Genetic variations in fatty acids and oil compositions among 188 Indian mustard [*Brassica juncea* (Linn.) Czern & Coss] genotypes

Abstract

The experiment was conducted to evaluate variability among 188 Indian mustard genotypes based on diverse biochemical parameters *viz*., palmitic, oleic, linoleic, linolenic, erucic acids and oil content. Analysis of variance indicated the existence of substantial magnitude of variability among studied mustard genotypes which suggest better possibilities for their improvement. Genotypic and phenotypic coefficient of variation was found to be higher for oleic acid tracked by erucic and palmitic acids. Erucic, oleic, palmitic, linoleic and linolenic acids had maximum heritability and genetic advance. Significant negative correlation of erucic acid was documented with palmitic, oleic, linoleic and linolenic acids. Genotypic and phenotypic path coefficient analysis had the higher positive direct effect of palmitic acid on erucic acid, whereas highest negative direct effect on erucic acid was evidenced by linoleic, oleic, linolenic acids and oil percentage. Genetic divergence using Euclidean distance cluster grouped the genotypes into eighteen different clusters. Among all studied biochemical parameters, erucic acid was found to be low in 9, moderate in 57 and higher in 122 genotypes. In cluster analysis of qualitative traits, maximum inter cluster distance was observed between cluster 18 (Karishma) and cluster 12 (Maya). Thus, these genotypes may be utilized as parents in mustard breeding scheme for improvement of diverse qualitative traits.

Key words: Indian mustard, Biochemical traits, Correlation coefficient, Path coefficient, Quantitative traits, Principle component analysis.

1. Introduction

The genus *Brassica* is continuously gaining industrial importance due to the presence of oil rich species such as *Brassica juncea*, *B. carinata*, *B. rapa* and *B. napus* in it [1]. Specific nutritional values are basic criteria to select the oil for edible and industrial applications. Among all the mustard species *B. juncea* has gained higher adaptability in India, China and Pakistan due to high oil contents up to 44% [2-4] and grown as oilseed crop. Apart from oil content various biochemical parameters such as essential and non-essential fatty acids are also considered to ensure industrial as well as nutritional importance of mustard oil [5-7]. Among nutritional parameters of edible oil fatty acids resembling oleic, linolenic, erucic, palmitic and linoleic acids is very important. Indian mustard (*B. juncea*) genotypes have been reported with higher fractions of erucic acid and glucosinolates in the oil part [4]. Low erucic acid containing mustard genotypes are preferred due to cardiac problems with higher erucic acid. Industrial qualities of oils are also important for their use in the production of detergents, cosmetics, lubricants, hydraulic oils or bio-diesel and other non-edible items [8, 7, 3]. Thus, it is essential to develop superior mustard cultivars with required qualities for human consumption as well as industrial purposes [9].

Shelf life of oil and food frying qualities are generally depending on higher mono and low poly-unsaturated as well as very low levels of saturated fatty acid [10, 3]. To fulfill the said objectives, the researchers involved in mustard crop improvement need to identify diverse genotypes with each other in terms of targeted concerns [11-16] with sufficient heritability and selection criteria. To understand the level of relationship between two parameters generally correlation analysis

conducted. Several studies have been conducted on correlation analysis for quantitative traits in crops including Canola [17] in addition to in *B. campestris*, *B. napus*, *B. carinata* and *B.* [18-20]. In the similar way, path analysis has also been used extensively by researchers for the improvement of crops [21]. For the current investigation, genotypic and phenotypic correlations were estimated to generate significant information for the future improvement programme of *Brassica*. Thus, this investigation was undertaken to screen the Indian mustard germplasm lines for biochemical parameters that further may be included in *Brassica* breeding programme to breed optimum range of fatty acid containing varieties.

2. Materials and Methods

A set of 188 Indian mustard genotypes acquired from the Zonal Agricultural Research Station, Morena, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya (RVSKVV), Gwalior, India (AICRP on Rapeseed and Mustard) and Indian Agricultural Research Institute, New Delhi were used in present investigation (Table 1). All selected genotypes of mustard were grown in randomized block design with two replications during *Rabi* 2016-17 at the experimental field of department of Genetics & Plant Breeding, College of Agriculture, RVSKVV, Gwalior. Each genotype was grown in a plot of one row of 2-meter length with a spacing of 30 cm apart between rows and 15 cm plant to plant. The crop was provided with protective irrigations and recommended package of practices right through the growing season. Seeds were analyzed for the diverse biochemical parameters, *i.e.*, palmitic acid, oleic acid, linoleic acid, linolenic acid, erucic acid and oil percentage for analysis of mean performance, genotypic (GCV) and phenotypic coefficient of variation (PCV) as per formula given by Burton [22]; heritability in broad sense (h^2) as suggested by Burton and De [23] and genetic advance as per method described by Johnson et al. [24]. Fatty acid analysis was carried out at Quality Lab, Division of Genetics, Indian Agricultural Research Institute, New Delhi and the oil extraction at Department of Soil Science and Agricultural Chemistry, College of Agriculture, RVSKVV, Gwalior, India by using Soxhlet method. The profiling of fatty acid was conducted by employing Gas – Liquid Chromatography (GLC). Fatty acid methyl esters (FAME) of oil sample from each variety were extracted. Gas chromatography (Perkin Elmer Claurus 500) fitted with megabore column (30 meter long and 0.53mmicro) fitted with OV-101, equipped with a Flame Ionization Detector (FID) was used for FAME analysis. The conditions maintained were Column temperature: 1500C-2700C, Injector temperature: 2500C and Detector temperature: 2500C. Ultrapure nitrogen gas was practiced as transporter. GLC was programmed for the temperature at the rate of 100C per minute upsurge and lastly it was upholded at 270^0C. In gas chromatographs, area under each peak is calculated automatically, it can be computed by measuring the peak height and width at half height (Triangulation method). After computing total peak area for each sample, calculate percent area under each peak that would spring percentage of corresponding fatty acid.

Genotypic and phenotypic correlations were calculated by using the formula furnished by Weber and Moorthy [25] and Miller [26]. Principal component analysis was done on PAST v3.14 software based on correlation matrix (normalized variance-covariance) because the variables are calculated in diverse units; this suggests standardizing all variables by means of division by their standard deviations.

3. Results and Discussion

Variations in genetic parameters help breeders to frame a successful hybridization programme with targeted traits because of their use in the estimation of inherent distance among or between the genotypes [27-33]. These analyses also help in the selection of assorted promising parents to initiate crossing programme [34]. During present study, variance analysis indicated subsistence of generous sum of variability amongst diverse genotypes for all the chosen biochemical parameters *viz*., palmitic acid, oleic acid, linoleic acid, linolenic acid, erucic acid and oil content.

3.1 Mean performance of selected parameters

In the current experiment a total of six biochemical parameters were analyzed in 188 Indian mustard genotypes. The proportion of different fatty acids in the oil from mustard seeds is depends upon various hereditary features of cultivars selected for the investigation [35]. Palmitic acid ranged from 3.94 to13.27%, with a mean value of 6.82% (Table1). Similar ranges for palmitic acid have been reported previously by different research groups [36-43]. The genotypes of mustard with high palmitic acid are considered better for industrial purposes for the production of soap and other similar items because of skincare and moisturizing properties of palmitic acid [44]. However, the role of palmitic acid has been reported in numerous elementary natural functions at cellular as well as tissue levels also [45]. In the present study, genotype IDM-67 had maximum palmitic acid content (13.27%) tracked by ISC-12 (12.17%) and PM28 (12.05%) so, these mustard genotypes may have potential for industrial applications. Minimum (3.94%) palmitic acid was observed in MRNJ-21.

