Applied Biological Research 21(1): 20-27; (2019)
DOI: 10.5958/0974-4517.2019.00003.X

FATTY ACID AND MINERAL COMPOSITION OF SOME AGRO-MORPHOLOGICALLY DISTINCT QUALITY GERMPLASM OF INDIAN MUSTARD (*Brassica juncea* L.)

H. Punetha*[1], Usha Pant[3] and Om Prakash[2]

*[1]*Department of Biochemistry,* [2]*Department of Chemistry, College of Basic Sciences & Humanities,* [3]*Department of Genetics and Plant Breeding, College of Agriculture, G.B. Pant University of Agriculture & Technology, Pantnagar-263 145, Uttrakhand (India)*
*e mail: *punetha_hp @rediffmail.com, hpunetha15@gmail.com*

(Received 9 November, 2017; accepted 4 October, 2018)

ABSTRACT

Indian mustard (*Brassica juncea* L.) which occupies largest area among the all oleiferous *Brassicas*, is an important source of nutritionally important fatty acid and micronutrients for animal including humans. The present study was aimed to evaluate the fatty acid and mineral composition of 30 agro-morphologically distinct quality germplasm of Indian mustard. The quality germplasms were evaluated for fatty acid profiling by injecting methyl ester sample into SP-2300 (2%) + SP-2310 (3%) packed silica column. Micro-nutrients were determined by atomic absorption spectrophotometric method. Fatty acid variability in quality germplasm revealed the erucic acid content of <2% in genotypes BC3-BC4-1 (0.57%), F3-F4-1 (0.67%), F3-F4-3 (1.05%), NUDH-YJ-3-3 (0.28%), F3-F4-2 (0.74%), F4-F5-1 (0.72%), PRQ 2004-8 (0.51%) and PRQ-2005-1 (1.24%). ω6/3 ratio was fairly better in genotypes PLGM-2002-2-7(2.28), LG BC 2005-6-8 (2.20), PRQ 2004-9 (1.92), PRQ-2005-11-BE (1.91) and F4-F5-5 (2.13). The mineral proportion of meals showed that all quality genotypes had variable amounts of N, P, K, S, Ca, Mg, Fe, Mn, Zn and Cu. The identified genotypes having low erucic acid, optimal ratio of essential fatty acids and promising micronutrients can be used for preparation of functional food or for determining the quality traits and nutritional status of Indian mustard.

Key words: Fatty acid profiling, germplasm, Indian mustard, mineral composition, quality

INTRODUCTION

Indian mustard (*Brassica juncea* L.) is one of the important oilseed crops contributing ~27% edible pool in India and accounts for about 13% global production of edible oil (Pratap *et al.,* 2014). In global vegetable oil market, India is among the largest consumers and producers of Indian mustard. Mustard seeds are rich in phytonutrients, dietary minerals, vitamins and anti-oxidants; and the meal, a bye-product during oil extraction, is considered an important component of human nutrition and animal feed due to its good protein content and desirable amino acid profile (Punetha *et al.,* 2018). Defatted meal with low level of antinutrients but high antioxidant levels can be utilized in the preparation of functional foods (Punetha *et al*., 2015).

In North-Western and Eastern India, the presence of greater amounts of monounsaturated fatty acids (MUFAs) in mustard oil is desirable for edible purpose (Simopoulos, 2008). The major components of fatty acids are oleic, linoleic, linolenic, eicosenoic and erucic acid. Mustard oils reduce the possibility of coronary heart disease and show beneficial effects on inflammation, depression,

autoimmune disease, diabetes and cancer due to the presence of ω_3 fatty acid component (Cunnane, 1995; Baylr *et al.*, 2006). Various chronic diseases are often linked with abnormalities in polyunsaturated fatty acids (PUFA) metabolism (Zamaria, 2004). PUFA to saturated fatty acid (SFA) ratio is reportedly better in rapeseed-mustard oil than groundnut or soybean oil (Kale, 2007). However, its use in animal feed is restricted due to various anti-nutritional factors such as glucosinolates, phytic acid and phenolics (Prem *et al*., 2012). Among *Brassica*, Indian mustard provides various phytochemicals and minerals which are good constituents in aquaculture, animal and human diets (FAOSTAT, 2011). Essential minerals are nutritionally important for human health which are best obtained from dietary sources. Mustard meal is rich in various bioactive substances which have health promoting properties, as well as in antioxidative factors and dietary minerals like Na, K, Ca, Mg, Cl, P and S and micronutrient like Fe, Zn, Mn and Cu essential for human being (Punetha *et al.*, 2017). Therefore, the present study was aimed to assess fatty acids and mineral composition of 30 agro-morphologically distinct germplasm of Indian mustard which depict their quality and nutritional status; and to ascertain their potential for developing new and better cultivars.

MATERIALS AND METHODS

Plant material

Thirty quality germplasm, including parental lines, advanced lines and their various crosses procured from Oilseed Breeder, Department of Genetics and Plant Breeding, GBPUAT, Pantnagar (India) and were cultivated in Crop Research Centre, GBPUAT, Pantnagar (India) during winter 2015-16. The site lies in Northern-Western part of India (28.97° N, 79.41° E). Three replicates of each genotypes were maintained for assessment of these collections.

