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Combining ability analysis and reciprocal cross effects in Indian mustard (*Brassica juncea*)*

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The knowledge of nature of gene action and combining ability is important in deciding the appropriate parents in an efficient breeding programme. In this context the present investigation was undertaken to understand the combining ability for seed yield and its attributes in Indian mustard [*Brassica juncea* (L.) Czernj & Cosson].

The material for the present investigation comprised 10 strains of Indian mustard, viz 'Agra Local', 'EC 259602', 'Glossy Mutant', 'Poorbijaya', 'DIRA 313-6', 'Tetralocular', 'Zem 1', 'Zem 2', 'EC 322092' and 'Varuna', was selected on the basis of variability for various developmental, quantitative and qualitative characters. The parents were crossed in all possible combinations including reciprocals. The material consisting of 10 parents, 45 F_1s and 45 reciprocal F_1s were sown in randomized block design with 3 replications during the winter 1995–96. Each plot consisting of 5 m length having a spacing of 45 cm between rows and 15 cm between plants within a row. Observations were recorded on early vigour, days to 50% flowering, days to maturity, plant height, number of primary and secondary branches, length of main axis, number of siliqua on main axis, length of siliqua, seeds/siliqua, seed yield/plant, oil content and 1 000-seed weight from 5 random plants in each plot. Visual scoring (1–10 : 1, for very poor; 5, intermediate; and 10, highly vigorous) was given for the character early vigour at 40–45 days after sowing. The combining ability analysis was carried out

*Short note

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Table 1 Estimates of general combining ability (gca) effects of 10 parents for 13 characters in a 10 ×10 diallel cross of Indian mustard

Parents	Early vigour	Days 50% flowering	Days maturity	Plant height (cm)	No. of primary branches	No. of secondary branches	Length of main axis (cm)	No. of siliquae on main axis	Length of siliqua (cm)	No. seeds/ siliqua	Seeds/ plant (g)	Oil content (%)	1 000-seed weight (g)
'Agra Local'	–0.3**	–3.9**	5.8**	–25.0**	–0.2*	–1.6**	–6.3**	–8.7**	0.1**	–0.1	–5.2**	–2.1**	0.1
'EC 259602'	–0.3**	–4.4**	–5.9**	–28.9**	0.1	–0.1	–5.1**	–2.7**	–0.2**	0.2	–1.7**	–0.6**	0.9**
'Glossy Mutant'	–0.2*	–3.5**	–4.1**	–18.2**	–0.5**	–0.7**	0.9	–4.2**	–0.2**	0.3	–0.9*	–0.9**	-0.7**
'Poorbijaya'	0.2**	–0.3	–2.5**	6.8**	–0.2*	–0.3	1.0	–0.9	0.1	–0.1	–0.2	0.1	0.5**
'Varuna'	0.1	–0.3	–3.8**	–0.2	–0.5**	–1.5**	2.2**	–0.4	0.1	0.4*	–0.7	0.1	0.3**
'DIRA 313-3'	0.02	0.3	–0.3	5.8**	–0.5**	–1.6**	1.3	–0.8	0.3**	0.2	–1.2**	2.1**	0.2**
'Tetralocular'	–0.1	–0.3	0.7*	1.3	–0.4**	–2.4**	4.1**	1.6**	–0.04*	0.8**	–1.4**	–0.2	0.6**
'Zem 1'	0.3**	1.0**	1.12**	13.6**	–0.2	0.3	4.5**	5.4**	0.2**	–0.6*	0.9*	1.4**	0.2**
'Zem 2'	0.10	4.8**	4. 9**	18.8**	0.6**	1.1**	1.6	6.7**	–0.1*	–0.02	2.4**	–0.4**	-0.04
'EC 322092'	–0.1	6.6**	15.7* *	26.1**	1.8**	6.6**	–4.1**	3.9**	–0.3**	–0.2	8.0**	0.5**	-0.3**
SE (gi)±	0.1	0.3	0.14	0.9	0.1	0.3	0.8	0.6	0.04	0.2	0.4	0.1	0.04
CD (*P*=0.05)	0.1	0.7	0.30	1.70	0.2	0.7	1.6	1.2	0.1	0.3	0.7	0.2	0.1
CD (*P*=0.01)	0.2	0.9	0.78	2.2	0.3	0.9	2.1	1.6	0.1	0.4	0.9	0.3	0.1
SE (gi–gj)±	0.1	0.5	0.21	1.3	0.2	0.5	1.3	0.9	0.1	0.3	0.5	0.2	0.1
CD (*P*=0.05)	0.2	1.0	0.41	2.6	0.3	1.0	2.5	1.8	0.1	0.5	1.1	0.3	0.1
CD (*P*=0.01)	0.2	1.3	0.54	3.3	0.4	1.3	3.2	2.3	0.2	0.6	1.4	0.2	0.4
Correlation (r p, gca)	0.55	0.57*	0.32	0.80**	0.17	0.20	0.00	-0.45	0.18	0.12	0.21	0.20	0.78**