The content of oleic acid was varied between 6.06 to 37.1% with a mean value of 15.36%. Analogous results regarding range of oleic acid have been documented earlier [46, 38, 40, 41, 42] and [43]. In terms of genotypic difference, genotype ISC-18 produced maximum oleic acid (37.1%) followed by MRNJ-30 (32.21%), MRNJ-25 (26.82%) and PM30 (25.6%) while, minimum was noted in genotype RVM-1 (6.06%). Higher concentrations of oleic acid are considered nutritionally imperative for human diet because it improves the intensity of High-density lipoproteins and declines low density lipoproteins in our body. Furthermore, elevated oleic acid substance in seed oil provides thermo stability and makes it appropriate for food preparation [47]. To one side from playing a significant role in rising the competence of cooking oil, oleic acid puts together the seed oil better for industrial applications too [48].

Linoleic and linolenic acids are omega-6 and omega-3 fatty acid correspondingly. Both of these are considered as poly-unsaturated fatty acids. These are essentially important fatty acids because human body cannot synthesize them and they must be taken from food materials. Linoleic acid ranged between 14.9 to 37.33%, with a mean count of 24.01%. Among all studied genotypes ISC-12 exhibited the highest linoleic acid content (37.33%) followed by PM22 (36.2%) however, the lowest value was in Maya (14.97%). Reports are available on the effect of the consumption of high linoleic acid edible oil on blood cholesterol and prevention from atherosclerosis [49]. Dupont et al. [50] reported the role of linoleic acid on maintenance of the uprightness of the skin, cell membranes and the immune system. Reports are also available on harmful effects of consumption of high linoleic acid on human health due to its function as an enhancer of inflammation. Studies are also available on their role in cancer development [51, 52]. However, more authentic studies are required to confirm the possible role of linoleic acid as a causative agent of cancer. The exclusion of *trans* fatty acids from various food items has circuitously yielded in the improvement of oil seed cultivars [53]. Linolenic acid ranged between 8.29 to 16.75% with a mean recital of 11.34%. Similarly, Lavkopr et al. [54] found 3.3 - 13.1% linolenic acid in *Brassica* cultivars during their study. Joughi *et al*. [41], and Shyam and Tripathi [43] have also been documented almost similar range of linolenic acid among different *Brassica*

genotypes. In our study, maximum linolenic acid was noted in genotype LES-39 (16.75%) followed by genotypes PM28 (15.3%) and PM-25 (15.25%) while, the lowest value (8.29%) was exhibited by genotype MRNJ-42. Low linolenic acid containing canola cultivars have been found superior in terms of storage and frying stability. Linolenic acid is considered as a significantly important fatty acid but its occurrence may be a reason of off flavour and rancidity of the oil [40]. Linoleic and linolenic acid generally play central role in the synthesis of membrane lipids. They are also the precursor of prostaglandins, thromboxanes and leukotrienes which are important signaling molecules. The increased numbers of double bonds speed up the oxidation process and oils rich in linoleic and linolenic acid decline quickly upon contact to air at elevated temperatures, with a reduction of quality for human consumption [55].

Erucic acid belongs to monosaturated fatty acid which is a limiting factor of mustard seed oil for human as well as animal due to their indigestibility in both. Sometimes erucic acid also works as a toxic substance [56]. In the present study, erucic acid content varied between 0.92 to 51.44% with a mean value of 30.99%. Among studied Indian mustard genotypes, the highest level of erucic acid was documented in genotype Maya (51.44%) persuaded by JM-1 (46.24%), RVM-2 (45.06%) and IDM-41 (43.75%) while, PM29 had minimum erucic acid content. Similar to present investigation, Kumar et al. [57] observed the range of percentage of erucic acid between 0.5-57.3 in the genotypes of *B. juncea*. However, range of erucic acid contents was found to be high (35.7-51.4) in Indian mustard varieties [58]. Mustard varieties with optimum level of erucic acid could be developed with the help of breeding approaches. Some of the mustard cultivars with optimum level of erucic acid are under cultivation in many countries [59]. Mustard oil rich in erucic acid is considered objectionable for consumption in human diet because of its anti-nutritional properties. It has been also reported as a causative agent of lipidosis in children. However, mustard oil rich in erucic acid are preferred to manufacture many business products such as super quality lubricants, emulsifiers, plastics, textile softeners, coatings, biodiesel and surfactants [60]. Efforts are also in progress for the development of low erucic acid (less than 2%) containing *B. juncea* cultivars with the help of breeding approaches to take the Indian mustard cultivars in the category of international quality standards. For the application of breeding approach, the information on number of genes and their inheritance that control level of erucic acid in mustard is pre-requisite. Previously, Saini et al. [61] verified the role of two genes controlling erucic acid level in *B. juncea*. In our study, oil of nine genotypes *viz*., PM-25 (1.00), PM-26 (1.55), PM-28 (1.14), PM-21 (1.05), PM-22 (1.13), PM-24 (1.18), PM-29 (0.93), PM-30 (1.08) and Karishma (1.24) had less than 2 per cent erucic acid content. However, fifty-seven genotypes showed moderate erucic acid content having 2 to 30 %. However, 122 genotypes had high erucic acid content greater than 30%. Earlier, Saini et al. [61] and Rai et al. [44] also documented diversity in erucic acid content among Indian mustard genotypes.

Oil percentage may give importance to *Brassica* seeds only when if they have superior nutritional qualities like better blend of saturated and unsaturated fatty acids. In our investigation, oil percentage varied from 20.5 to 40.5% with a mean value of 34.68%. In a comparable study conducted by Tahira et al. [4], range of oil contents was found between 22.02 to 41.69% in *B. juncea* genotypes of Pakistan. Similar range (27.9 to 41.72%) of oil contents in *B. juncea* have been evidenced by Mandal et al. [62]. In the present study, NRCDR-2, JM-1, Rohini, CS-54, RB-50 and PM28 showed the highest oil percentages followed by genotypes GM-2, RH74.9 and JD6 (39.5) whereas MRNJ98 (20.5%) exhibited minimum oil percentage. The differences in oil content may be due to the variations in genetic constituents of genotypes as well as environmental factors. The findings of the present study highlight great possibilities for

the selection of studied genotypes as parents in future breeding programme because of higher variability in oil contents [63]. However, in an earlier report low variability for oil content was observed among Indian mustard genotypes [58].

3.2 Variation in genetic parameters

Before starting a hybridization programme, a plant breeder needs to decide a frame of work and for this it is necessary to assess genetic parameters of target crop with different statistical attributes like genetic advance, coefficient of variation and heritability. In the current investigation, many of the targeted traits had high level of genetic inconsistency with advanced standards of variation of genotypic coefficient. Oleic acid had highest GCV and PCV (Table 2) followed by erucic and palmitic acid. However, linoleic and linolenic acid had moderate GCV and PCV values while, oil percentage exhibited very low values for both. Earlier studies [20, 38] conducted on mustard genotypes exhibited similar trends of GCV and PCV values. The broad sense heritability estimates for erucic acid (99.51) had possessed higher heritability tracked by oleic acid (99.05), palmitic acid (95.95), linoleic acid (95.63) and linolenic acid (86.94). Parallel pronouncements have also been addressed earlier by Khan et al. [46] as they reported maximum heritability for oleic and erucic acid while moderate for oil percentage. The ratio of genotypic to phenotypic variance is called the heritability and if its expression is in the form of genetic advance, it is considered more advantageous for the study. In our study, genetic advance was found to be higher for oleic acid (58.28) followed by erucic acid (56.71) however, it was found to be low for oil percentage (8.77). In few other studies, comparative results of higher genetic advance were found for oleic and linolenic acid [58, 38] however, Ali et al. [20] reported low genetic advance for oil percentage.

