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Full Length Article

Studies on Variability for Quality Traits, Association and Path Analysis in Raya (*Brassica juncea*) Germplasm

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Abstract

Raya [*Brassica juncea* (L.) Czern.] germplasm included in the *Brassica* breeding program for the development of canola type verities was screened for quality traits. Significant differences were observed for quality characters among Raya germplasm. Oil contents ranged from 22.02 to 41.69%. Lowest total glucosinolate concentration (21.15 µmoles/g) was detected in J-90-43001, a line introduced from Canada. Palmitic and stearic acid ranged between 1.98-4.18 and 1.03-2.7%, respectively. All the accessions except J-90-43001 and RBJ-96026 contained oleic acid less than 20%. Higher levels of linoleic (23.12%) and linolenic acid (14.92%) were identified in the collected germplasm. Erucic acid contents ranged from 1.62 to 52.17%. Oleic acid showed high negative correlation with erucic acid and negative association with linolenic acid. Quality parameters including oil contents, oleic and linoleic acid could be used as selection criteria in Raya for the development of canola type varieties. Keeping in view strong direct effect of total glucosinolates and moderate direct effect of linolenic acid, these quality parameters could also serve for the selection of lines with low erucic acid in *Brassica* breeding programs. © 2015 Friends Science Publishers

Keywords: *Brassica juncea*; Oil Quality; Erucic acid; Oleic acid; Glucosinolate; Path analysis

Introduction

Brassicaceae family consists of more than 350 genera, among them Brassica is the most economically important genus consisting of oilseeds, vegetables and forage crops. The oilseed Brassicas are found within *Brassica juncea*, *B. carinata*, *B. rapa* and *B. napus* and are commonly called oilseed rape. Due to wider adaptability to the hotter and drier areas, resistance to disease and pod shattering; and relatively high oil contents up to 44%, *B. juncea* is being widely grown in Pakistan, India, China and in south-western areas of the former Soviet Union as oil seed crop (Stoutjesdijk *et al*., 2000; Pandey *et al*., 2013). However, *B. juncea* types grown in Pakistan are known as mustard quality as they contain high levels of erucic acid in the oil fraction and high levels of glucosinolates in the meal.

Use of the oil for edible and non-edible purposes depends upon certain persistent and dietetic values of the oils, particularly on the composition of different fatty acids like oleic acid, linolenic acid, erucic acid etc. For food frying and longer shelf life, development of cultivars having oil with high mono-unsaturated, low poly-unsaturated and very low saturated fatty acid contents is required (Rakow and Raney, 2003). Low/zero erucic acid contents are desirable due to its role as an agent of cardiac problems. Different oil quality characteristics are also mandatory for the production of non-edible products including detergents, lubricants, cosmetics, hydraulic oils or bio-diesel (Jham *et al*., 2009).

Rapeseed meal is a high protein by-product rich in lysine and methionine after oil extraction (Mailer *et al*., 1998). Rapeseed meal also contains sulfur containing secondary metabolites, among these; glucosinlates are the most important compounds.

Main objective in Brassica (rapeseed and mustard) breeding is to improve the seed and oil quality to meet the potential edible and industrial oil requirements (Shengwu *et al*., 2003). Correlation studies have been reported for quantitative characters in *B. napus* (El-Beltagi and Mohamed, 2010), in Canola (Fayyaz-ul-Hassan *et al*., 2005), in *B. campestris* (Rahman *et al*., 1999) and in *B. carinata* (Belete, 2011). Plant breeders have widely used path analysis for identifying useful traits that may be used as selection criteria for improving crop yield (Milligan *et al*., 1990).

We hypothesize that genotypic and phenotypic correlation in larger number of germplasm may provide important information that may be used to improve oil quality in *Brassica*. Present study was carried out to screen the Raya germplasm for quality traits included in *Brassica* breeding program for the development of canola type

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varieties. Phenotypic and genotypic correlation between quality characters was also studied to elucidate their direct and indirect effects on erucic acid contents.

Materials and Methods

Plant Material

High yielding Raya (*Brassica juncea*) accessions (30), comprising released varieties as well as exotic and local germplasm lines (Tahira *et al.,* 2013), implicated in breeding program of Oilseeds Research Institute, Faisalabad were included in the study to determine the correlation between quality characters.