*,** *P*=0.05; *P*=0.01**

Table 2 Crosses showing high specific combining ability effects (sca) and rank correlation (rs) between sca effects and per se performance of the crosses

Character	Best cross-combinations on sca basis	Estimated sca effects	Rank correlation (rk)	Parent ranking (gca basis)
Days to 50% flowering	'Zem 2 × 'EC 322092'	—6.44	0.40	H × H
	'Agra Local × 'EC 322092'	—5.19		L × H
	'Glossy Mutant' × 'EC 322092'	—3.97		L × H
Plant height	'Zem 2' × 'EC 322092'	—44.76	0.44	H × H
	'Agra Local' × 'EC 322092'	—8.62		L × H
	'Glossy Mutant × 'EC 322092'	—6.36		A × H
Primary branches	'Zem 2' × 'EC 322092'	1.98	0.05	H × H
	'Poorbijaya' × 'Zem 1'	1.35		A × H
	'Poorbijaya' × 'EC 322092'	1.34		A × H
Secondary branches	'Zem 1' × 'EC 322092'	11.26	0.52*	H × H
	'Poorbijaya' × 'Zem 1'	6.97		A × H
	'Poorbijaya' × 'EC 322092'	6.65		A × H
Length of main axis	'Zem 2' × 'EC 322092'	14.34	0.45	H × H
	'EC 259602' × 'EC 322092'	14.28		L × H
	'Glossy Mutant' × 'Zem 2'	13.58		L × H
Number of siliqua on main axis	'EC 259602' × 'Zem 2'	8.76	0.50*	L × H
	'Poorbijaya' × 'Zem 2'	7.59		A × H
	'Tetralocular' × 'Zem 1'	7.04		A × H
Length of siliqua	'DIRA 313-6' × 'Zem 1'	0.46	0.71**	A × H
	'Poorbijaya' × 'Zem 2'	0.41		A × H
	'Poorbijaya' × 'Zem 1'	0.37		A × H
Seeds / siliqua	'Zem 1' × 'EC' 322092'	1.82	0.72*	A × H
	'DIRA 313-6' × 'EC 322092'	1.80		A × H
	'Poorbijaya' × 'Zem 2'	1.70		A × H
Seed yield / plant	'Poorbijaya' × 'Zem 2'	9.07	0.48	A × H
	'Zem 1' × 'EC 322092'	10.02		H × H
	'Poorbijaya' × 'EC 322092'	9.18		A × H
Oil content	'DIRA 313-6' × 'Zem 1'	1.77	0.33	H × H
	'EC 259602' × 'Varuna'	1.54		A × H
	'Agralocal' × 'Zem 2'	1.41		A × H
1 000-seed weight	'Poorbijaya' × 'Varuna'	0.67	0.67*	H × H
	'Tetralocular' × 'Zem 1'	0.65		H × H
	'Agra Local' × 'Zem 2'	0.55		A × H

following Model-I, Method-I of Griffing (1956).

The analysis of variance (ANOVA) revealed significant differences among parents and crosses for all the characters except for early vigour. The differences due to parents vs crosses were also highly significant for most of the characters except early vigour, number of primary branches and 1 000-seed weight. This indicated that significant differences existed among the experimental material.

The variances for general combining ability (gca) and specific combining ability (sca) were highly significant for all the characters. The mean square due to reciprocal cross effects (rce) was also significant for all the characters except early vigour and siliqua length, indicating the importance of both additive and non-additive gene action. Additive gene action was predominant for plant height and 1 000-seed weight. These findings are in agreement with those of Yadav (1992) and Pradhan *et al.* (1993) for plant height; Pradhan *et al.* (1993) and Singh *et al.* (1996) for 1 000-seed weight. Non-additive gene action was predominant for early vigour, number of primary and secondary branches, length of main axis, number of siliqua on main axis, seeds/siliqua and seed yield/plant. Pradhan *et al.* (1993) and Kumar *et al.* (1994) also supported non-additive genetic control for seed yield and its components in Indian mustard. It would be useful to adopt bi-parental mating (Singh and Murthy 1980), recurrent selection and diallel selective mating (Jensen 1970) than conventional pedigree or back cross technique. Breeding for the high yield would be manageable through heterosis exploitation (Anand and Rawat 1984). This has been possible through the discovery of cytoplasmic male sterility (Rawat and Anand 1979, Prakash and Chopra 1990).

