Studies on Genetic Variability and Path Analysis for Quality Characters in Rapeseed-Mustard *(Brassica* species)

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A two-year study was carried out during rabi 2003-04 and 2004-05 with 40 varieties of rapeseed-mustard to assess the nature of variability and association for fatty acid profile, oil, protein and glucosinolate content. Analysis of variance indicated significant differences for all the quality characters investigated. The environmental effects were significant for erucic, oleic acid, glucosinolate and protein content and the influence of environmental factors appeared to be less on other characters. The genotype x environment interactions were non-significant for all the characters, hence the data were pooled over the years and discussed on the basis of mean of two years. The coefficients of variation at phenotypic level varied from 4% for protein content to 50.9% for oleic acid. The genotypic coefficients of variability were high for oleic, palmitic + stearic, erucic and linolenic acid. Protein and oil content had the least genotypic variation (GCV: 2.6-2.7%). The heritability in broad-sense was relatively high for oleic (61.5%) and erucic acid (56.3%). The high heritability was associated with high genetic advance only for oleic acid suggesting the role of additive gene action in the inheritance of this character. Erucic acid was negatively and significantly correlated with the rest of the fatty acids except linolenic acid. It had positive association with glucosinolate content (r =0.331). Glucosinolate content had negative and significant correlations with oleic (r =-0.536) and eicosenoic acid (r =-0.260). The negative association of palmitic + stearic, oleic, linoleic, linolenic and eicosenoic with erucic acid was the result of their high to moderate negative direct effects. Although glucosinolate content had very low direct effect (-0.051) on erucic acid but its positive association was the result of its strong positive indirect effect via oleic acid (0.435), which was partially neutralized by negative indirect effects (-0.112) via linolenic acid. The implications of these results in the quality-breeding programme were discussed in this paper.

Key Words: ***Brassica* species, Path analysis, Correlation coefficients, Fatty acid profile, Glucosinolate content, Rapeseed-mustard**

Introduction

Rapeseed-mustard is extensively grown in India and the major source of edible oil. Oil quality is determined by fatty acid profile, whereas, level of glucosinolates predicts the quality of seed meal. In the present era of health consciousness, the quality of oil remains a cause of concern among consumers and hence its improvement gained the paramount importance among the breeding objectives in recent years. The success of any crop improvement programme relies upon the extent of variability for a character to be improved. Correlation studies among various characters help breeders to formulate the appropriate breeding strategy to improve a number of characters simultaneously. Path analysis provides an insight into the causes of correlations between two characters. Such information for oil and seed meal quality characters is limited in the rapeseed-mustard varieties grown in India. Therefore, the present investigation attempts to assess the extent of genetic variation and nature of associations among quality characters in rapeseed-mustard. Further, the correlation coefficients of erucic acid with other characters were partitioned in to direct and indirect effects by path analysis to precisely elucidate the nature of association.

Materials and Methods

The experimental material consisted of 40 released varieties of rapeseed mustard (Indian mustard 25; gobhi sarson 4; toria 6; yellow sarson 2; karan rai 2 and taramira 1). These were grown in Randomized Complete Block design during 2003-04 and 2004-05 rabi seasons with two replications in 5-row plot of 5 m length, keeping 45 cm row–to-row and 15 cm plant-to-plant spacing. The experiment was conducted at 80:40:40 kg/ha of $N:P_2O_5:K_2O$. Half the dose of nitrogen and full doses of P_2O_5 and K_2O were applied basally at the time of sowing and the remaining dose of nitrogen was top dressed after first irrigation (35 days after sowing). The crop was also irrigated at 60 days after sowing. The observations were recorded on composite sample from central three rows. The oil and protein content were analyzed using NIR (Dicky John Insta Lab 600). Fatty acid profile was analyzed by gas liquid chromatograph (Nucon Model 5765) using SP 2300 + 2310 SS columns. Hyola PAC 401, a double low hybrid of gobhi sarson (*Brassica napus*) and Varuna a non-canola variety of Indian mustard (*Brassica juncea*) were used as checks. The detailed method for fatty acid analysis has been described earlier (Chauhan *et al*., 2002a). ELISA reader at 405 nm analyzed the glucosinolate content of the seeds following tetrachloropalladate method (Kumar *et al*., 2004). The mean values were used for analysis of variance using multiple Randomized Complete Block Design by indostat software. The genotypic (GCV) and phenotypic coefficients of variation (PCV), heritability in broad-sense and genetic advance were calculated by the formulae given by Johnson *et al.* (1955). The genotypic and phenotypic correlations were calculated as per the method of Al-Jibouri *et al.* (1958). Path coefficient analysis was done according to the method of Dewey and Lu (1959).