Among all targeted biochemical parameters, palmitic acid displayed significant positive correlation (Table 3) with linoleic and linolenic acid while, significant negative correlation with erucic and oleic acid after evaluation of genotypic and phenotypic correlation coefficients. In a previous study, Tahira et al. [4]) observed similar correlation of palmitic acid with linolenic acid. But in contrast to our findings, they reported positive relation of palmitic acid with oleic acid while they reported that palmitic acid had significant negative correlation with erucic acid which is similar to our results. The same correlation between palmitic acid and erucic acid was observed by Chauhan et al. [58] also. Further, oleic acid showed significant negative correlation with linolenic acid and erucic acid. The similar correlation for oleic acid content with linolenic and erucic acid contents was reported by Kumar et al [57] but, they reported negative correlation of oleic acid content with linoleic acid also. Our findings indicate that linoleic and linolenic acids both had significant negative correlations with erucic acid while linoleic acid perused significant positive correlation with linolenic acid.

In this research, erucic acid content was considered as dependent variable while path coefficient analysis was done. The analysis (Table 4) indicated that palmitic acid had maximum positive direct effect on erucic acid, whereas highest negative direct effect on erucic acid was imposed by linoeic acid followed by oleic acid, linolenic acid and oil percentage. The characters having significant correlation values with erucic acid were only considered for the analysis of the indirect effect. Palmitic acid showed maximum positive indirect effect *via* oleic acid and oil percentage, whereas negative indirect effect *via* linoeic acid and linolenic acid. Oleic acid showed maximum positive indirect effect *via* linolenic acid and oil percentage while negative indirect effect by way of palmitic acid and linoeic acid. Linoeic acid exhibited maximum positive indirect effect through palmitic acid and oil percentage however, negative indirect effect by means of oleic acid and linolenic acid. In an earlier study conducted by Tahira et al. [4] on

mustard genotypes, genotypic path coefficient analysis revealed positive direct effect of palmitic acid and negative direct effect of oil percentage, oleic and linoleic acid on erucic acid. In the similar way, during phenotypic path coefficient analysis, negative direct effect of oleic and linoleic acid on erucic acid was reported [58]. In the principal component analysis, the first principal component had contributed 41.19 % of the total for the biochemical traits including linoleic acid, palmitic acid, linolenic acid and oleic acid. Second principal component estimated 20.38 % variations and third component accounted for 17.13 % variations. The total contribution of fourth principal components was 13.41 %, including palmitic, oleic, linoleic acids with oil percentage and erucic acid (Table 5). Fifth principal component contributed a total of 5.57 % variation and sixth component explained 2.29 % of the total variation.

Cluster analysis grouped the studied 188 Indian mustard genotypes into 18 different clusters (Table 6, Fig. 1). Cluster 1 had highest 82 genotypes, followed by cluster 1 (36), cluster 4 (18), cluster 5 (17), cluster 3 (12), cluster 8, 10, 14 and 17 (3 genotypes each), cluster 9 and 11 (2 genotypes each) and cluster 6, 7, 12, 13, 15, 16 and 18 (1 genotype each). The highest cluster mean value (11.70) for palmitic acid was found in cluster 8 (Table 7) and lowest in cluster 7 (4.16). For oleic acid, cluster 13 had highest value (37.10), whereas it was lowest in cluster 12 (6.08). The highest and lowest values for linoleic acid were identified in cluster 16 (36.20) and cluster 12 (14.97) respectively, while the highest and lowest cluster means were recorded for linolenic acid in cluster18 (16.75) and cluster 15 (9.80) respectively. Profile of biochemical parameters and scatter plot of grouping of genotypes have been presented (Fig. 2 and Fig. 3). Cluster 10 exhibited highest cluster mean (39.83) for oil percentage and lowest value (33.17) oil percentage was recorded in the cluster 8. For erucic acid highest value (51.44) was in cluster 12 and lowest in cluster 17 (1.06). Inter cluster distance (Table 8) is important to select the genotypes as parents for future breeding programme. In our study, the highest distance (57.46) was identified between cluster 18 and cluster 12 followed by between cluster 17 and cluster 12 (55.45), cluster 16 and cluster 12 (55.04), cluster 14 and cluster 12 (53.02), cluster 15 and cluster 12 (51.12), cluster 18 and cluster 11 (49.72), cluster 16 and cluster 11 (47.99), cluster 17 and cluster 11 (47.93), cluster 14 and cluster 11 (46.25) and cluster 12 and cluster 7 (45.06). The lowest value (6.95) of inter cluster distance was demonstrated between clusters 3 and 11.

4. Conclusions

In conclusion, the Indian mustard genotypes showed higher genetic variability for the levels of studied biochemical parameters. In near future, if our objective is to develop Indian mustard genotypes with superior oil quality then we should target to raise the oleic acid to more than 50 percent, linoleic and linolenic acid below 40% and 14% respectively. Cluster analysis provides the information about inter cluster distance and, maximum inter cluster distance was documented between cluster 18 (Karishma) and cluster 12 (Maya). Consequently, these genotypes can be practiced as parents in mustard breeding. Owing to pattern obtained for genetic variability among the studied genotypes for different studied traits, it is concluded that low erucic acid containing genotypes may be developed through either direct selection or by hybridization method with low erucic acid containing genotypes as parent. The presence of variability among a large set of Indian mustard genotypes indicating high possibilities of the improvement targeting nutritional as well as industrial importance.

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Table 1: Values of different biochemical parameters in 188 Indian mustard genotypes

Genotypes	Source	Palmitic acid (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)	Erucic acid (%)	Oil %
MRNJ1	ZARS, Morena	7.4	13.8	25.3	11.6	36.0	31.5
MRNJ2	ZARS, Morena	6.1	17.3	22.3	10.7	35.2	33.5
MRNJ3	ZARS, Morena	7.1	18.4	25.0	11.7	30.1	34.5
MRNJ4	ZARS, Morena	7.2	19.7	24.7	10.8	29.0	33.5
MRNJ5	ZARS, Morena	7.6	19.6	23.0	10.7	29.2	37.0
MRNJ6	ZARS, Morena	5.8	17.8	16.4	8.9	40.0	36.5
MRNJ7	ZARS, Morena	7.8	14.3	26.0	11.7	33.9	36.5
MRNJ8	ZARS, Morena	8.6	21.5	29.0	11.6	21.3	34.5
MRNJ9	ZARS, Morena	7.4	22.3	26.2	11.0	25.2	34.5
MRNJ10	ZARS, Morena	4.9	15.0	20.8	10.7	37.3	35.0
MRNJ11	ZARS, Morena	4.8	13.9	20.2	10.3	37.6	32.5
MRNJ12	ZARS, Morena	6.1	6.5	23.0	14.3	35.3	32.5
MRNJ13	ZARS, Morena	4.7	18.4	20.5	11.3	33.7	33.0
MRNJ14	ZARS, Morena	4.6	14.7	19.7	12.6	37.1	34.5
MRNJ15	ZARS, Morena	5.8	14.2	19.7	12.0	38.5	33.5
MRNJ16	ZARS, Morena	6.6	8.3	22.4	14.0	34.0	34.0
MRNJ17	ZARS, Morena	5.6	15.8	21.8	11.0	34.0	36.0
MRNJ18	ZARS, Morena	4.2	15.3	17.0	10.3	40.1	36.0
MRNJ19	ZARS, Morena	5.8	10.3	20.3	10.0	39.3	34.0
MRNJ20	ZARS, Morena	5.0	16.1	19.1	10.3	36.2	33.0
MRNJ21	ZARS, Morena	3.9	15.5	19.8	10.4	35.8	34.5
MRNJ-22	ZARS, Morena	4.0	14.6	18.3	9.3	37.9	31.5
MRNJ-23	ZARS, Morena	4.9	8.6	21.1	11.8	40.4	30.5
MRNJ-24	ZARS, Morena	4.4	15.8	18.4	11.8	37.3	32.5
MRNJ-25	ZARS, Morena	5.3	26.8	25.1	11.4	21.5	34.5
MRNJ-26	ZARS, Morena	4.8	16.2	20.3	10.4	35.4	35.0
MRNJ-27	ZARS, Morena	4.7	18.3	23.1	11.4	29.7	37.0
MRNJ-28	ZARS, Morena	4.2	19.1	21.2	10.3	29.9	34.5
MRNJ-29	ZARS, Morena	4.3	20.5	20.4	11.1	32.7	32.5
MRNJ-30	ZARS, Morena	4.2	32.2	23.1	12.0	16.1	33.5
MRNJ-33	ZARS, Morena	4.8	16.3	19.9	10.4	36.2	37.0
MRNJ-34	ZARS, Morena	6.5	14.4	24.9	11.2	30.4	35.5
MRNJ-35	ZARS, Morena	5.5	19.8	21.1	10.2	34.8	36.5
MRNJ-36	ZARS, Morena	5.4	17.5	19.4	9.2	37.4	37.5
MRNJ-37	ZARS, Morena	5.5	19.2	20.2	10.0	32.7	37.5
MRNJ-38	ZARS, Morena	7.4	10.3	23.3	9.9	36.8	34.5
MRNJ-39	ZARS, Morena	6.0	14.7	24.0	9.9	33.5	36.5
MRNJ-40	ZARS, Morena	5.7	19.3	21.1	10.6	31.3	38.5
MRNJ-41	ZARS, Morena	7.0	10.5	24.0	9.2	37.2	34.5
MRNJ-42	ZARS, Morena	6.8	17.5	22.0	8.3	35.1	35.5