Oil Contents

Oil contents of the whole seeds were determined non-destructively through pulsed NMR analyzer "Oxford MQA 7005". Magnet temperature was maintained at 25ºC and it was assured before operating that power supply was not interrupted for last 6 h. Instrument was standardized for frequency and pulse time using QT 821 MQ-11-Low Oil High Moisture and QT 821 MQ-11-High Oil Low Moisture standards. For calibration, *B. juncea* seed samples with known oil contents were used. These standards were prepared through Soxhlet's apparatus following standard procedures outlined in AOAC (AOAC 945.16, 2000).

Total Glucosinolates

Total glucosinolates in Raya seeds were determined by indirect method involving hydrolysis of glucosinolate by thioglucosidase (EC 3.2.3.1) and release of D glucose molecules (Wetter and Youngs, 1976). This released glucose was measured colorimetrically after specific enzymatic oxidations with readily available reagents containing a glucose oxidase, peroxidase and a chromogen. Absorbance was recorded at 510 nm using spectrophotometer (APEL, PD 303 UV).

Fatty Acid Profile

Oil samples (50 µL oil) were dissolved in 4 mL KOH (1M) for one hour at room temperature (Boocock *et al*., 1998). Fatty acid methyl esters (FAMES) were taken out with hexane (HPLC grade) and analyzed by Gas Chromatograph (Varian, 3900) immediately using a WCOT fused Silica 30 m × 0.25 mm (coating CPWAX 52CBDF = 0.25 µM, CP8713). Flame ionization detector was used and nitrogen as carrier gas with a flow rate of 3.5 mL/min. Injector, column oven and detector temperature were 260, 222 and 260ºC with a GC split ratio of 1:32. Total run time was 7.5 min. The fatty acids were identified by chromatographic retention time by comparison with standards (Supelco, USA).

Statistical Analysis

Analysis of variance was carried out to assess the level of significance among the accessions for different quality characters (Steel and Torrie, 1980). Genotypic and phenotypic correlation coefficients and path coefficients were calculated by following y Singh and Chaudhry (1979). The significance of genotypic correlation coefficients was tested with the help of standard errors as suggested by Reeve and Rao (1981) and path coefficient analysis was conducted according to Dewey and Lu (1959).

Results

Brassica Oil Quality

Mean values for quality characters for Raya are presented in Table 1. Significant differences were observed for quality traits among Raya germplasm. Highest oil contents were observed in BARD-1 (41.69%) followed by Canadian line J-90-43001 (41.22%). Lowest oil contents were recorded for Raya 63/2 (22.02%). Lines KH-33, KH-34 and KH-38 exhibited 29.46, 33.74 and 28.34% oil contents, respectively. Khanpur Raya, a high yielding variety showed 32.56% oil contents. In these studies, range for total glucosinolates was recorded to be from 21.15 (J-90-43001) to 269.33 µmol/g (RBJ-02017). KJ-117 and RBJ-96026 were the lines having 185.33 and 175.00 µmol/g glucosinolates.

During present studies, palmitic and stearic acid in Raya germplasm ranged from 1.98 to 4.18% and 1.03 to 2.7%, respectively. Australian line "Zem-II" showed lowest levels of saturated fatty acids i.e., palmitic (1.98%) and stearic acid (1.03%).

Canadian line J-90-43001 stood at the top for oleic acid contents (45.13%). RBJ-96026 exhibited 26.59% oleic acid among all other local lines and varieties having oleic acid percentage less than 20%. Varuna and RBJ-02017 showed less than 10% oleic acid contents. BARD-1 and Khanpur Raya showed 18.90 and 15.80% oleic acid contents, respectively. High levels of polyunsaturated fatty acids were recorded in Raya germplasm. Khanpur Raya showed highest level (23.12%) of Linoleic acid. Lowest levels (8.84%) were observed in KJ-119. Zem-II and Varuna showed lower levels i.e., 13.59 and 12.11%, respectively. Range for linolenic acid was observed to be 4.78 (Zem-II) to 14.92% (Varuna).

Lowest levels of erucic acid were recorded in Zem-II (1.60%) and J-90-43001 (1.72%). Both are exotic lines introduced from Canada and Australia in local breeding program. Varuna, Indian variety exhibited highest erucic acid contents (52.17%). All the other lines and released varieties exhibited higher levels of erucic acid.