Phenotypic characterization

The morphological traits observed were plant height, main shoot length, number of siliqua on main shoot, siliqua length, beak length, number of primary and secondary branches, number of seeds in pod, siliqua density, 1000-seed weight andyieldplant^{-1}. Pearson-correlation coefficient analysis was used to determine relationships among the various studied traits.

Fatty acid profiling

Fatty acid profiling was carried out as per Paquot and Hautfenne (1987) with slight modifications. Briefly, 1.0 µL methyl ester sample was injected into SP-2300 (2%) + SP-2310 (3%) packed silica column of a gas chromatograph equipped with flame ionization detector (FID) [Nucon model 5765]. The oven, injector and detector temperatures were programmed at 240, 230 and 250°C, respectively. The programme was setup at N_2 flow rate: 30 mL min^{-1} and H_2 flow rate: 30 mL min^{-1}. Fatty acid methyl ester peaks were identified by comparing their retention time with standards runs under similar operational conditions. Individual fatty acids were expressed as per cent of total fatty acids.

Mineral composition and nitrogen content

Meal samples (0.5 g) of mustard were transferred into digestion tubes, then 10 mL conc. HNO_3 added to each and kept as such for overnight. The samples were kept on a hot plate (80°C) for 10 min, cooled and 10 mL of nitric acid, sulphuric acid and perchloric acid (10:1:4 v/v/v) added to each sample. Samples were again placed on hot plate for complete digestion and on cooling 5 mL 6 N HCl was added and volume made upto 50 mL with distilled water. The digests were filtered through a Whatman filter paper No.1 and transferred to storage vials. A blank digest was also run.

Total nitrogen content in samples was determined by micro-Kjeldhal's method with some modifications (Warnke and Barber, 1974). Fe, Mn, Zn and Cu contents in samples was determined by atomic absorption spectrophotometric (AAS) method (Elwell and Gidley, 1967) and Ca, Mg

analyzed by complexometric method (Jackson, 1979). The P, K and S contents were determined by standard method (Rahman, 1971; Jackson, 1979).

Statistical analysis

The data was subjected to statistical analysis using the SPSS16.0 software and the results expressed as mean ± standard error of triplicate determinations.

RESULTS AND DISCUSSION

The morphological traits exhibited broad variability among the breeding materials tested (Table 1). Most of the correlation coefficients derived were positive. Although technically positive correlation, the relationship between different variables were weak, except between main shoot length and number of siliqua on main shoot, and between siliqua length and beak length (Table 2).

The GLC analysis for different fatty acids in mustard genotypes revealed that erucic acid was in the range of 0.28 (NUDH-YJ-3-3) to 33.97% (PRQ 2005-4 BL) [Table 3]. The quality genotypes having erucic acid< 2% were BC3-BC4-1 (0.57%), F3-F4-1 (0.67%), F3-F4-3 (1.05%), NUDH-YJ-3-3 (0.28%), F3-F4-2 (0.74%), F4-F5-1 (0.72%), PRQ 2004-8 (0.51%) and PRQ-2005-1 (1.24%). High content of erucic acid is considered undesirable for human consumption as it leads to fibrotic changes in myocardium and elevates the level of adrenal cholesterol (Aaes-Jorgensen, 1972). Charlton *et al.* (1975) has reported that the rats fed with erucic acid enriched-diet revealed lipidosis. Eicosanoic acid was maximum in F4-F5-7 (29.43%) and minimum in LG BC 2005-6-8 (7.33%).

The optimal ω_6/ω_3 ratios (2:1-3:1) have been reported to be four times lower than the current intake (Khan *et al*., 2013). In present study, ω_6/ω_3 were fairly better in genotypes PLGM-2002-2-7 (2.28), LG BC 2005-6-8 (2.20), PRQ 2004-9 (1.92), PRQ-2005-11-BE (1.91) and F4-F5-5 (2.13) [Table 3]. Other genotypes had ω_6/ω_3 ratio in the range of 0.68 (F4-F5-1) to 1.83 (F4-F5-7). The ω_6/ω_3 ratio of rapeseed-mustard oil reported earlier was 1.17 (Kumar *et al.*, 2014). The linoleic and linolenic acid contents in seed oil of genotypes revealed variation. Linoleic acid ranged from 22.05 (PDLM-2002-4-14) to 33.81% (F3-F4-2). Linolenic acid ranged from 10.54 (LG BC 2005-6-8) to 42.63% (F4-F5-1). The intake of PUFA is useful in decreasing cholesterol (Cunnane, 1995) but higher dietary intake enhances lipid peroxidation (Mouri *et al*., 1984). Linoleic acid has beneficial effects on inflammation, depression, diabetes, cancer and autoimmune disorder (Baylr *et al*., 2006). Low dietary linolenic acid reportedly is linked with high risk of ischaemic heart disease (Dolecek, 1992). In human tissues the most abundant PUFA is linoleic acid (Whelan, 2008), the low levels of which indicates various symptoms associated with dietary insufficiency.