Results and Discussion

Analysis of variance indicated significant differences for all the quality characters investigated. The environmental effects were significant for erucic, oleic acid, glucosinolate and protein content but the environment influence was less on the other characters. The interactions between genotype x environment were non-significant for all the characters, hence the data were pooled over the years and discussed on the basis of mean of two years. All the genotypes showed same pattern of variability for both years for linoleic, linolenic, eicosenoic acid and oil content. Erucic acid ranged from 30.7% (PC 5) to 52.2% (Neelam) and glucosinolate content from 90.7 (RH 8812) to 106.6 m moles/g defatted seed meal (GM 1). The range for linolenic acid was 5.7% (RH 30) to 19.6% (Varuna). The range for palmitic + stearic and oleic acid was 2.3 % (Bhawani)-6.0 % (RH 8812) and 8.9% (JT 1)-22.7% (RH 30), respectively. Linoleic acid was the highest in Basanti (25.7%). In general, all the characters had higher magnitude of PCV than GCV (Table 1) indicating that environment influenced the expression of these characters but to a varying extent. However, the trend of PCV and GCV was similar. The coefficients of variation at phenotypic and genotypic level varied from 4% (protein content) to 50.9% (oleic acid) and 2.6% (oil content) to 39.9% (oleic acid), respectively. The genotypic coefficients of variation were high for oleic, palmitic + stearic, erucic and linolenic acid, which provide good opportunity for selection for desirable level of these fatty acids. Protein and oil content had the least variation (Table 1). Heritability values ranged from 11.9% (linoleic acid) to 61.5% (oleic acid). The heritability was relatively high for oleic (61.5%) and erucic acid (56.3%). The characters like linolenic acid, oil and protein content showed moderate heritability while, rest of the characters showed low heritability. However, in earlier studies (Chauhan *et al.*, 2002a, b) high heritability estimates were reported for erucic, oleic and linoleic acid. The high genetic advance was observed only for oleic acid (64.5%) while the other characters showed low to moderate genetic advance. The high heritability was associated with high genetic advance only for oleic acid suggesting the role of additive gene action in the inheritance of this character. The results were in agreement with earlier reports (Chauhan *et al.*, 2002 b). The extent of variation for oil, protein and glucosinolate content was found to be low, accompanied by low to moderate estimates of heritability and low genetic advance indicating thereby the chances of improvement of these characters by simple selection are limited.

Correlations

Phenotypic level:Erucic acid is an undesirable fatty acid found in rapeseed-mustard oil of prevalent Indian cultivars. It had negative and significant relationships with most of the other fatty acids but showed positively significant correlation with linolenic acid and glucosinolate content (Table 2). The results implied that an increase in the level of other fatty acids, particularly that of oleic acid, which had the highest negative direct

Table 1. Mean, standard error, range, coefficients of phenotypic (PCV) and genotypic variance (GCV), heritability in broad-sense (h^2) and genetic advance for quality characters in rapeseed-mustard

Characters	Mean ± SEm	Range	PCV (%)	GCV (%)	h^2 (%)	Genetic advance (%)
Palmitic + stearic acid (%)	3.6 ± 0.6	2.3-6.0	36.4	16.9	21.6	16.2
Oleic acid (%)	15.8 ± 2.5	8.9-22.7	50.9	39.9	61.5	64.5
Linoleic acid (%)	19.6 ± 2.0	14.3-25.7	22.1	7.6	11.9	5.4
Linolenic acid (%)	13.4 ± 1.5	5.7-19.6	27.6	15.9	33.0	18.8
Eicosenoic acid (%)	7.0 ± 1.2	4.6-10.4	35.8	12.6	12.4	9.2
Erucic acid (%)	40.3 ± 2.9	30.7-52.2	21.7	16.3	56.3	25.1
Oil content (%)	39.1 ± 0.7	35.7-41.6	4.6	2.6	32.2	3.0
Protein content (%)	19.7 ± 0.3	18.5-21.2	4.0	2.7	46.0	3.8
Glucosinolate content (m moles/g defatted seed meal)	99.3 ± 4.5	90.7-106.6	10.7	5.6	27.5	6.0