MRNJ-43	ZARS, Morena	6.3	19.9	22.6	10.0	30.9	36.0
MRNJ-44	ZARS, Morena	6.1	17.7	20.9	9.8	35.1	37.5
MRNJ-45	ZARS, Morena	7.4	18.4	28.6	10.1	25.9	38.5
MRNJ-46	ZARS, Morena	5.7	18.1	22.8	10.8	30.3	38.5
MRNJ-47	ZARS, Morena	5.7	16.4	21.6	9.4	35.8	36.5
MRNJ-48	ZARS, Morena	5.7	17.4	21.1	10.8	33.8	35.0
MRNJ-49	ZARS, Morena	7.4	17.7	25.6	9.8	30.1	34.0
MRNJ-50	ZARS, Morena	6.2	22.1	23.8	10.0	25.5	35.0
MRNJ-51	ZARS, Morena	5.3	14.7	19.9	8.9	39.6	36.0
MRNJ-52	ZARS, Morena	5.7	15.4	20.4	10.7	35.3	35.5
MRNJ-53	ZARS, Morena	6.2	10.2	21.0	10.1	37.3	34.0
MRNJ-54	ZARS, Morena	6.1	8.8	19.7	9.0	42.4	33.0
MRNJ-55	ZARS, Morena	6.3	15.7	21.9	10.1	33.4	33.5
MRNJ-56	ZARS, Morena	6.8	10.7	20.0	9.2	38.4	35.5
MRNJ-57	ZARS, Morena	6.7	12.5	19.1	9.5	38.0	37.0
MRNJ-58	ZARS, Morena	7.6	16.4	24.2	11.7	29.6	35.5
MRNJ-59	ZARS, Morena	7.5	10.5	27.3	11.8	31.1	32.0
MRNJ-60	ZARS, Morena	5.7	14.3	21.2	11.6	33.6	31.5
MRNJ-61	ZARS, Morena	5.2	12.8	21.9	11.2	35.9	32.0
MRNJ-62	ZARS, Morena	6.2	15.2	24.9	13.0	28.5	35.0
MRNJ-63	ZARS, Morena	5.7	10.5	24.0	14.1	33.7	34.5
MRNJ-64	ZARS, Morena	4.4	14.4	19.3	12.7	36.1	34.0
MRNJ-65	ZARS, Morena	8.1	18.3	27.1	13.2	24.0	34.5
MRNJ-66	ZARS, Morena	6.1	10.6	23.7	13.2	34.1	36.0
MRNJ-67	ZARS, Morena	6.4	10.0	24.9	12.4	32.2	32.5
MRNJ-68	ZARS, Morena	6.1	16.0	23.4	12.1	29.5	30.5
MRNJ-69	ZARS, Morena	5.3	15.8	20.2	10.3	34.2	32.5
MRNJ-70	ZARS, Morena	6.4	8.7	21.2	12.5	37.1	34.5
MRNJ-71	ZARS, Morena	6.8	16.3	23.0	12.3	31.1	34.5
MRNJ-72	ZARS, Morena	5.4	16.7	18.8	9.8	39.1	30.5
MRNJ-73	ZARS, Morena	7.2	18.8	22.9	12.2	29.2	32.5
MRNJ-74	ZARS, Morena	6.3	16.3	21.6	10.4	32.3	32.5
MRNJ-75	ZARS, Morena	4.8	15.3	19.4	11.0	35.1	30.5
MRNJ-76	ZARS, Morena	5.7	16.3	22.4	11.3	31.0	31.5
MRNJ-77	ZARS, Morena	5.6	14.5	20.3	13.0	33.3	33.5
MRNJ-78	ZARS, Morena	4.6	15.3	19.9	11.9	36.3	32.5
MRNJ-79	ZARS, Morena	5.5	15.7	18.7	10.9	38.2	32.5
MRNJ-80	ZARS, Morena	6.3	18.8	22.9	11.0	30.3	33.5
MRNJ-81	ZARS, Morena	7.2	22.5	22.8	10.1	26.5	35.5
MRNJ-82	ZARS, Morena	6.2	17.2	23.9	12.9	28.7	37.5
MRNJ-83	ZARS, Morena	5.4	14.1	18.8	10.6	38.3	35.5
MRNJ-84	ZARS, Morena	6.1	15.2	21.8	11.0	35.4	33.5
MRNJ-85	ZARS, Morena	5.8	16.0	23.6	10.9	32.3	34.5
MRNJ-86	ZARS, Morena	6.7	16.8	22.3	9.8	31.9	31.5
MRNJ-87	ZARS, Morena	7.4	16.2	24.9	10.3	30.9	31.5
MRNJ-88	ZARS, Morena	7.1	17.8	23.6	10.9	30.9	32.5

