × Pusa Bold showed significant BPH for SB, PB and S/Sq. Heterosis for seed yield components were reported by Duhoon and Basu [4], Kumar *et al.* [5] and Pradhan *et al.* [6]. The respective parents of these crosses recorded significant positive sca effects for seed yield and these were also desirable for PB and SB. Hence, heterobeltiosis observed in these crosses may be due to additive and non-additive gene effects [7]. Therefore, it may be possible to utilize heterobeltiosis in hybrid breeding as well as part of heterosis may be fixed in subsequent generations.

For DM, NKG 207 × Varuna, BEC 201AB × Varuna, NKG 207 × Kranti, NKG 207 × Pusa Bold, NKG 207 × PR 45, NKG 207 × Prakash and NIC 11703 × Prakash exhibited significant desirable BPH as well as significant negative sca effects. Other crosses with negative sca effects though BPH were non-significant were IB 618 × Varuna, NIC 11703 × Kranti, IB 618 × BIO 772 and IB 618 × Prakash. The negative sca effects in the desirable direction in these crosses indicated operation of non-additive gene action. However, negative gca (desirable for earliness) of the respective parents involved in most of the above mentioned crosses, suggested the role of additive and additive × additive type of interaction as well.

For the major yield contributing characters, namely PB, SB and S/Sq the BPH was either due to high gca effects of the parents or due to high sca effects of the respective cross. The role of both additive as

Table 4. Crosses with significant desirable heterosis over better parent (per cent) and sca effects

Tester	DF			DM			PH			MSL			PB		
	Line	BPH	sca	Line	BPH	sca	Line	BPH	sca	Line	BPH	sca	Line	BPH	sca
Varuna	PSR-18	–5.83	–5.46**	NKG-207	–7.99	–2.69				PRG-904	27.69	5.64*			
	Strain-23	–5.00	–6.03**	IB-618	–9.74	–0.45									
				NIC-11703	–7.38	0.26									
				BEC-201AB	–7.99	–10.98**									
Kranti	VSL-5	–4.44	–0.06	NKG-207	–9.25	–3.62							Prak-A	37.5	1.15**
	RCC-462	–5.22	–2.58*	IB-618	–8.44	1.95									
				NIC-11703	–9.11	–2.0									
Pusa Bold				NKG-207	–9.25	–4.3	PSR-18	–10.62	–29.94**	PSR-18	29.19	9.91**	DBS-10	28.57	0.50
				IB-618	–9.52	–0.4				SKM-93-28	26.99	10.03**			
				NIC-11703	–10.67	0.65				RL-1359	26.62	6.39**			
										YSRL-10	21.66	2.94			
BIO-772				IB618	–10.17	–1.53				NPJ-30*	29.11	6.04*			
				NIC-11703	–6.51	1.18				Strain-26	28.46	12.03**			
										Oxy A	39.11	12.36**			
RH-30	SKM-93-28	–5.43	–3.38**	IB-618	–7.03	1.59				RL-1359	26.76	8.81**	RH-930 3	22.22	1.03**
				NIC-11703	–5.26	1.64				PRG-904	38.43	10.56**			
										Oxy A	30.57	10.29**			
PR-45	SKM-93-28	–9.31	–5.49**	NKG-207	–7.96	–2.66				NPJ-30	32.42	3.27	DBS-10	23.53	1.14**
	TM-38	–4.18	–1.97	IB-618	–8.87	0.25				TM- 38	28.71	8.9**	PrakA1	29.41	0.95**
	RCC-462	–4.94	–0.64	NIC-11703	–6.51	0.96				PRG-904	34.57	5.64*			
										Oxy A	33.42	3.76			
Prakash				NKG-207	–9.07	–4.31	BEC-201 AB	–24.64	–44.29**	DBS-10	29.55	6.92**	Strain-26	22.22	0.84**
				IB-618	–10.39	–1.41							KBJ-3	22.22	1.17**
				NIC-11703	–9.33	–2.69									
Varuna	PSR-18	34.15	3.05**	PSR-18	12.2	1.11*	SKM-93-28	3.33	0.05**				RL-1359	11.56	3.76*
	DBS-10	39.02	1.95				TM-38	22.22	0.05**						
							Strain-26	14.81	0.02**						
Kranti	SKM-9-28	45.65	3.69**	PSR-18	12.2	0.74	TM-38	13.16	0.02*	SKM-93-28	31.35	13.62**			
	VSL-5	30.43	3.41**	RCC_462	13.95	1.79**	NPJ-35	9.21	0.02*	VSL-5	41.39	7.76**			
				Strain-23	21.95	1.89**	DBS-10	19.74	0.05**						
Pusa Bold	SKM-93-28	28.26	1.98	DBS-10	11.9	1.84**				YSRL-10	73.75	12.22**			
	RCC-462	31.71	2.65**							AD 2041	61.64	2.72			
	DBS-10	77.14	3.22**							PSMT-34	46.41	8.00**			
	PrakA	45.71	3.26**							DBS-10	53.31	8.39**			
	YSRL-10	26.00	4.17**												
BIO-772	TM-38	12.2	2.03*	TM-38	6.76	0.00	Strain-26	30.95	16.11**			VSL-5	7.82	–0.32	
				PSMT-34	57.53	0.10**							NDR-82 08	11.84	1.14
													DLM-55	7.84	1.47*
													BEC-20 1AB	8.62	2.40**
													DBS-10	6.84	0.77
RH-30	PSR-18	41.67	0.88	RCC-5	18.18	2.49*	VSL-5	8.33	0.03**	NPJ-35	49.14	8.47**			
	NPJ-30	36.11	1.35				DLM-55	10.29	0.02*						
	IB-642	55.26	3.88**				PSMT-34	9.59	0.01						
PR-45	RH-9303	62.5	2.05*				NPJ-35	12.82	0.05**	NPJ-30	46.12	13.66**			
	KBJ-3	34.62	3.48*				IB-642	34.62	0.11**						
Prakash	PSR-18	50.0	4.98**				PSR-18	10.0	0.33**	VSL-5	46.59	2.07			
	SKM-9328	27.08	–0.69				NPJ-35	8.57	0.02*	KBJ-3	50.42	4.73			
	Strain-26	39.58	2.26**				BEC-201 AB	8.57	0.02*						
	IB-618	41.67	1.98												
	SKM-92-66	50.0	6.50**												
	DBS-10	41.67	1.88												
	KBJ-3	43.75	1.50												

*,** Significant at 5% and 1% level

well as non-additive gene action for BPH expression was evident suggesting the development of heterotic combination for use in hybrid breeding programme.

Oil content is an important economic component of seed yield. Six crosses showed highly significant BPH for OC (high heterosis also reported by Varma *et al.*, [8]). Among these, crosses RL-1359 × Varuna, DLM-55 × BIO-722 and BEC-201AB × BIO-772 had significant sca as well as one of the parents of these crosses had significant gca effects, suggesting operation of non-additive and additive gene effects. On the other hand, two of these crosses viz., VSL-5 × BIO-772 and DBS-10 × BIO-772 had non-significant sca effects but both of their parents had significant gca effects, suggesting operation of additive gene effects for BPH. Therefore, it may be possible to fix the BPH in subsequent generaitons.

Results of the present study suggested some concept on breeding methodology to be followed in mustard and cross combination to be followed for further improvement. Seed yield and major yield components showed the significance of both additive and non-additive type of gene action in different cros combinations for different characters. The presence of additive gene action suggested that a part of the heterosis can be fixed in subsequent generations to take advantage in further selection. The predominance of non-additive gene action, however brought out that heterosis component could be exploited in hybrid development in Indian mustard.

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