In present study maximum oleic acid was found in genotype PRQ-2005-1 (36.15) and minimum in PDLM-2002-4-14 (7.21%). The oleic acid level in rapeseed oil is in the range of 3.6 to 32.2% (Chauhan and Kumar, 2011). Oleic acid has no ill effect on human and increases the shelf life of oil. Therefore, the oils having low saturated fats, moderate level of linoleic acid and low linoleneic acid are considered suitable for edible purpose. The stearic acid was maximum in genotypes PRQ-2005-1, PRQ2002-4 (YE) and LG2005-6-8(B)-6 (0.78%) and negligible in F3-F4-3. The high stearic acid, a saturated fatty acid, in plasma are a threat as it leads to atherosclerotic vascular disease. Abnormal levels in erythrocyte membranes cause alteration in biological membrane fluidity with several consequences. Low levels increase fluidity which is linked to active tumour proliferation (Zamaria, 2004). Palmitic acid was maximum in genotype LG BC 2005-6-8 (4.69%) and minimum in genotype LG 2005-36-1 (1.77%).

Brassica species are good source of essential mineral for human consumption which includes Na, K, Ca, Mg, Cl, P and S and trace elements like Fe, Zn, Mn and Cu (House, 1999; Papola *et al.*, 2016). The analysis revealed that all quality genotypes contained variable amounts of N, P, K, S, C, Ca, Mg, Fe, Mn, Zn and Cu. These minerals play a major role in structural and functional aspect of both plants and animals. In present study, highest N content was noticed in DC F4-F5 (2) and DL-2005-3-47(Y-7)

Table 1: Descriptive statistics of different phenotypic traits* of quality germplasm