MRNJ-89	ZARS, Morena	7.4	17.6	26.0	11.8	26.3	33.0
MRNJ-90	ZARS, Morena	8.4	10.9	29.7	13.0	27.1	34.0
MRNJ-91	ZARS, Morena	5.8	20.2	22.0	9.6	29.4	33.5
MRNJ-92	ZARS, Morena	6.7	22.5	24.9	11.9	23.8	31.0
MRNJ-93	ZARS, Morena	7.5	19.0	23.9	11.0	27.1	31.5
MRNJ-94	ZARS, Morena	8.2	13.1	25.5	10.9	31.3	33.0
MRNJ-95	ZARS, Morena	8.3	13.1	24.1	11.1	31.3	31.0
MRNJ-96	ZARS, Morena	7.5	17.4	23.7	10.0	31.1	33.5
MRNJ-97	ZARS, Morena	8.5	12.7	27.7	12.0	29.1	35.0
MRNJ-98	ZARS, Morena	8.8	9.6	27.8	11.3	31.2	20.5
MRNJ-99	ZARS, Morena	6.4	16.3	22.1	11.1	32.8	36.0
MRNJ-100	ZARS, Morena	6.0	14.5	21.6	10.0	37.0	36.0
MRNJ-101	ZARS, Morena	5.3	16.0	20.7	10.2	35.3	33.5
MRNJ-102	ZARS, Morena	6.5	17.8	22.6	10.0	33.0	34.5
MRNJ-103	ZARS, Morena	7.4	18.8	25.9	9.9	28.0	35.0
MRNJ-104	ZARS, Morena	8.1	19.8	26.7	10.0	28.1	33.5
MRNJ-105	ZARS, Morena	8.2	18.9	27.6	10.8	26.3	34.5
MRNJ-106	ZARS, Morena	5.5	18.1	22.0	10.0	33.0	33.5
MRNJ-107	ZARS, Morena	7.0	19.5	27.3	13.3	23.6	32.5
MRNJ-108	ZARS, Morena	7.2	10.8	28.1	14.3	27.2	33.5
MRNJ-109	ZARS, Morena	5.8	18.5	23.5	12.2	28.3	33.5
MRNJ-110	ZARS, Morena	5.4	16.4	20.8	11.6	34.4	35.5
MRNJ-111	ZARS, Morena	7.6	22.0	26.2	10.8	23.9	35.5
MRNJ-113	ZARS, Morena	7.5	21.1	26.9	12.3	23.4	37.5
MRNJ-114	ZARS, Morena	8.3	19.7	28.0	10.8	24.9	38.5
MRNJ-115	ZARS, Morena	7.4	16.1	24.2	11.8	32.8	37.0
MRNJ-116	ZARS, Morena	7.1	18.9	24.2	11.8	27.8	36.5
MRNJ-117	ZARS, Morena	7.3	18.4	25.2	13.7	27.2	35.5
MRNJ-118	ZARS, Morena	6.5	17.1	23.0	11.3	32.8	35.5
MRNJ-119	ZARS, Morena	7.4	18.7	25.0	13.2	25.2	31.5
MRNJ-120	ZARS, Morena	8.8	11.9	29.4	13.2	26.9	32.5
MRNJ-121	ZARS, Morena	7.4	19.1	25.0	10.4	29.1	33.5
MRNJ-122	ZARS, Morena	10.3	11.7	32.6	12.3	27.1	33.5
MRNJ-123	ZARS, Morena	8.1	13.7	25.1	10.0	34.0	33.5
MRNJ-124	ZARS, Morena	7.8	9.7	29.3	10.8	30.7	32.5
MRNJ-125	ZARS, Morena	5.0	9.9	20.0	10.0	41.7	32.5
MRNJ-126	ZARS, Morena	9.7	14.4	32.8	10.2	20.7	33.5
MRNJ-127	ZARS, Morena	5.4	17.1	22.2	12.4	29.8	33.5
MRNJ-128	ZARS, Morena	7.4	10.7	28.0	14.3	26.6	34.5
MRNJ-129	ZARS, Morena	8.3	8.9	27.3	14.0	29.7	35.5
MRNJ-130	ZARS, Morena	7.1	19.6	21.1	12.7	32.1	36.5
MRNJ-131	ZARS, Morena	8.1	22.3	23.7	11.2	27.0	37.5
MRNJ-135	ZARS, Morena	9.7	12.0	28.0	13.4	24.9	32.5
MRNJ-136	ZARS, Morena	9.4	11.8	27.6	12.6	30.7	33.5
MRNJ-137	ZARS, Morena	8.3	20.8	24.0	13.2	26.6	33.0
MRNJ-138	ZARS, Morena	6.4	17.8	23.7	12.3	29.7	35.5

MRNJ-139	ZARS, Morena	8.3	11.0	25.0	12.0	33.9	34.5
MRNJ-140	ZARS, Morena	8.9	12.5	28.6	11.0	28.9	35.0
MRNJ-142	ZARS, Morena	9.4	11.5	28.2	12.3	30.6	36.5
MRNJ-143	ZARS, Morena	7.4	16.8	23.0	13.7	29.4	37.5
MRNJ-144	ZARS, Morena	7.2	17.0	22.9	12.8	30.3	35.5
MRNJ-145	ZARS, Morena	6.1	11.8	18.9	10.0	25.9	36.5
IDM-2	ZARS, Morena	7.3	14.7	25.9	13.9	30.2	35.5
IDM-8	ZARS, Morena	8.3	15.0	26.8	10.6	30.0	33.0
IDM-10	ZARS, Morena	8.9	13.7	24.9	9.0	37.2	34.5
IDM-11	ZARS, Morena	8.6	13.7	25.9	9.6	34.7	33.5
IDM-12	ZARS, Morena	9.0	13.1	28.7	11.0	32.8	36.5
IDM-15	ZARS, Morena	7.6	14.6	27.1	13.9	30.4	35.5
IDM-16	ZARS, Morena	7.2	15.2	23.9	11.8	36.2	34.5
IDM-25	ZARS, Morena	8.2	11.6	22.6	10.7	42.6	32.5
IDM-31	ZARS, Morena	8.5	14.0	27.7	10.1	34.7	35.5
IDM-41	ZARS, Morena	4.6	16.9	19.9	10.9	43.8	36.5
IDM-42	ZARS, Morena	7.7	17.4	28.4	11.0	25.6	33.0
IDM-53	ZARS, Morena	8.1	11.2	27.0	12.1	35.0	34.5
IDM-58	ZARS, Morena	7.2	20.0	22.0	10.9	33.8	31.5
IDM-64	ZARS, Morena	8.5	11.0	26.0	12.2	33.8	33.5
IDM-66	ZARS, Morena	9.2	9.9	26.5	9.4	34.7	35.5
IDM-67	ZARS, Morena	13.3	11.0	35.6	11.2	22.2	34.5
IDM-69	ZARS, Morena	7.6	12.0	25.1	12.9	30.2	32.5
NRCDR-2	DRMR, Bharatpur	7.4	10.8	26.2	13.0	36.7	40.5
NRCHB-101	DRMR, Bharatpur	8.1	9.7	27.3	14.0	36.2	38.5
DRMRIJ-31	DRMR, Bharatpur	7.1	10.9	23.6	12.9	39.9	37.5
DRMR-150-35	DRMR, Bharatpur	6.2	13.7	24.0	12.0	35.0	35.5
RVM-1	RVSKVV,Gwalior	7.1	6.1	23.8	11.2	41.7	35.5
RVM-2	RVSKVV,Gwalior	4.8	8.3	18.6	11.3	45.1	37.5
JM-1	RVSKVV,Gwalior	5.3	12.3	18.9	10.4	46.2	40.5
JM-3	RVSKVV,Gwalior	7.5	14.5	19.7	11.2	41.1	38.5
Rohini	CSAUAT, Kanpur	4.0	16.0	16.8	9.7	37.8	40.5
Maya	CSAUAT, Kanpur	4.5	6.1	15.0	10.1	51.4	38.5
GM-2	SDAU,Banaskantha	5.5	12.0	20.6	12.9	41.0	39.5
L-4	Canada	10.7	12.5	31.2	14.0	24.2	33.0
L-6	Canada	6.1	11.1	22.7	11.6	36.9	33.5
CS-54	CSSRI, Karnal	5.9	12.9	21.7	12.1	41.4	40.5
RB-50	CCS, Hisar	7.4	11.3	25.6	13.0	35.8	40.5
RH-74.9	CCS, Hisar	5.1	14.1	23.7	10.0	42.3	39.5
MC-25	Rasi seed company	7.3	13.4	24.3	11.7	29.9	29.5
ISC-3	Rasi seed company	9.2	13.4	29.0	11.0	30.2	33.5
ISC-12	Rasi seed company	12.2	14.8	37.3	10.4	19.6	31.5
ISC-17	Rasi seed company	11.0	15.1	31.7	11.3	24.8	33.5