The parents 'Zem 1', 'Zem 2' and 'EC 322092' were good general combiners for seed yield and most of its attributes based on their gca effect and also showing high *per-se* performance. This indicated that gca for seed yield was influenced by number of other plant characters (Table 1). Significant positive correlation between gca effects of the parents and their *per-se* performance was observed for days to 50% flowering, plant height and 1 000-seed weight. All other characters also showed positive correlation between gca effects of the parents and their *per-se* performance. Badwal and Labana (1987) also reported such type of correlation observed for different characters. The parents 'DIRA 313-6' and 'Zem 1' were good for oil content and 1 000-seed weight. These parents may be utilized in the hybridization programme for getting recombinants.

It was observed that the crosses, which showed high *per-se* performance for seed yield and its components also gave high sca effect (Table 2). Number of crosses also showed significant reciprocal effect for different traits were : 5 crosses for early vigour, 9 for days to flowering, 8 for days to maturity, 17 for plant height, 6 for primary branches, 14 for secondary branches, 8 for length of main axis, 6 for number of siliqua on main axis, 9 seeds/siliqua, 17 for seed yield, 12 for 1 000-seed weight and 14 for oil content. Several reciprocal crosses gave higher mean performances than the direct crosses. The important reciprocal crosses showing high mean performances are 'EC 259602' × 'Varuna', 'Poorbijaya' × 'Varuna' for early vigour; 'Poorbijaya' × 'EC 322092', 'DIRA 313-6' × 'Zem 2' for days to 50% flowering; 'EC 259602' x 'Varuna', 'Glossy Mutant' × 'DIRA 313-6' for plant height; 'Tetralocular' × 'EC 322092', 'DIRA 313-6' × 'Zem 2' for primary branches; 'Zem 1' × 'EC 322092', 'DIRA 313-6' × 'Zem 2' for secondary branches; 'Agra Local' × 'Zem 1', 'DIRA 313-6' × 'Varuna' for length of main axis; 'Poorbijaya' × 'varuna', 'Tetralocular' × 'Varuna' for length of siliqua; 'EC 259602' × 'Glossy Mutant', 'Poorbijaya' × 'Tetralocular' for seeds/siliqua; 'Zem 1' × 'EC 322092', 'Agra local' × 'EC 322092' for seed yield/plant; 'Glossy Mutant' × 'Zem 2', 'Glossy Mutant' × 'DIRA 313-6' for oil content; 'DIRA 313-6' × 'Tetralocular' and 'Glossy Mutant' × 'Zem 2' for 1 000-seed weight. These were considered to be good potential cross-combinations for further improvement of this material. Under such a situation the choice of suitable female parent is likely to further enhance the best use of beneficial non-additive effects in a specific cross (Rawat 1992). All the crosses giving high sca and reciprocal effect including high mean performances involved high × high or high × low combining parents.

These were the potential cross-combinations from which desirable transgressive segregants could be obtained and can easily be handled by conventional breeding methodology requiring some modification. Instead of continuous selfing in latter generation, alternate intermating and selfing of the selected segregants would further increase the scope of selection and would lead to more desirable segregants.

SUMMARY

Combining ability analysis in a diallel cross of 10 parents of Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson] revealed the presence of significant general (gca) and specific combining ability (sca) variances for seed yield/plant, days to 50% flowering, days to maturity, early vigour, plant height, number of primary branches, number of secondary branches, length of main axis, number of siliquae on main axis, length of siliqua, seeds/siliqua, oil content and 1 000-seed weight. Reciprocal cross effects were also significant for all the characters except early vigour and length of siliqua. There was significant positive correlation between *per-se* performance of the parents and gca of the parents for days to 50% flowering plant height, seed yield/plant and 1 000-seed weight. On the basis of these 2 factors, 3 parental lines, 'Zem 1' 'Zem 2' and 'EC 322092', were promising for seed yield and its attributes for utilization in the hybridization programme. On the basis of sca effects and performances of the crosses including reciprocals, 5 cross-combinations were the best. The crosses involved either high × high or high × low general combining ability (gca) parents and could be exploited for further improvement of seed yields and its components.

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