Breeding material	PH (cm)	MSL (cm)	SMS	SL (cm)	BL (cm)	PB	SB	SP	SD	SW (g)	YP (g)
F4-F5 (1)	91.3±5.0	36.0±5.3	16.0±1.7	3.0±0.0	0.5±0.1	4.0±0.3	6.3± 2.9	11.0± 4.4	0.5±0.01	2.5± 0.1	3.7± 1.8
F4-F5(2)	112.3±2.5	49.7±10.0	20.7± 3.1	3±0.87	0.5±0.2	4.7± 0.6	10.7± 4.0	8.7± 4.9	0.4± 0.1	3.5± 0.2	5.8± 1.6
F4-F5 (4)	101.0±10.5	38.7±3.5	17.3± 4.0	3.3±0.3	0.5± 0.1	5.8± 0.3	5.±2.6	15.3± 3.2	0.4±0 0.1	3.5± 0.2	5.8± 1.5
F4-F5 (5)	141.7±43.7	50.7±17.2	21.7± 6.5	3±0	0.6± 0.1	4.3± 0.6	10.7± 3.5	13.7± 1.5	0.4± 0.1	2.5± 0.6	4.8± 3.4
F4-F5 (6)	121.0± 9.8	37.3±5.1	17.3±0.6	2.7±0.3	0.6± 0.4	3.7± 1.2	4.3± 2.5	9.7± 2.9	0.5± 0.2	2.8± 0.5	2.9± 1.2
F4-F5 (7)	119.7±1.5	37.0±7.0	18.0±0.5	3.2±0.3	0.9± 0.1	3.7± 0.6	5.7± 2.3	11.7± 3.2	0.5± 0.0	2.8± 0.8	3.4± 0.6
F3-F4 (1)	118.3±22.4	49.7±15.9	22.0±1.7	2.7±0.6	0.5± 0.1	4.0±1.0	8.3± 4.0	14.7± 2.1	0.5± 0.1	2.5± 0.3	6.7± 2.4
F3-F4 (2)	94.7± 3.5	41.3±4.6	20.7± 5.1	2.5±0.5	0.5±0.2	4.7± 0.6	9.0±0.9	15.3± 3.5	0.5± 0.1	2.2± 0.5	5.8± 1.1
F3-F4 (3)	131.0± 6.2	38.0± 1.7	24.3±0,3	2.2±0.3	0.4± 0.1	4.0±1.0	5.7± 3.5	13.3± 0.6	0.4± 0.0	2.5± 0.6	4.7± 2.4
BC3-BC4 (1)	111.0± 2.7	32.3±2.1	19.7±1.5	3.3±0.3	0.5±0.1	3.7± 0.6	5.3± 1.2	14.0± 1.7	0.6± 0.1	2.2± 0.5	3.2± 0.2
BC3-BC4 (2)	115.0± 7.8	39.0± 6.1	16.0±3.5	3.3±0.3	1.2± 0.8	4.7±0.6	9.0±3.0	11.7± 4.7	0.4± 0.1	3.2± 0.3	3.5± 0.3
BC3-BC4(3)	106.7±6.2	38.0± 1.7	24.3±0.3	2.2±0.3	0.4± 0.1	6.3± 0.6	5.63±2.4	10.3± 3.1	0.6± 0.0	2.0± 0.2	3.1± 1.3
DC F4-F5 (1)	98.0±7.2	46.7±6.7	23.0±4.3	2.8±0.3	0.3± 0.2	3.7± 0.6	6.7± 2.5	12.3± 2.5	0.6± 0.2	3.4± 0.3	3.5± 0.3
DC F4-F5 (2)	106.7±7.6	36.0± 4.6	19.3±0.3	3±0	0.5±0.2	4.3± 0.6	6.7± 3.8	13.7± 3.2	0.5± 0.1	3.1± 0.3	4.1± 1.3
DC F4-F5 (3)	117.7±3.0	42.3±10.2	24.0±1.7	2.8± 0.3	0.6± 0.4	4.0±0.5	5.7±3.0	14.7± 1.2	0.5±0.1	2.3± 0.1	4.1±1.5
DL-2005-3-47(Y)-7	82.0±6.6	32.3±4.7	22.3± 3.8	3±0	0.6± 0.2	4.7± 1.1	7.0±1.0	13.0± 1.0	0.7± 0.2	2.1± 0.3	2.6± 0.3
PDLM-2002-4-14	81.0±8.6	32.7±3.2	15.7±0.7	3.5±0.5	0.5±0.1	4.7± 0.6	4.0± 2.8	13.0±2.0	0.5± 0.1	3.5± 0.5	3.7± 1.8
PRQ-2005-4 BL	103.7±11.5	43.3±8.6	26.0±0.9	2.5±0.5	0.5±0.1	4.0±0.3	4.0± 3.0	11.0±1.0	0.6± 0.1	4.0± 0.1	6.1± 2.8
PRQ-2005-11(BE)	108.7±6.5	33.3±2.3	20.3± 4.7	3.2±0.3	0.5±0.1	4.7± 0.6	8.7± 2.1	8.3± 2.1	0.6± 0.1	2.9± 0.3	5.1± 0.3
LG-2005-6-8-B-6	106.7±16.6	26.3±3.2	18.7± 1.2	3±0	0.4± 0.2	4.0±0.7	7.3± 2.3	13.3± 2.3	0.7± 0.1	2.1± 0.2	2.4± 0.6
PRQ-2002-4 (YE)	92.0±9.8	30.7±2.3	11.7± 1.5	3.8±0.3	0.5± 0.1	5.7± 1.5	13.3± 2.1	13.0± 3.0	0.4± 0.0	2.8± 0.4	4.6 ± 2.1
LG BC-2005-6-8	103.7±18.2	25.3±14.7	9.3±0.8	3±0.5	0.5±0.2	4.3± 0.6	9.7± 2.5	7.3± 1.5	0.4± 0.1	2.1± 0.2	2.4± 0.6
PRQ-2004-8	105± 13.23	31.7±4.0	18.7± 3.2	3.3± 0.6	0.6±0.1	4.7±1.1	6.7±1.5	14.7±1.5	0.6± 0.1	2.1 ± 0.1	4.3 ± 1.9
PRQ-2004-9 (B)	113.3± 9.6	41.7±5.8	16.3± 1.5	3.0±0.5	0.6± 0.4	4.0±0.6	8.0±3.5	12.7± 3.1	0.4±0.1	2.0 ± 0.1	4.3 ± 1.9
PLGM-2002-2-1	123.3±3.1	27.7±2.1	14.3±0.5	2.2±0.3	0.3± 0.1	4.0±0.5	8.7± 1.5	14.0±1.0	0.5± 0.02	1.8± 0.3	1.9± 0.5
PLGM-2002-2-7	97.3±3.1	27.7±2.1	14.3±…	2.2±0.3	0.3± 0.1	3.7± 1.5	5.0±1.0	14.0±1.0	0.5± 0.1	2.6± 0.2	5.3± 2.4
PRQ-2005-1	99± 17.4	56.7±14.1	26.7±…	2.5±0.5	0.3± 0.2	3.7± 0.6	5.0± 2.6	11.3± 1.2	0.5± 0.1	2.6± 0.3	4.1± 1.4
NUDH-YJ-3-3	129.3±14.0	36.0±0.8	23.0±7	2.8±0.3	0.5± 0.6	4.3± 1.1	6.0±2.0	14.3± 0.6	0.6± 0.1	3.1± 0.2	3.8± 1.2
PDLM-2003-9-6	97.7± 4.0	35.3±4.5	18.3±0.0	3.0±0.0	0.7± 0.3	4.7± 0.6	10.0± 1.0	10.3± 0.6	0.5± 0.1	3.0± 0.3	7.5± 1.8
LG 2005-36-1	102.5±16.1	23.6±10.4	9.3±0.0	3.0±0.4	0.4±0.0	4.9± 0.6	10.1± 3.1	8.2± 1.7	0.4± 0.6	1.9± 0.4	2.5± 0.6
$CD_{0.01}$	28.22	16.78	8.63	0.83	0.48	1.50	4.93	5.44	0.20	0.78	2.95
$CD_{0.05}$	21.20	12.61	6.49	0.62	0.36	1.13	3.70	4.09	0.15	0.59	2.22
SEM+	7.48	4.45	20.53	0.22	0.13	0.40	1.31	1.44	0.52	0.21	0.78

PH = Plant height; MSL = Main shoot length; SMS = No of siliqua on main shoot; SL = Siliqua length; BL = Beak length; PB = No. of 1˚ branches; SB = No. of 2˚ branches; SP = No. of seeds in pod; SD = Siliqua density; SW = 1000-seed weight; YP = Yield plant^{-1}

[20.81±0.70 and 20.71±0.45%, respectively], whereas least N content was found in BC3-BC4-1 (11.3±0.3%) [Fig. 1]. The P and K concentration were high in genotypes F4-F5-6 and PDLM 2003-9-6 (1.4±0.5 and 0.6±1.2%, respectively). Least P and K content was found in PLGM-2002-2-7 (0.3±0.3%) and F4-F5-7 (0.2±0.6%) [Fig. 2]. Potassium is an indispensable nutrient with significant