ISC-18	Rasi seed company	7.4	37.1	32.8	11.4	27.0	33.5
ISC-20	Rasi seed company	7.9	13.3	25.2	9.9	32.7	33.5
ISC-23	Rasi seed company	8.7	16.0	24.8	9.0	34.0	35.5
JD-6	IARI, New Delhi	5.6	9.8	20.3	11.2	31.7	39.5
PM-25	IARI, New Delhi	8.6	8.8	28.2	15.3	1.0	38.5
PM-26	IARI, New Delhi	6.3	10.1	25.2	9.8	1.6	38.5
PM-28	IARI, New Delhi	12.1	9.2	28.8	15.3	1.1	40.5
PM-21	IARI, New Delhi	10.0	12.1	30.8	13.1	1.1	35.5
PM-22	IARI, New Delhi	6.9	11.8	36.2	11.1	1.1	35.5
PM-24	IARI, New Delhi	6.9	22.8	31.0	14.0	1.2	34.5
PM-29	IARI, New Delhi	6.2	21.6	32.6	9.6	0.9	36.5
PM-30	IARI, New Delhi	5.5	25.6	26.4	13.3	1.1	36.5
Karishma	IARI, New Delhi	7.4	23.2	35.9	16.8	1.2	37.5
Mean		**6.82**	**15.36**	**24.01**	**11.34**	**30.99**	**34.68**
SEm		**0.163**	**0.214**	**0.410**	**0.270**	**0.299**	**0.535**
CV		**0.471**	**0.619**	**1.186**	**0.780**	**0.863**	**0.0081**
$CD_{0.05}$		**4.792**	**2.790**	**3.421**	**4.761**	**1.931**	**1.528**

Table 2 Genetic parameters of variations for biochemical parameters

Parameters	Mean	Range		PCV (%)	GCV (%)	h^2	GA	GA (%)
		Min.	Max.					
Palmitic acid (%)	6.82	3.94	13.27	23.74	23.25	95.95	3.20	46.92
Oleic acid (%)	15.37	6.07	37.10	28.56	28.43	99.05	8.96	58.28
Linoleic acid (%)	24.01	14.97	37.34	16.36	16.00	95.63	7.74	32.24
Linolenic acid (%)	11.35	8.29	16.75	13.18	12.29	86.94	2.68	23.60
Erucic acid (%)	30.99	0.93	51.44	27.66	27.60	99.51	17.58	56.71
Oil (%)	34.76	29.50	41.00	8.32	5.95	51.18	3.04	8.77

Table 3 Genotypic and phenotypic correlation coefficient for biochemical parameters

Parameter	Palmitic acid (%)		Oleic acid (%)		Linoeic acid (%)		Linolenic acid (%)		Erucic acid (%)		Oil (%)	
	GCC	PCC	GCC	PCC	GCC	PCC	GCC	PCC	GCC	PCC	GCC	PCC
Palmitic acid (%)	1	1										
Oleic acid (%)	-0.173**	-0.170**	1	1								
Linoeic acid (%)	0.798**	0.768**	0.053	0.05	1	1						
Linolenic acid (%)	0.248**	0.224**	-0.117*	-0.110*	0.381**	0.354**	1	1				
Erucic acid (%)	-0.402**	-0.394**	-0.325**	-0.322**	-0.685**	-0.669**	-0.390**	-0.365**	1	1		
Oil (%)	-0.094	-0.063	-0.011	-0.008	-0.106*	-0.064	0.073	0.03	-0.037	-0.027	1	1

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Table 4 Genotypic path-coefficient direct and indirect effects of various biochemical parameters on erucic acid

Genotypic path-coefficient						
Parameters	Palmitic acid (%)	Oleic acid (%)	Linoeic acid (%)	Linolenic acid (%)	Oil (%)	Correlation
Palmitic acid (%)	**0.213**	0.046	-0.628	-0.042	0.009	-0.402**
Oleic acid (%)	-0.037	**-0.267**	-0.041	0.020	0.001	-0.325**
Linoeic acid (%)	0.170	-0.014	**-0.787**	-0.064	0.010	-0.685**
Linolenic acid (%)	0.053	0.031	-0.300	**-0.168**	-0.007	-0.390**
Oil (%)	-0.020	0.003	0.084	-0.012	**-0.092**	-0.037
Phenotypic path-coefficient						
Palmitic acid (%)	**0.124**	0.049	-0.530	-0.040	0.004	-0.394**
Oleic acid (%)	-0.021	**-0.286**	-0.035	0.020	0.0005	-0.322**
Linoeic acid (%)	0.095	-0.014	**-0.691**	-0.063	0.004	-0.669**
Linolenic acid (%)	0.028	0.031	-0.244	**-0.178**	-0.002	-0.365**
Oil (%)	-0.008	0.002	0.044	-0.005	**-0.061**	-0.027

Table 5 Principal components for biochemical parameters

Traits	PC1	PC2	P 3	PC4	PC5	PC6
Palmitic acid	0.506	0.275	-0.217	0.405	0.401	-0.545
Oleic acid	0.047	-0.857	0.104	0.035	0.499	-0.037
Linoeic acid	0.595	0.012	-0.111	0.196	0.031	0.771
Linolenic acid	0.356	0.202	0.256	-0.816	0.314	-0.046
Oil percentage	-0.006	0.170	0.915	0.355	0.080	0.040
Erucic acid	-0.511	0.346	-0.166	0.060	0.696	0.322

Table 6 Grouping of 188 Indian mustard genotypes in various clusters

Cluster number	No. of genotypes	Name of genotypes
1	36	MRNJ1, MRNJ7, MRNJ-59, MRNJ-67, MRNJ-87, MRNJ-90, MRNJ-94, MRNJ-95, MRNJ-97, MRNJ-98, MRNJ-108, MRNJ-120, MRNJ-122, MRNJ-123, MRNJ-124, MRNJ-128, MRNJ-129, MRNJ-135, MRNJ-136, MRNJ-139, MRNJ-140, MRNJ-142, IDM-8, IDM-10, IDM-11, IDM-12, IDM-31, IDM-53, IDM-64, IDM-66, IDM-69, L-4, MC-25, ISC-3, ISC-17 and ISC-20
2	82	MRNJ2, MRNJ3, MRNJ4, MRNJ5, MRNJ10, MRNJ11, MRNJ13, MRNJ14, MRNJ15, MRNJ17, MRNJ20, MRNJ21, MRNJ-22, MRNJ-24, MRNJ-26, MRNJ-27, MRNJ-28, MRNJ-29, MRNJ-33, MRNJ-34, MRNJ-35, MRNJ-36, MRNJ-37, MRNJ-39, MRNJ-40, MRNJ-42, MRNJ-43, MRNJ-44, MRNJ-46, MRNJ-47, MRNJ-48, MRNJ-49, MRNJ-52, MRNJ-55, MRNJ-58, MRNJ-60, MRNJ-62, MRNJ-64, MRNJ-68, MRNJ-69, MRNJ-71, MRNJ-72, MRNJ-73, MRNJ-74, MRNJ-75, MRNJ-76, MRNJ-77, MRNJ-78, MRNJ-79, MRNJ-80, MRNJ-82, MRNJ-84, MRNJ-85, MRNJ-86, MRNJ-88, MRNJ-91, MRNJ-96, MRNJ-99, MRNJ-100, MRNJ-101, MRNJ-102, MRNJ-103, MRNJ-104, MRNJ-106, MRNJ-109, MRNJ-110, MRNJ-115, MRNJ-116, MRNJ-117, MRNJ-118, MRNJ-121, MRNJ-127, MRNJ-130, MRNJ-138, MRNJ-143, MRNJ-144, IDM-2, IDM-15, IDM-16, IDM-58, DRMR-150-35 and ISC-23
3	12	MRNJ6, MRNJ18, MRNJ-51, MRNJ-57, MRNJ-83, IDM-41, DRMRIJ-31, JM-3, Rohini, GM-2, CS-54 and RH-749
4	18	MRNJ8, MRNJ9, MRNJ-45, MRNJ-50, MRNJ-65, MRNJ-81, MRNJ-89, MRNJ-92, MRNJ-93, MRNJ-105, MRNJ-107, MRNJ-111, MRNJ-113, MRNJ-114, MRNJ-119, MRNJ-131, MRNJ-137 and IDM-42
5	17	MRNJ12, MRNJ16, MRNJ19, MRNJ-23, MRNJ-38, MRNJ-41, MRNJ-53, MRNJ-54, MRNJ-56, MRNJ-61, MRNJ-63, MRNJ-66, MRNJ-70, MRNJ-125, IDM-25, RVM-1 and L-6
6	1	MRNJ-25
7	1	MRNJ-30
8	3	MRNJ-126, IDM-67 and ISC-12
9	2	MRNJ-145 and JD-6
10	3	NRCDR-2, NRCHB-101 and RB-50
11	2	RVM-2 and JM-1
12	1	Maya
13	1	ISC-18
14	3	PM-25, PM-28 and PM-21
15	1	PM-26
16	1	PM-22
17	3	PM-24, PM-29 and PM-30
18	1	Karishma