Correlation Analysis

Genotypic and phenotypic correlations coefficients between

Table 1: Mean values for quality characters in Raya germplasm

Cultivars	Traits							
	Oil contents (%)	Total glucosinolate (µmol/g)	Palmtic acid (%)	Stearic acid (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)	Erucic acid (%)
Zem-II	36.78±0.09^{b}	212.67±2.08^{g}	1.98±0.01^{kn}	1.03±0.02^{k}	12.43±0.18^{q}	13.59±0.01^{r}	4.78±0.05^{t}	1.62±0.01^{n}
J-90-43001	41.22±0.02^{a}	21.15±0.21^{o}	3.02±0.01^{g-j}	2.23±0,01^{b-f}	45.13±0.01^{a}	17.29±0.01^{o}	9.42±0.01^{o}	1.72±0.08^{n}
RBJ-96026	28.66±0.05^{n}	175.00±1.73^{n}	3.04±0.024^{f-j}	2.10±0.01^{d-h}	26.59±0.04^{b}	18.11±0.01^{m}	10.24±0.02^{ij}	31.32±0.01^{m}
Khanpur Raya	32.56±0.18^{h}	203.00 ±1.00^{h-j}	3.32±0.01^{c-h}	1.94±0.01^{e-h}	15.80±0.04^{g}	23.16±0.01^{a}	10.90±0.02^{f}	32.49±0.01^{lm}
RBJ-99026	28.57±0.16^{no}	198.00±1.73^{k}	3.42±0.01^{c-g}	1.88±0.01^{f-h}	19.23±0.01^{c}	20.43±0.12^{fg}	9.23±0.02^{p}	34.06±0.02^{kl}
RBJ-2K024	31.27±0.11^{jk}	196.00±1.15^{kl}	4.21±0.01^{a}	1.83±0.01^{g-i}	15.42±0.02^{h}	20.09±0.06^{h}	11.10±0.01^{e}	34.40±0.01^{jk}
KJ-117	26.34±0.15^{p}	185.33±0.88^{m}	3.56±0.01^{b-f}	1.77±0.01^{j}	17.16±0.07^{e}	19.81±0.04^{i}	10.82±0.01^{f}	34.86 ±0.01^{i-k}
BARD-1	41.69±0.09^{a}	191.67±1.20^{l}	3.65±0.01^{bc}	1.46±0.01^{ij}	18.90±0.01^{d}	19.39±0.01^{jk}	10.52±0.01^{h}	35.11±0.01^{hk}
RBJ-07010	35.00±0.24^{cd}	235.00±2.08^{e}	3.18±0.02^{g}	2.58±0.01^{ab}	15.71±0.05^{g}	20.73±0.02^{de}	9.85±0.01^{lm}	35.70 ±0.03^{h-k}
RBJ-2K027	33.29±0.16^{fg}	206.33±1.76^{h}	2.93±0.01$^{g_-j}$	2.53±0.01^{a-c}	16.09±0.01^{f}	17.46±0.06^{no}	10.33±0.01^{i}	35.90 ±3.35^{h-j}
RBJ-03050	31.62±0.07^{i}	204.67±4.06^{h}	3.38±0.01^{c-h}	2.32±0.03^{b-e}	14.44±0.01^{k}	20.16±0.01^{gh}	11.25±0.07^{d}	36.16±0,01^{hi}
RBJ-2K022	30.96±0.31^{jk}	204.33±0.88^{h}	3.40±0.01^{c-g}	2.28±0.12^{b-e}	14.91±0.02^{j}	16.57±0.01^{p}	10.06±0.02^{k}	36.36 ±0.01^{g-i}
KS-74	34.41±0.35^{e}	203.00 ±1.53^{h-j}	4.04±0.01^{ab}	1.74±0.00^{h-j}	13.52±0.03^{m}	20.36±0.03^{f-h}	10.66±0.02^{g}	36.41 ±0.01^{g-i}
RL-18	34.72±0.22^{de}	198.33±2.03^{jk}	2.73±0.01^{ij}	2.52±0.00^{a-c}	12.71±0.04^{p}	22.50^{b}±0.03	11.52±0.02^{b}	36.71±0.05^{gh}
