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Inheritance of essential fatty acids and correlation among different fatty acids in Indian mustard (*Brassica juncea*)*

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Indian mustard [*Brassica juncea* (L) Czern & Coss.] is a major winter (*rabi*) season oilseed crop in India. The oil from cultivated varieties of this crop contains fatty acids, viz palmitic (1.5–3.0%), stearic (2.0–35%), oleic (8–18%), eicosenoic (2–10%), erucic (43–52%), linoleic (10–21%) and linolenic (7–19%). Linoleic and linolenic acids are the nutritionally essential fatty acids for human health and these are the basis for prostaglandin and other essential body regulators (Lichenstein *et al*. 2006). An increase of these fatty acids in edible oil would be of great value for human being with low fat intakes. But on the other hand, high levels of these fatty acids are susceptible to oxidation during heating and storage which involves production of free radicals, implicated in a number of diseases and off flavour in oil (Carre *et al*. 2003). It is, therefore, imperative to breed mustard varieties with optimum levels of linoleic and linolenic fatty acids to enhance the nutritional quality as well as versatility of oil. In the present investigation the knowledge of inheritance of these fatty acids and association among different fatty acids has been undertaken which will help to breed genotypes with desirable levels of different fatty acids. Although a number of genetic studies have been conducted in different *Brassica* species, however, information is scanty in Indian mustard.

Three crosses and their reciprocals ('PRQ 9701' × 'Kranti', 'PLEM 2003-9' × 'Varuna' and 'PLEM 2003-9' × 'PLEM 2003-35') of 2 cultivars and 3 advanced quality lines of Indian mustard were made during *rabi* 2003–04 at Crop Research Centre of the University. During 2004–05, 6 generations, viz P_1, P_2, F_1, F_2, BC_1 and BC_2 were grown in a randomized complete block design. The number of plants selected for observation were 15 for P_1 and P_2, 30 for F_1, 120 for F_2 and 40 for backcrossed generations.

*Short note:

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The fatty acid profile was analyzed using direct methylating method by Gas Chromatograph (Chemito GC 7610) fitted with 25 m long capillary column. The oven, injector and flam ionization detector were held at 180ºC, 260ºC and 250ºC, respectively. Mean and variance were calculated separately for each generation and used for statistical analysis. The c^2 test was applied for F_2, backcrossed generations to ascertain the segregation pattern. The total variability of linoleic and linolenic acid content in F_2 and back crossed generations was divided into three and two classes respectively. The reciprocal effects were calculated by paired t-test and minimum number of effective factor pairs was calculated by following Burton 1951, Castle and Wright (1921) and Weber (1950).

The non-significant differences between F_1 and their reciprocals in all crosses for both the fatty acids indicated absence of cytoplasmic/maternal influence. In other words both the parents had equal contribution in the inheritance of these fatty acids. The intermediate levels of linoleic and linolenic acids in F_1 seed also indicated that embryo was controlled by the genotype of the developing embryo rather

Table 1 Estimation of minimum number of effective factors for linoleic and linolenic fatty acids in various crosses under 3 methods

Fatty acid	Cross	Castle Wright (1921)	Burton (1951)	Weber (1950)	Mean
Linoleic	'PRQ 9701' × 'Kranti'	1.23	1.21	1.09	1.18
	'PLEM 2003-9' × 'Varuna'	1.31	1.14	1.21	1.22
	Mean	1.27	1.18	1.15	1.20
Linolenic acid	'PLEM 2003-9' × 'Varuna'	1.06	1.07	1.02	1.05
	'PLEM 2003-9' × 'PLEM 2003-35'	1.08	0.89	0.98	0.98
	Mean	1.07	0.98	1.00	1.02

than genotype of the female parents. Similar observations with regard to embryonic control of different fatty acid synthesis were reported by Bhat *et al*. (2002), Rio *et al*. (2003) in *B. juncea*. The minimum number of effective factor pairs ranged from 1.08 to 1.31 with overall mean of 1.15 for linoleic acid and 0.89 to 1.08 with overall mean of 0.99 for linolenic acid was observed (Table 1). Hence, both fatty acids are believed to be controlled by the single gene pair. These results are in agreement with earlier reports by Velasco *et al*. (2002) Agarwal *et al*. (2003) and Sivaraman *et al*. (2004).

The χ^2 values for heterogeneity were non-significant between the crosses for linoleic and linolenic acids, therefore, pooled analysis of χ^2 was carried out to test the goodness of fit for the observed ratios in F_2 and back crosses. The F_2 population segregated in 84:205:77 and 50:120:48 ratio (high, medium and low) for linoleic and linolenic acids, respectively. The observed ratio was in agreement with expected ratio of 1:2:1 indicated by nonsignificant values of chi-square (linoleic; χ^2 =5.56, *P*=0.10–0.01 and linolenic; χ^2 =2.26, *P*=0.50–0.30). Further, the nonsignificant ^{2} value in backcrossed generations for observed and expected ratio for both the fatty acids confirmed the segregation pattern of F_2 generation (Table 2).

The correlation studies carried out for each cross separately which showed similar results, therefore, pooled data was used for interpretation of results (Table 3). The present study revealed that the erucic acid exhibited significant and negative association with all the fatty acids except eicosenoic acid which was positive (0.325**). Oleic acid had positive and significant correlation with linoleic (0.564**) and linolenic acid (0.498**), but it was negatively associated with eicosenoic (–0.467**) and erucic acid (–0.799**). The correlation between linoleic and linolenic acid was significant and positive (0.465**). The palmitic and stearic acids had positive and significant correlations with oleic (0.416** and 0.564**) and linoleic acid (0.591** and 0.310*). Similar results were reported by Mandal *et al*. (2002) and Choudhary *et al.* (2004).