Table 7 Mean performance of individual clusters for 6 biochemical parameters

Class	Palmitic acid (%)	Oleic acid (%)	Linoeic acid (%)	Linolenic acid (%)	Oil (%)	Erucic acid (%)
1	8.46	12.26	27.23	11.70	33.69	30.84
2	6.06	16.89	22.20	11.07	34.49	32.81
3	5.59	14.32	19.77	10.66	37.75	40.27
4	7.59	20.25	26.08	11.52	34.56	25.10
5	6.26	9.74	22.04	11.29	33.71	37.92
6	5.26	26.82	25.13	11.39	34.50	21.53
7	4.16	32.22	23.11	12.03	33.50	16.05
8	11.70	13.39	35.25	10.58	33.17	20.82
9	5.86	10.78	19.59	10.60	38.00	28.78
10	7.61	10.57	26.37	13.31	39.83	36.23
11	5.05	10.27	18.79	10.86	39.00	45.65
12	4.49	6.08	14.97	10.06	38.50	51.44
13	7.37	37.10	32.79	11.45	33.50	27.05
14	10.21	10.02	29.27	14.55	38.33	1.06
15	6.30	10.10	25.20	9.80	38.50	1.55
16	6.85	11.75	36.20	11.10	35.50	1.13
17	6.20	23.32	29.95	12.28	35.83	1.06
18	7.35	23.15	35.85	16.75	37.50	1.24

Table 8 Inter and intra-cluster distance of 188 genotypes

Cluster	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0.00	7.58	13.21	9.97	9.41	17.72	25.55	13.34	9.56	8.58	18.31	25.58	25.76	30.47	29.97	31.14	32.04	33.32
2		0.00	8.90	9.39	8.84	15.33	22.84	18.98	8.54	10.25	15.55	23.15	23.59	33.90	32.40	35.04	33.35	35.57
3			0.00	17.88	6.99	23.39	30.66	26.02	12.03	9.45	6.95	14.76	29.75	41.02	39.34	42.60	41.58	43.59
4				0.00	17.13	7.90	15.72	13.01	12.69	15.76	24.53	32.33	18.28	26.89	26.05	27.40	24.63	26.64
5					0.00	23.91	31.46	22.60	10.48	8.11	10.02	16.55	31.37	38.19	36.85	39.52	40.14	41.97
6						0.00	8.11	18.09	18.81	22.79	30.27	38.03	14.15	27.71	26.43	27.74	21.40	24.13
7							0.00	24.16	25.67	30.66	37.53	45.06	15.79	28.67	27.17	28.72	18.99	22.64
8								0.00	19.31	19.82	31.24	38.51	25.03	21.96	23.27	20.51	23.61	23.56
9									0.00	10.74	16.95	23.65	29.89	29.95	27.83	32.38	32.26	34.88
10										0.00	12.64	20.09	29.55	35.44	34.93	36.80	37.83	38.60
11											0.00	8.17	36.03	46.25	44.60	47.99	47.93	49.72
12												0.00	43.71	53.02	51.12	55.04	55.45	57.46
13													0.00	38.24	38.28	36.47	29.68	30.24
14														0.00	7.40	9.07	14.31	15.15
15															0.00	11.61	14.52	18.28
16																0.00	13.22	12.89
17																	0.00	7.68
18																		0.00