Raya 49/2	24.30±0.08^{r}	205.00±1.73^{h}	3.33±0.01^{c-h}	2.24±0.02^{b-f}	14.46±0.04^{k}	19.31±0.01^{jk}	10.92±0.01^{f}	36.82±0.01^{gh}
Raya 63/2	22.02±0.11^{t}	199.33 ±1.45^{i-k}	3.61±0.01^{b-d}	2.15±0.02^{c-g}	12.55±0.02^{pq}	20.51±0.05^{ef}	9.84±0.01^{lm}	37.93±0.01^{fg}
RBJ-97001	33.01±0.13^{gh}	228.67±2.03^{f}	3.06±0.01^{e-j}	2.24±0.001^{b-f}	14.39±0.01^{k}	18.77±0.06^{l}	9.89±0.01^{l}	38.94±0.01^{ef}
KH-33	29.46±0.27^{m}	204.33±1.45^{h}	3.34±0.02^{c-h}	2.23±0.01^{b-f}	15.23±0.01^{i}	20.85±0.02^{cd}	7.15±0.02^{s}	39.03±0.02^{ef}
KH-38	28.34±0.10^{no}	203.67±1.45^{hi}	3.34±0.01^{c-h}	1.95±0.01^{e-h}	14.10±0.01^{l}	19.26±0.34^{jk}	9.64^{n}±0.02	39.67±0.01^{e}
KH-34	33.74±0.25^{f}	204.33±0.88^{h}	2.93±0.02^{g-j}	2.54±0.01^{ab}	11.91±0.03^{s}	15.88±0.03^{q}	9.31±0.14^{p}	39.76±0.02^{e}
RBJ-07017	28.52±0.28^{no}	258.67±1.45^{b}	3.18±0.01^{c-i}	2.43±0.01^{a-d}	13.27±0.10^{n}	19.28 ±0.01^{jk}	10.87±0.01^{f}	40.03±0.01^{de}
KJ-119	28.03±0.35^{o}	205.00±1.53^{h}	3.11±0.01^{d-j}	2.48±0.01^{a-d}	11.69±0.01^{t}	8.85±0.03^{t}	10.24±0.02^{ij}	41.52±0.01^{cd}
RBJ-02018	30.49±0.27^{kl}	238.67±1.20^{de}	2.88±0.01^{h-j}	2.54±0.01^{ab}	12.17±0.01^{r}	18.64±0.01^{l}	10.47±0.02^{h}	41.69±0.02^{cd}
Sultan Raya	23.44±0.17^{s}	224.33±0.33^{f}	3.04±0.00^{k}	2.22±0.01^{b-f}	13.29±0.01^{n}	19.45±0.13^{j}	10.19±0.01^{j}	41.78±0.01^{bc}
RBJ-96024	30.76 ±0.21^{jk}	244.33±1.76^{c}	2.88±0.01^{h-j}	2.51±0.01^{a-c}	14.18±0.01^{l}	18.20±0.08^{m}	9.76±0.02^{m}	41.93±0.01^{bc}
RBJ-02019	30.16±0.06^{l}	258.67±1.76^{b}	2.63±0.02^{j}	2.70±0.01^{a}	13.10±0.05^{o}	19.44±0.01^{jk}	8.80±0.04^{q}	42.28±0.02^{bc}
RBJ-03047	30.45±0.07^{kl}	240.67±2.33^{cd}	3.04±0.01^{g-j}	2.38±0.01^{a-d}	11.71±0.02^{t}	19.18±0.03^{k}	9.33±0.01^{op}	42.64±0.01^{bc}
KJ-127	25.01±0.21^{q}	254.33±1.45^{b}	2.92±0.01^{g-j}	2.54±0.01^{ab}	11.75±0.11st	21.06±0.02^{c}	8.64±0.01^{r}	42.91±0.01^{bc}
RBJ-02017	23.15±0.17^{s}	269.33±2.33^{a}	2.96±0.01^{g-j}	2.54±0.02^{ab}	9.32±0.14^{u}	17.61±0.04^{n}	11.39±0.01^{c}	43.49±0.05^{b}
Varuna	35.48±0.13^{c}	243.33±2.40^{cd}	3.57±0.02^{b-e}	1.81±0.01^{g-j}	7.19±0.06^{v}	12.11±0.02^{s}	14.92±0.01^{a}	52.17±0.01^{a}
LSD $_{(0.05)}$	0.55	4.85	0.04	0.03	0.17	0.22	0.10	1.73