effect (Table 3), would result in the reduction of erucic acid content. The negative relationships of erucic with oleic and linoleic acid have been reported earlier also (Zhou and Liu, 1987; Singh *et al.*, 2001; Chauhan *et al.*, 2002a; Meena, 2006]. Increase in the level of oleic acid might also result in the high protein content as both characters were positively correlated and reduction in the glucosinolate content because of negative relationship between oleic acid and glucosinolate (Table 2). Glucosinolate content had negative and significant correlations with oleic and eicosenoic acid while, linolenic and erucic acid showed positively significant correlation with glucosinolate content.

Genotypic level: Erucic acid showed moderately high positive correlation with linolenic acid. Oleic acid had negative association with linolenic, erucic acid and oil content while positively related with linoleic, palmitic + stearic, eicosenoic and protein content (Table 2). Glucosinolate content was negatively correlated with most of the characters except linolenic (r=0.890) and erucic acid (r=0.450). On the basis of present investigation, it would be appropriate to enhance the level of oleic acid, which had high extent of variability and negative relationship with erucic acid through hybridization among varieties/donors having high level of oleic acid and low erucic acid as well as low glucosinolate content. However, the pattern of correlations between erucic acid and other quality characters were similar at both genotypic and phenotypic levels except linoleic acid with eicosenoic and glucosinolate content; oleic, linoleic and eicosenoic acid with oil content (Table 2). These results indicated that environment played an important role in the expression of these relationships.

Path Analysis

Phenotypiclevel: Correlation coefficients only describe the nature and magnitude of association between any two variables but path analysis enables interpretation of cause and effect relationship. Therefore, correlation coefficients of erucic acid (dependent variable) with other quality characters (independent variables) were partitioned into direct and indirect effects. The negative association of palmitic + stearic, oleic, linoleic, eicosenoic acid and protein content with erucic acid was the result of their high to moderate negative direct effect. Palmitic + stearic acid had negative direct effect (-0.127) on erucic acid. The indirect effects via linoleic, linolenic acid and glucosinolate content were positive, however, the correlation coefficients remained negative and significant (-0.208) due to major negative indirect effect via oleic acid (Table 3). Oleic acid had the highest direct negative effect (-0.812) on erucic acid and also had major positive indirect effect via linoleic acid. The indirect effects via other characters were low, hence the correlation between oleic and erucic acid remained negative but significant. Linoleic acid also had major negative direct effect (-0.318) though it had been diluted by positive indirect effects via palmitic + stearic, linolenic, eicosenoic and oil content, however, due to negative indirect effects via oleic acid, protein and glucosinolate content the correlation coefficient remained significant and negative. Mainly positive indirect effects via oleic, eicosenoic acid and protein content had nullified the direct negative effect of

Table 2. Correlation coefficients at phenotypic (P) and genotypic (G) levels among quality characters

Characters		Oleic acid	Linolenic acid	Linolenic acid	Eicosenoic acid	Erucic acid	Oil content	Protein content	Glucosinolate content
Palmitic + Stearic acid	P	0.184*	–0.146	–0.208**	0.165*	–0.208*	–0.111	0.195*	–0.096
	G	0.539	–0.065	–0.319	0.821	–0.546	–0.556	0.715	–0.277
Oleic acid	P		0.0001	–0.646**	0.453**	–0.678**	0.039	0.201*	–0.536**
	G		0.426	–0.929	1.105	–0.766	–0.127	0.287	–0.708
Linoleic acid	P			–0.084	–0.287**	–0.193*	0.084	0.018	0.056
	G			–0.664	0.436	–0.319	0.099	0.306	–1.105
Linolenic acid	P				–0.303**	0.265**	–0.030	–0.258**	0.293**
	G				–0.687	0.600	0.280	–0.596	0.890
Eicosenoic acid	P					–0.407**	0.041	–0.001	–0.260**
	G					–0.936	–0.129	–0.113	–0.587
Erucic acid	P						0.068	–0.153	0.331**
	G						0.227	–0.310	0.450
Oil content	P							–0.103	–0.065
	G							–0.320	–0.593
Protein content									–0.144
									–0.564