Table 2: Pearson-correlation matrix of selected morphological characters of quality germplasms ($p<0.05\%$)

Traits	Plant height (cm)	Main shoot length	No of siliqua on main shoot	Siliqua length	Beak length	No. of 1˚ branches	No. of 2˚ branches	Seeds pod^{-1}	Siliqua density	1000 seed weight (g)
Main shoot length	0.252									
Siliqua on main shoot (No.)	0.219	0.652								
Siliqua length	-0.270	-0.177	-0.410							
Beak length	0.111	0.008	-0.185	0.506						
No. of 1˚ branches	-0.26	-0.126	-0.106	0.266	0.082					
No. of 2˚ branches	0.081	-0.013	-0.373	0.318	0.159	0.300				
Seeds (No.) per pod	0.085	0.005	0.142	-0.017	-0.122	-0.031	-0.172			
Siliqua density	-0.139	-0.254	0.442	-0.171	-0.257	-0.027	-0.372	0.113		
1000-seed weight (g)	-0.139	0.296	0.148	0.256	0.181	0.068	-0.162	-0.184	-0.111	
Yield per plant (g)	-0.044	0.425	0.238	-0.012	0.034	0.155	0.185	0.086	-0.321	0.443

Table 3: Fatty acid composition and essential fatty acid ratio of quality germplasm

S. No.	Quality germplasm	% contribution of fatty acids							ω6/ω3 ratio
		Palmitic acid (C16:0)	Stearic acid (C18:0)	Oleic acid (C18:1)	Linoleic acid (C18:2)	Linolenic acid (C18:3)	Eicosanoic acid (C20:0)	Erucic acid (C22:1)	
1	F4-F5(7)	2.27	0.68	12.37	27.06	14.71	29.43	14.13	1.83
2	F4-F5(6)	2.50	0.40	12.54	24.34	16.67	32.40	11.51	1.46
3	F3-F4(3)	2.39	0.00	21.95	27.50	37.40	9.69	1.05	0.735
4	PRQ 2005-4(BL)	2.49	0.55	9.97	22.35	12.30	18.72	33.97	1.81
5	DCF4-F5(2)	2.39	0.35	10.96	26.33	24.40	20.00	15.90	1.07
6	PLGM-2002-2-1	3.48	0.49	11.97	26.38	21.54	20.59	14.97	1.22
7	PDLM-2002-4-14	2.77	0.37	7.21	22.05	20.30	14.00	33.64	1.08
8	PLGM-2002-2-7	2.15	0.40	14.03	30.93	13.52	24.16	12.36	2.28
9	BC3-BC4(3)	2.34	0.37	23.70	32.40	20.93	17.01	3.62	1.54
10	PRQ-2005-1	4.07	0.78	36.15	29.32	19.03	10.07	1.24	1.54
11	LG BC 2005-6-8	4.69	0.75	32.61	23.26	10.54	7.33	20.78	2.20
12	PDLM 2003-9-6	3.63	0.38	11.85	24.56	14.32	19.16	26.44	1.71
13	F3-F4(2)	2.87	0.40	22.74	33.81	20.56	20.00	0.74	1.64
14	LG 2005-36-1	1.77	0.48	9.40	24.79	20.39	19.20	24.62	1.21
15	NUDH-YJ-3-3	3.60	0.42	14.52	33.43	30.24	18.08	0.28	1.10
16	BC3-BC4(1)	2.63	0.40	22.54	31.57	23.57	20.00	0.57	1.33
17	BC3-BC4(2)	2.19	0.37	18.77	29.23	21.17	20.07	8.54	1.38
18	PRQ-2004-9	2.31	0.32	12.60	21.20	11.02	26.18	20.41	1.92
19	PRQ 2004-8	4.00	0.38	14.48	29.13	31.80	20.00	0.51	0.91
20	F4-F5(2)	2.76	0.41	23.60	29.35	20.96	14.08	9.28	1.40
21	F4-F5-1	3.23	0.59	15.39	29.18	42.63	8.81	0.72	0.68
22	F3-F4(1)	3.14	0.38	16.18	29.58	30.60	20.08	0.67	0.966
23	PRQ2002-4 (YE)	2.57	0.78	17.33	32.38	22.75	20.46	4.92	1.42
24	DCF4-F5(1)	3.07	0.32	20.04	29.92	20.26	16.00	8.30	1.47
25	F4-F5(4)	3.37	0.38	24.99	30.14	21.42	20.06	0.50	1.40
26	DCF4-F5(3)	3.24	0.40	16.88	27.63	21.67	20.07	9.56	1.27
27	PRQ-2005-11(BE)	2.62	0.37	8.68	24.26	12.67	26.23	25.51	1.91
28	LG2005-6-8(B)-6	2.47	0.78	14.84	24.80	13.78	26.36	17.72	1.79
29	F4-F5(5)	3.18	0.30	15.65	26.65	12.47	27.51	14.52	2.13
30	DL-2005-3-47(Y)-7	3.53	0.30	17.10	31.25	23.28	20.00	4.82	1.34

significant association in the biosynthesis of amino acids and proteins. Sulphur, responsible for pungency in mustard, was highest in genotype F4-F5-6 (0.9±0.1%) and least in BC3-BC4(1), 0.3%±0.3 (Fig. 2). Ca and Mg were highest in genotypes DC F4-F5-3 and LG-2005-6-8-9-1 (1.6±0.2 and 0.8±0.2%, respectively) and least in PLGM-2002-2-1 and F3-F4-2, respectively (Fig. 2).