*Means with same letters are statistically not different

Table 2: Phenotypic and genotypic correlation coefficients between erucic acid and other quality characters

Traits		Total glucosinolates	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	Erucic acid
Oil	rg	-0.426*	0.0645	-0.295	0.393*	-0.143	-0.033	-0.470**
	rp	-0.424*	0.0496	-0.295	0.392*	-0.142	-0.033	-0.466**
Total glucosinolates	rg		-0.178	0.278	-0.890**	0.025	0.090	0.704**
	rp		-0.143	0.226	-0.888**	0.024	0.090	0.698**
Palmitic acid	rg			-0.271	0.050	0.212	0.496**	0.252
	rp			-0.204	0.402	0.175	0.399*	0.204
Stearic acid	rg				-0.107	0.087	0.147	0.477**
	rp				-0.093	0.072	0.125	0.405*
Oleic acid	rg					0.090	-0.1442	-0.678**
	rp					0.090	-0.144	-0.674**
Linoleic acid	rg						-0.023	0.078
	rp						-0.023	0.077
Linolenic acid	rg							0.537**
	rp							0.534**

erucic acid and other quality traits are presented in Table 2. The results indicated that oil contents were positively correlated with oleic acid contents in oil at both genotypic and phenotypic level, while negatively correlated with glucosinolates and erucic acid contents. Negative correlation was observed with stearic acid, linoleic and linolenic acid contents. Total glucosinolates showed positive correlation with erucic acid and highly significant negative correlation with oleic acid both at genotypic and phenotypic level. Total glucosinolates were also positively correlated with stearic acid, linoleic acid and linolenic acid contents.

Palmitic acid showed positive genotypic and phenotypic correlation with linolenic acid. Negative correlation was observed of palmitic acid with stearic acid while positive one was recorded with oleic, linoleic and erucic acid. Stearic acid was significantly positively correlated with erucic acid and positively correlated with linoleic and linolenic acid contents at genotypic and phenotypic level. Oleic acid showed highly significant negative correlation with erucic acid and negative

Table 3: Direct (parenthesis) and indirect effect matrix (dependent variable is erucic acid). The last column shows genotypic correlations of independent variables with erucic acid

Traits	Oil	Total glucosinolates	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	Erucic acid
Oil	(-0.127)	-0.167	0.020	-0.105	-0.088	0.003	-0.009	-0.470
Total glucosinolates	0.054	(0.384)	-0.056	0.099	0.199	-0.001	0.023	0.704
Palmitic acid	-0.008	-0.068	(0.316)	-0.097	-0.011	-0.005	0.127	0.253
Stearic acid	0.037	0.106	-0.085	(0.358)	0.024	-0.002	0.038	0.478
Oleic acid	-0.050	-0.342	0.015	-0.038	(-0.224)	-0.002	-0.037	-0.678
Linoleic acid	0.018	0.009	0.067	0.031	-0.020	(-0.022)	-0.006	0.078
Linolenic acid	0.004	0.034	0.156	0.053	0.032	0.001	(0.255)	0.537

correlation with linolenic acid.

Path Coefficient Analysis

The data presented in the Table 3 revealed that direct effect of oil contents on erucic acid was negative (-0.127). Its indirect effects via total glucosinolate (-0.167), stearic acid (-0.105), oleic acid (-0.088) and linolenic acid (0.009) were also negative while indirect effect via palmitic acid (0.020) and linoleic acid (0.003) were positive. Direct effect of total glucosinolate on erucic acid was positive (0.384). Indirect effects of total glucosinolate via palmitic acid (0-0.056 and linoleic acid (-0.001) were negative whereas its indirect effect via stearic acid (0.099), oleic acid (0.199), linolenic acid (0.023), and oil (0.054) were positive.

Path coefficient analysis (Table 3) indicated that palmitic acid (0.316) and stearic acid (0.358) had positive direct effects on erucic acid. Palmitic acid showed negative indirect effects via all the other traits except linolenic acid. Similarly stearic acid showed positive indirect effects via all the traits except palmitic (-0.085). Linolenic acid showed both positive direct and indirect effects via all the traits.

It is evident from Table 3 that direct effect of both oleic acid and linoleic acid were negative i.e., -0.0224 and -0.022, respectively. The Indirect effect of oleic acid via palmitic acid was positive (0.015) only and with all other traits it was negative. Similarly, linoleic acid exerted positive indirect effects via oil contents, total glucosinolate, palmitic and stearic acid but via oleic acid and linoleic acid it showed negative effect. .

Discussion

Raya (*B. juncea*) breeding is aimed to improve agronomic performance, quality traits and disease resistance. For canola type varieties, high oil content, low glucosinolate content, and a fatty acid profile low in erucic and saturated fatty acid content are preferred. For industrial uses, high glucosinolate contents and moderate levels of erucic acid are required. Oil fraction plays a critical role in the worth of *Brassica* seeds which has long been accepted for its top quality dietetic attributes especially good combination of saturated fatty acids and monounsaturated fatty acids along with assenting omega-3 fatty acid profile.