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

Table 3. Path analysis at phenotypic (P) and genotypic (G) level taking erucic acid as dependent variable

Characters		Palmitic acid + stearic acid	Oleic acid	Linolenic acid	Linolenic content	Eicosenoic content	Oil content	Protein content	Glucosinolate
Palmitic + Stearic acid	P	**–0.127**	–0.150	0.047	0.080	–0.040	–0.011	–0.011	0.005
	G	**–0.364**	–0.094	0.004	–0.115	–0.089	–0.083	0.199	–0.005
Oleic acid	P		0.0001	–0.646**	0.453**	–0.678**	0.039	0.201*	–0.536**
	G		0.426	–0.929	1.105	–0.766	–0.127	0.287	–0.708
Linoleic acid	P			–0.084	–0.287**	–0.193*	0.084	0.018	0.056
	G			–0.664	0.436	–0.319	0.099	0.306	–1.105
Linolenic acid	P				–0.303**	0.265**	–0.030	–0.258**	0.293**
	G				–0.687	0.600	0.280	–0.596	0.890
Eicosenoic acid	P					–0.407**	0.041	–0.001	–0.260**
	G					–0.936	–0.129	–0.113	–0.587
Erucic acid	P						0.068	–0.153	0.331**
	G						0.227	–0.310	0.450
Oil content	P							–0.103	–0.065
	G							–0.320	–0.593
Protein content									–0.144
									–0.564

*, ** Significant at 5% and 1% level of probability
(Direct effects in bold)

linolenic acid (-0.383) and resulted into its significant and positive correlation with erucic acid. Looking into positive relationship, it would be desirable to practice selection for low linolenic acid. Negative direct effect of eicosenoic acid (-0.243) and its negative indirect effect via oleic acid is an indication of reduction in eicosenoic acid by an increase in oleic acid and in turn the reduction in erucic acid. Oil content had low positive direct effect (0.101) as well as positive but non-significant correlation with erucic acid. Protein content also had non-significant negative correlation with erucic acid. Hence, a change in fatty acid profile would not affect the protein and oil content. Glucosinolate content had negative direct effect but it had been neutralized by positive indirect effect via oleic and eicosenoic acid, which resulted into positive and significant correlation with erucic acid.

Genotypic level: The highest negative direct effect of palmitic + stearic acid (-0.364) on erucic acid and their negative indirect effects via oleic, linolenic, eicosenoic acid, oil and glucosinolate content was the cause of negative association with erucic acid. Besides negative direct effect of oleic acid (-0.175), its negative indirect effects via linoleic, linolenic, eicosenoic acid and glucosinolate content were responsible for negative association between oleic and erucic acid. It is obvious that direct selection for high oleic content would be desirable to reduce the erucic acid. Linoleic and eicosenoic acid also showed negative direct effects on erucic acid. Its high indirect negative effect via linolenic acid (Table 3) indicated that linoleic acid would reduce with an increase in linolenic acid. The correlation coefficient between eicosenoic and erucic acid was the highest (-0.936) and negative due to its negative direct and indirect effects via other characters except linolenic acid. The high positive association between linolenic and erucic acid was the result of its highest positive direct effect. Oil, protein and glucosinolate content showed positive direct effects on erucic acid. Oil and glucosinolate content also had positive association with erucic acid. The relationship between glucosinolate content and erucic acid needs to be broken because both erucic acid and glucosinolate are considered undesirable. In the present investigation, the characters studied contributed 63% to the variability in the erucic acid content, hence many other factors responsible for variation in this fatty acid remained unknown, which need to be further investigated.

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