The Fe, Mn, Cu and Zn contents in mustard is given in Fig. 3. These elements are essential activators for enzyme-catalyzing reactions (Ayaz *et al*., 2006). Fe content was maximum in genotype DC F4-F5-2 (267±1.4 mg kg^{-1}) and minimum {24±0.4 mg kg^{-1}} in PRQ 2004-9(B) and F4-F5 (2). Fe is a micronutrient required for haemoglobin production and also a cofactor for important enzyme. Mn content was high in genotype DC F4-F5-2 (71±0.6 mg kg^{-1}) and low in LG BC 2005-6-8 (12±0.5 mg kg^{-1}). Mn is required for skeletal growth and development, and functions with vitamin K in prothrombin synthesis. Zn is required for regulation of cellular growth, essential in gene expression and acts as a cofactor of various enzymes (Camera and Amaro, 2003). In present study Zn content was high in genotype PRQ 2005-1 (93±0.1 mg kg^{-1}) and low in BC3-BC4-2 (31±0.1 mg kg^{-1}). Cu is required in erythropoiesis, erythrocyte function and regulation of erythrocyte survival but its higher dose leads to diarrhea, blood loss through urine, hepatic damage and vomiting (Johnson, 2005). Cu content was high in genotype DC F4-F5-3 (59±0.4 mg kg^{-1}) and low [10±0.4 mg kg^{-1}] in PLGM-2002-2-1 and PRQ 2004-9(B). Cu and Mn act as cofactors of anti- oxidant enzymes and provide protection from reactive oxygen species that are produced during oxidative stress (Leung, 2009).

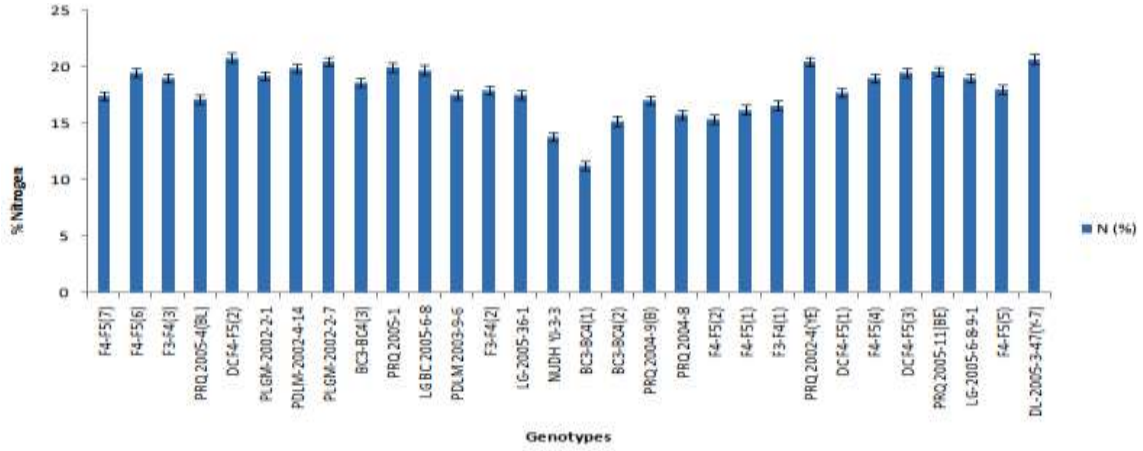

Fig. 1: N content (%) of promising quality germplasm of *Brassica juncea*

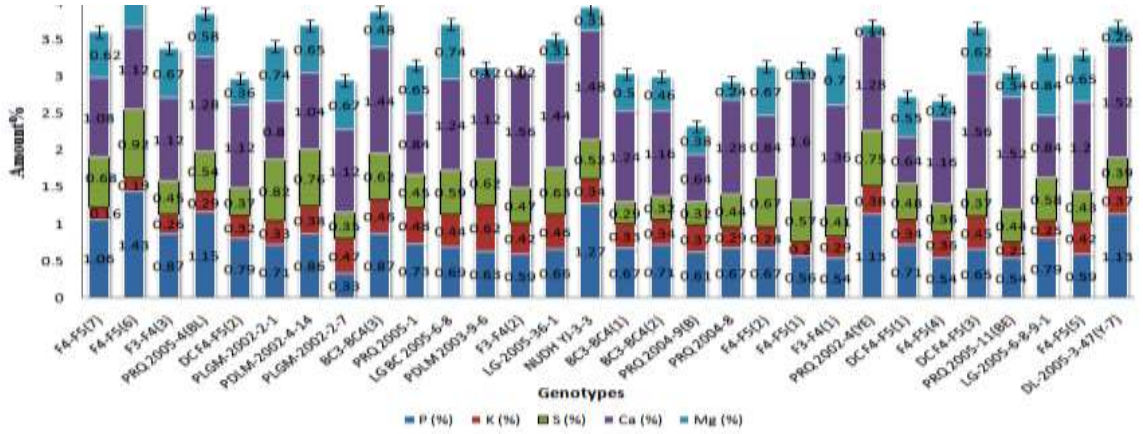

Fig. 2: P, K, S, Ca and Mg content (%) of promising germplasm of *Brassica juncea*