Oil contents in *B. juncea* ranged from 27.9 to 41.72% in earlier studies (Tahoun *et al*., 1990; Mandal *et al*., 2002). Present findings also revealed a large variation in oil contents among the accessions. This substantial disparity may be attributed to induction of different lines/varieties of raya in the breeding program and oil contents vary among different *Brassica* species (rapeseed and mustard) and among the cultivars (Alemayehu and Becker, 2005).

Glucosinolates impart specific taste to mustard when used as spice in food for human consumption but degradation products like isothiocyanates, nitriles, epithionitriles, and thiocyanates are toxic to animals when ingested in larger quantity. Therefore, it is crucial to evaluate the glucosinolate content in *Brassica* oilseeds for the improvement of crop nutritional characteristics. *B. napus* varieties contain lower levels of total glucosinolates up to 8 µmoles/g of whole seed (Mailer *et al*., 1999), while, *B. juncea* and *B. carinata* defatted meal is reported to contain higher levels of total glucosinolates up to 192 µmoles/g (Font *et al*., 1999; Hirani *et al*., 2012). A higher range of total glucosinolates during present studies may be ascribed to different lines, genetic and environmental factors (Rosa, 1997; Rangkadilok *et al*., 2002).

Variation in saturated, momounsaturated and polyunsaturated fatty acids during present studies could be beneficially used in designing new varieties with desired fatty acids. Composition of different fatty acids (type and quantity) determines the uses of oil. Breeding institutions in Canada focused on the reduction of saturates initially below 7%, with the long term objective of achieving reductions in palmitic and stearic acid levels below 4% (Scarth and McVetty, 1999). Dietetic suggestions center focus on reduction of saturated fat intake for provision of 10% of energy keeping in view the bad effects on blood cholesterol progression of cardiovascular disease (Damude and Kinney, 2008). Polyunsaturated fatty acids (PUFAs) are desirable for good health but due to susceptibility to oxidative degradation during frying and storage (Wijesundera *et al*., 2008), low polyunsaturated contents are desirable to avoid oxidation and rancidity during deep frying. These low levels of PUFAs are also required for non-food use of rapeseed oil such as biofuel production.

Erucic acid range similar to present investigations (0.5-57.3%) was reported by Kumar *et al*. (2010) in *B. juncea*. A higher range of erucic acid contents (35.7-51.4%) was also reported in an earlier study by Chauhan *et al*. (2007) in Indian mustard varieties. Due to undesirable effects of erucic acid on health, most *B. juncea* breeding programs are focused on reduction of erucic acid in oil up to 2%.

Many researchers have reported phenotypic and genotypic correlation for quality traits in different *Brassica* species. Rahman *et al*. (1999) found a positive correlation of palmitic acid with oleic and linoleic acid while, a negative correlation with erucic acid in *B. campestris* contradictory to present findings which may be due to difference in species. A negative correlation among palmitic and stearic acid was also reported in *B. campestris*. Khan *et al*. (2008) observed negative association between oleic acid and erucic acid; and oleic acid and linoleic acid in different Brassica populations. Islam *et al*. (2009) reported a positive association of oleic acid with linoleic and linolenic acid in *B. juncea* and *B. rapa*. During present studies, negative relation was found between linoleic acid and linolenic; and positive association between linoleic acid erucic acid genotypically and phenotypically. Linolenic acid was highly significantly positively associated with erucic acid contents both at genotypic and phenotypic level. In *B. napus*, Khan *et al*. (2008) observed a non-significant negative relation between linolenic acid and erucic acid. This may be due to difference in species. Present results are in line with Islam *et al*. (2009) who reported a positive relation between linolenic acid and erucic acid in *B. juncea*.

Estimation of direct and indirect effects of various quantitative characters on yield have been reported by many researchers in different *Brassica* species (Tuncturk and Ciftci, 2007; Marjanovic-Jeromela *et al*., 2008). Few reports are available about the direct and indirect effects of various quality traits on erucic acid. Chauhan *et al*. (2008) reported high to moderate negative effects of palmitic, stearic, oleic, linoleic, linolenic and eicosenoic on erucic acid in Indian mustard varieties. They also found strong positive indirect effect of glucosinolate on erucic acid via oleic acid, which was counterbalanced to some extent by negative indirect effects via linolenic acid. These results support present findings.

Conclusion

Quality parameters including oil contents, oleic and linoleic acid could be used as selection criteria in Raya for the development of canola type varieties. In view of the strong positive direct effect of total glucosinolates and moderate direct positive effect of linolenic acid, these quality traits may serve for the selection of lines with low erucic acid in Brassica breeding programs.

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