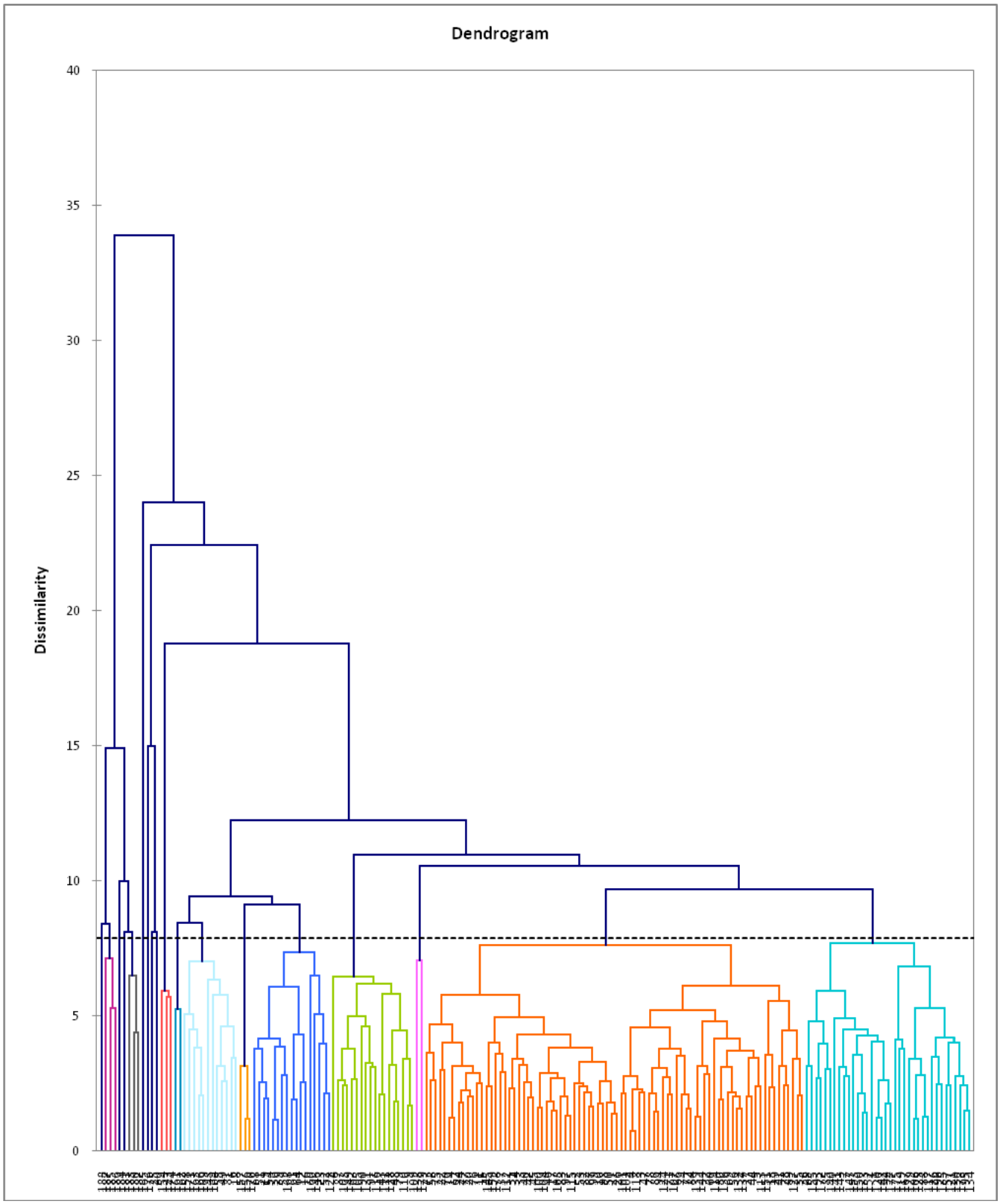

Fig. 1 Dendrogram of 188 Indian mustard genotypes based on biochemical traits using XLSTAT software

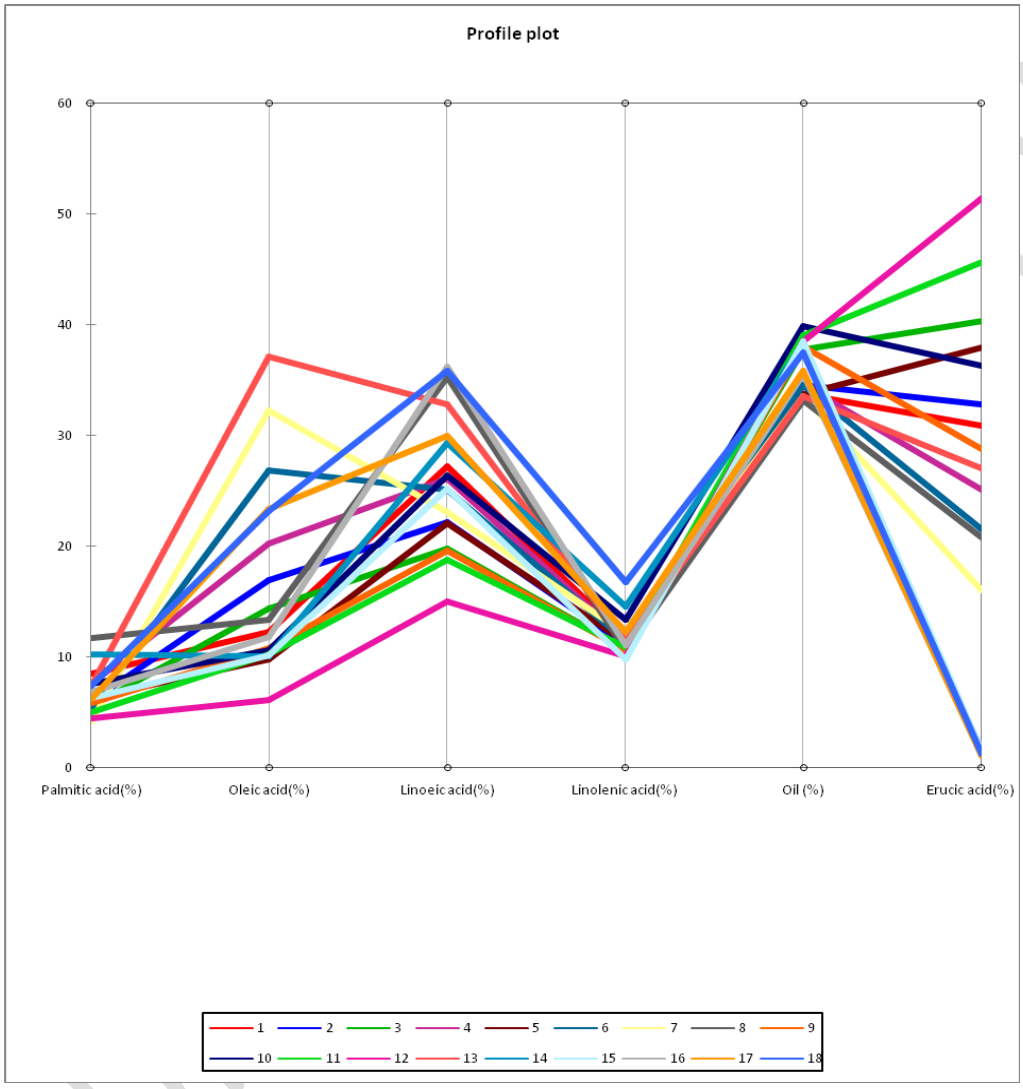

Fig. 2 Profile plot of 188 Indian mustard genotypes based on different biochemical traits

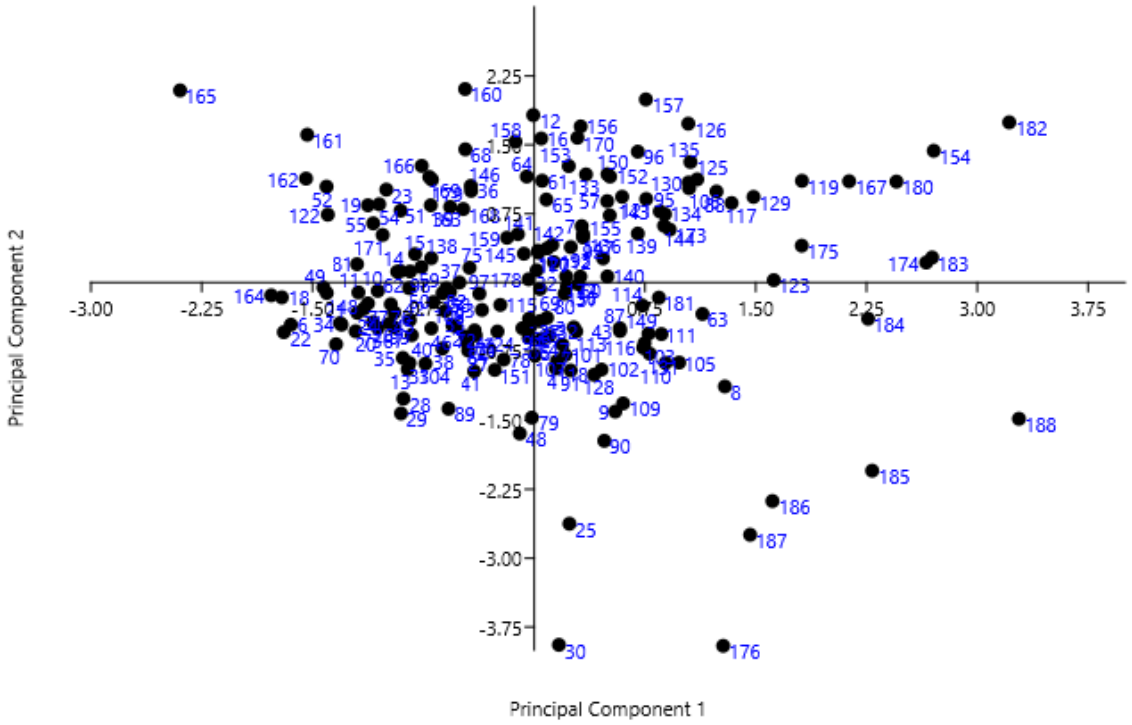

Fig. 3 Scatter plot of the genetic relationship among 188 *Brassica juncea L.* genotypes as revealed by first and second principal components