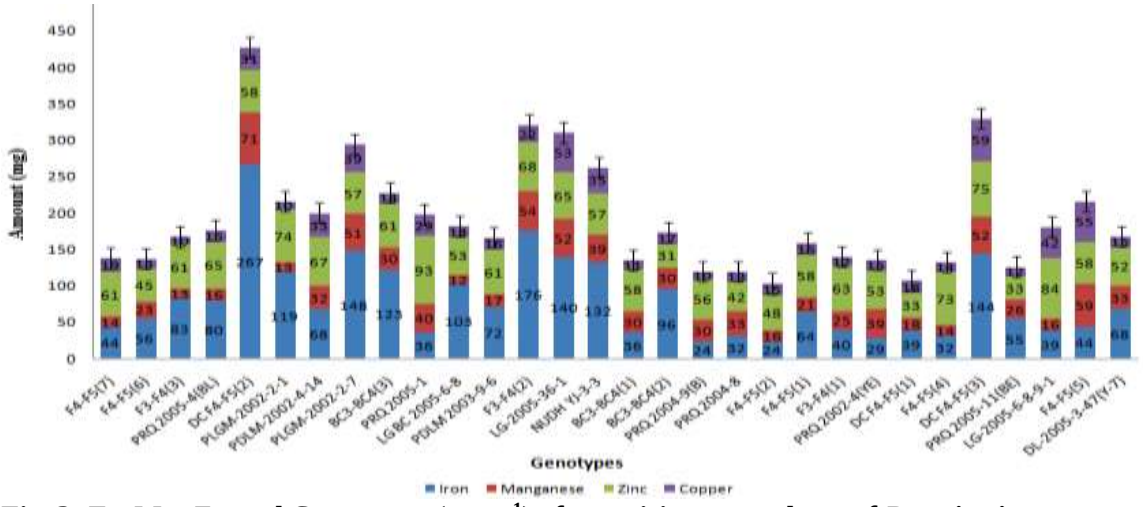

Fig. 3: Fe, Mn, Zn and Cu content (mg g^{-1}) of promising germplasm of *Brassica juncea*

Bioavailability of important minerals along with other trace elements reduced by the presence of glucosinolates and phytates (Atwal *et al*., 1980).

Conclusions: The present findings revealed that quality Indian germplasm is a rich source of health promoting dietary fatty acid and nutritionally-valued minerals which can be used for the formulation of balanced process foods and supplements in animal feeds. In present study some low erucic acids

lines were identified which may be used for enhancing quality traits. It is recommended that oil seeds should be assessed for protein, minerals and other micronutrients in food formulations. A desirable ω_6/ω_3 ratio should be in range of 5-10 but in Indian germplasm it was 2:1 to 3:1 which are ~4 times lower than the current intake. Hence, novel means and methods must be adapted for the selection of genotypes having optimal ratio of fatty acids useful for human diet.

Acknowledgement: Authors are thankful to SERB, Department of Science & Technology, New Delhi (India) for providing research grant for the present work.

Conflict of interest: The authors declare no conflict of interest.

REFERENCES

Aaes-Jorgensen, E. 1972. Nutritional value of rapeseed oil. pp. 301-353. **In**: *Rapeseed Cultivation, Composition, Processing and Utilization* (eds. L.A. Appelqvist and R. Ohlson). Elsevier, Amsterdam, Netherlands.

Atwal, A.S., Eskin, N.A.M., Mac, D.B.E. and Vaisy, G.M. 1980. The effects of phytate on nitrogen utilization and zinc metabolism in young rats. *Nutrition Reports International*, **21**: 257-267.

Ayaz, A.F., Glew, R.H., Millson, M., Huang, H.S., Chuang, L.T. and Sanz, C. 2006. Nutrient contents of kale (*Brassica oleraceae* L. var. *acephala* DC.). *Food Chemistry*, **96**: 57-579.

Baylr, A., Halilogglu, H.I., Sirkecioglu, A.N. and Aras, N.M. 2006. Fatty acid composition in some selected marine fish species living in Turkish waters. *Journal of the Science of Food and Agriculture*, **86**: 163-168.

Camera, F. and Amaro, C.A. 2003. Nutritional aspect of zinc availability. *International Journal of Food Science and Nutrition*, **47**: 143-151.

Charlton, K.M., Corner, A.H., Davey, K., Kramer, J.K., Mahadevan, S. and Sauer, F.D. 1975. Cardiac lesions in rats fed rapeseed oils. *Canadian Journal of Comparative Medicine*, **39**: 261-269.

Chauhan, J.S and Kumar, S. 2011. Assessment of oil and seed meal quality parameters of rapeseed-mustard group of crops. *Indian Journal of Agricultural Sciences*, **81**: 140-144.

Cunnane, S.C. 1995. Metabolism and function of linoleic acids in humans. pp. 99-127. **In**: *Flaxseed in Human Nutrition* (eds. S.C. Cunnane and L.U. Thompson). AOCS Press, Illinois, USA.