From the present findings, it is quite obvious that linoleic and linolenic fatty acids in Indian mustard oil are governed by single gene which can be easily transferred by backcrossing with mustard varieties having low erucic acid (<2%) content coupled with approximately 40–45% oleic acid, 30–35% linoleic acid, 15–20% linolenic acid and <5% saturated fatty acids may be developed.

Table 2 Frequancy distribution of F_2, BC_1 and BC_2 plants for linoleic and linolenic fatty acids and chi-square values

Fatty acid/cross	Progeny	No. of plants in various classes			Expected ratio	□^{2}value	Probability of □^{2}
		<20	20–35	>35%			
Linoleic acid							
'PRQ 9701' × 'Kranti'	F 2	24	68	28	1:2:1	2.40	0.50–0.30
'PLEM 2003-9' × 'Varuna'		29	70	23	1:2:1	3.25	0.20–0.10
Pooled		84	205	77	1:2:1	5.56	0.10–0.05
'PRQ 9701' × 'Kranti'	BC 1	18	24		1:1	0.88	0.50–0.30
'PLEM 2003-9' × 'Varuna'		18	23		1:1	0.63	0.50–0.30
Pooled		57	64		1:1	0.41	0.70–0.50
'PRQ 9701' × 'Kranti'	BC 2		26	16	1:1	2.4	0.20–0.10
'PLEM 2003-9' × 'Varuna'			24	18	1:1	0.88	0.50–0.30
Pooled			72	50	1:1	3.98	0.05–0.02
Linolenic acid		*No. of plants in various classes*					
		<8	8.–18	>18%			
'PLEM 2003-9' × 'Varuna'	F2	24	61	27	1:2:1	1.05	0.70–0.50
'PLEM 2003-9' × 'PLEM 2003-35'		26	59	21	1:2:1	2.05	0.50–0.30
Pooled		50	120	48	1:2:1	2.26	0.50–0.30
'PLEM 2003-9' × 'Varuna'	BC1	13	19		1:1	1.16	0.30–0.20
'PLEM 2003-9' × 'PLEM 2003-35'		17	12		1:1	0.89	0.50–0.30
Pooled		28	33		1:1	0.43	0.70–0.50
'PLEM 2003-9' × 'Varuna'	BC2		21	15	1:1	1.02	0.50–0.30
'PLEM 2003-9' × 'PLEM 2003-35'		22	12	1:1	2.97	0.10–0.05	
Pooled			43	27	1:1	3.67	0.10–0.05

Table 3 Correlation co-efficients of 3 crosses and pooled data of Indian mustard

Fatty acid		Correlation co-efficients					
		Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	Eicosenoic acid	Erucic acid
Palmitic acid	'PRQ 9701' × 'Kranti'	0.197	0.461**	0.492**	0.187	–0.127	–0.412**
	'JLM 23' × 'Kranti'	0.135	0.427**	0.518*	0.272*	–0.205	–0.557**
	'PLEM 2003-9' × 'Varuna'	0.210	0.396*	0.396**	0.203	–0.157	–0.408**
	Pooled	0.203	0.416**	0.591**	0.206	–0.214	–0.547**
Stearic acid	'PRQ 9701' × 'Kranti'		0.406**	0.196	0.153	–0.342**	–0.782*
	'JLM 2'3 × 'Kranti'		0.472*	0.284*	0.112	–0.312**	–0.523**
	'PLEM-2003-9' × 'Varuna'		0.612**	0.301**	0.102	–0.423*	–0.625**
	Pooled		0.564**	0.310**	0.213	–0.402**	–0.569**
Oleic acid	'PRQ 9701' × 'Kranti'			0.623**	0.421**	–0.421**	–0.812**
	'JLM-23' × 'Kranti'			0.712*	0.562**	–0.512**	–0.782*
	'PLEM 2003-9' × 'Varuna'			0.392**	0.461*	–0.391**	–0.835**
	Pooled			0.564**	0.498**	–0.467**	–0.799**
Linoleic acid	'PRQ 9701' × 'Kranti'				0.459**	–0.140	–0.521**
	'JLM 23' × 'Krant'				0.562**	–0.122	–0.701**
	'PLEM 2003-9' × 'Varuna'				0.431**	–0.102	–0.492**
	Pooled				0.465*	–0.206	–0.564**
Linolenic acid	'PRQ 9701' × 'Kranti'					–0.201	–0.213
	'JLM 23' × 'Kranti'					–0.195	–0.172
	'PLEM 2003-9' × 'Varuna'					–0.165	–0.211
	Pooled					–0.211	–0.209
Eicosenoic acid	'PRQ 9701' × 'Kranti'						0.374**
	'JLM 23' × 'Kranti'						0.312*
	'PLEM 2003-9' × 'Varuna'						0.354**
	Pooled						0.325**

* P=0.05 and ** P=0.01

SUMMARY

Three reciprocal crosses between 3 quality lines and 2 varieties attempted and segregation pattern in F_2 and backcrossed generations were studied during 2003–05. The non-significant differences between F_1 and their reciprocals for both the fatty acids indicated absence of the maternal influence. The observed ratio was in agreement with expected ratio of 1:2:1 in F_2 generation indicated by nonsignificant values of chi-square test. Further, segregation pattern of F_2 was confirmed by the nonsignificant χ^2 value in backcrossed generations and calculation of minimum number of effective factor pairs. Correlation studies among the fatty acids revealed that Erucic acid was negatively correlated with palmitic, stearic, oleic, linoleic and linolenic acids. The linoleic and linolenic acids had positively association with each other as well as with oleic acid. From the present findings, it is quite obvious that linoleic and linolenic fatty acids in Indian mustard oil are governed by single gene which can be easily transferred by backcrossing.

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