Dolecek, T.A. 1992. Epidemiological evidence of relationships between dietary polyunsaturated fatty acids and mortality in the multiple risk factor intervention trial. *Proceedings of the Society for Experimental Biology and Medicine*, **200**: 177-182.

Elwell, W.T. and Gidley, J.A.F. 1967. *Atomic Absorption Spectrophotometry*. MacMillan, New York, USA

FAOSTAT. 2011. *Food and Agriculture Commodities Production*. Food and Agriculture Organization of the United Nations, Rome, Italy.

House, W.A. 1999. Trace element bioavailability as exemplified by iron and zinc. *Field Crop Research*, **60**: 115-141.

Jackson, M.L. 1979. *Soil Chemical Analysis.* Prentice Hall, New Delhi, India.

Johnson, W.T. 2005. Copper and brain function. **In**: *Nutritional and Neuroscience* (eds. H.R. Lieberman, R.B. Kanarek, and C. Prasad). Taylor & Francis, Boca Raton, USA.

Kale, V. 2007. Newer trends in refining of rice bran oil. pp. 81-86. **In**: *Souvenir National Seminar on Changing Vegetable Oils Scenario: Issues and Challenges before India*. Indian Society of Oilseeds Research, Directorate of Oilseeds Research, Hyderabad, India.

Khan, A., Sankhyan, P. and Suresh Kumar. 2013. Biochemical characterization of mustard oil (*Brassica campestris* L.) with special reference to its fatty acid composition. *Asian Journal of Advanced Basic Sciences*, **1**: 1-9.

Kumar, S., Singh, D. and Dutta, M. 2014. Quality characteristics in rapeseed-mustard and role of some anti-nutritional factors in plant defense: Future strategies. *Journal of Oilseed Brassica*, **5(2)**: 87-95.

Leung, M. 2009. *The Useful Plants of India*. Publications and Information Directorate, CSIR, New Delhi, India.

Mouri, K., Ikesu, H., Esaka, T. and Igarashi, O. 1984. The influence of marine oil intake upon levels of lipids, alpha-tocopherol and lipid peroxidation in serum and liver of rats. *Journal of Nutritional Science and Vitaminology*, **30**: 307-318.

Papola, Poonam, Punetha, H., Tripathi, Sonal, Pant, A.K. and Om Prakash. 2016. Quantification of glucosinolate and mineral content in exotic collection of *Brassica juncea*. *Research in Environment and Life Sciences*, **9**: 343-346.

Paquot, C. and Hautfenne, A. 1987. *Standard Methods for the Analysis of Oils, Fats and their Derivatives.* Blackwell Scientific Publications, Oxford, UK.

Potts, D.A., Rakow, G.W. and Males, D.R. 1999. Canola-quality *Brassica juncea*, a new oilseed crop for the Canadian prairies. pp. 26-29. **In**: *Proceedings of Xth International Rapeseed Congress*. September 26-29, 1999, Canberra, Australia.

Pratap, P., Meena, P.D., Singh, B.K., Meena, H.S., Meena, S.S., Sharma, P. and Majumdar, R. 2014. Development and evaluation of Alternaria blight tolerant lines in Indian mustard (*B. juncea*). *Journal of Oilseed Brassica*, **5**: 141-148.

Prem, D., Gupta, K., Sarkar, G. and Agnihotri, A. 2012. Determination of oil, protein and moisture content in whole seeds of three oleiferous *Brassica* species near-infrared reflectance spectroscopy. *Journal of Oilseed Brassica*, **3**: 88-98.

Punetha, H., Chandra, M., Bhutia, S., Tripathi, S. and Prakash, O. 2015. Antioxidative properties and mineral composition of defatted meal of oileferous *Brassica* germplasm. *Journal of Biologically Active Products from Nature*, **5**: 43-45.

Punetha, H., Heena Sagar, Swati Panwar, Usha Pant and Prakash, O. 2017. Study on phytochemicals and antioxidative capacity of selected genotypes of *Brassica juncea*. *Research in Environment and Life Sciences*, **10**: 373-377.

Punetha, H., Kumar, S., Mudila, H. and Prakash, O. 2018. Brassica meal as a source of health protecting neutraceutical and its antioxidative properties. pp. 108-131. **In**: *Nutraceuticals and Innovative Food Products for Healthy Living and Preventive Care.* IGI Global, Pennsylvania, USA.

Rahman, M. 1971. Spectrophotometric determination of xanthate and total sulphur in viscose. *Analytical Chemistry*, **43**: 1614-1618.

Simopoulos, A.P. 2008. The omega-6/omega-3 fatty acid ratio, genetic variation and cardiovascular disease. *Asia Pacific Journal of Clinical Nutrition*, **17**: 131-134.

Warnke, D.D. and Barber, S.A. 1974**.** Root development and nutrient uptake by corn growth in solution culture. *Agronomy Journal*, **66**: 514-516

Whelan, J. 2008. (n-6) and (n-3) polyunsaturated fatty acids and the aging brain: Food for thought. *Journal of Nutrition*, **138**: 2521-2522.

Zamaria, N. 2004. Alteration of polyunsaturated fatty acid status and metabolism in health and disease. *Reproduction Nutrition Development*, **44**: 273-282.