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Original Article

Evaluation of Morphological and Fatty Acid Composition of Different Sesame Cultivars

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Abstract

Sesame (*Sesamum indicum* L.) an herbaceous annual plant belonging to the Pedaliaceae family is one of the most ancient and important oilseed crops in the world. It is cultivated for its edible oil for medical and pharmaceutical applications. This study was carried out to evaluate the morphological traits and fatty acids composition of 15 different sesame cultivars at Agricultural Research Farm of Islamic Azad University, Isfahan (Khorasgan) Branch in 2018. The morphological traits were measured according to International Descriptor for Sesame. Also, the oil extraction was done by Soxhlet method and fatty acid composition of the sesame oil was determined using gas chromatography (GC). The experiment was laid out on the basis of randomized complete block design (RCBD) with three replications. According to the results, plant height was varied from 70.67 to 130.67 cm. In relation to capsule length, Sabzevar × Pi599457 and Sabzevar cultivars had the highest and lowest value, respectively. The highest total seed yield was measured in Esfahan (3070.20 kg/ha) cultivar, while the lowest one was in Pi599457 (195.64 kg/ha) cultivars. The highest and lowest oil percent was observed in Sabzevar and Borazjan 2 cultivars, respectively. In terms of fatty acids compositions, Palmitic acid (7.08-10.87%) was the main saturated fatty acid (SFA) and the highest value was found in Esfahan cultivar and the lowest in Pi2358371 cultivar. Regarding unsaturated fatty acids (UFA) Pi2358371 cultivar and Esfahan cultivar showed the highest and the lowest values of oleic acid, respectively. Among the evaluated traits, a significant positive correlation was detected between all morphological and biochemical traits, whereas a negative correlation was found between saturated and unsaturated fatty acids contents. According to SFAs, arachidic acid was positively correlated with stearic acid ($r=0.8$; $p < 0.05$). In addition, palmitic acid was negatively correlated with oleic acid ($r=-0.78$; $p< 0.05$). As stated by the morphological and biochemical clusters, Esfahan cultivar and Pi161385 cultivar had the most distance in both cluster. The morphological characters of Sabzevar cultivar was very close with Pil61385 cultivar originated from South Korea. Morphological characters from Borazjan 2 cultivar were similar to Halil cultivar from Iran and placed in the same sub-cluster, while it had the same biochemical value as same as USA and South Korea origin cultivars. This analysis shows that cultivars with different origin had different relationships in biochemical and morphological traits. Morphological and biochemical characteristics among different sesame cultivars could be useful in breeding programs and will help to increase high quality production.

Keywords: Cluster analysis, Fatty acids, Morphological and biochemical traits, Oil percent, Variability

Introduction

Sesame (*Sesamum indicum* L.) is a flowering plant in the genus Sesamum, which belong to Pedaliaceae family. It is one of the most ancient and important oilseed crops used as traditional health food, with high quality oil, protein and natural antioxidants [1, 2]. This plant is annual plant growing 50 to 100 cm tall, with opposite leaves which grow 4 to 14 cm long [3]. The flowers

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may vary in color, with some being white, blue, or purple and tubular with a four-lobed mouth. Sesame seeds are also colored including white, buff, tan, gold, brown, reddish, gray, and black. Sesame fruit is a capsule, normally pubescent, rectangular in section, and typically grooved [4]. Sesame seeds are about 3 to 4 mm long by 2 mm wide and 1 mm thick. Thousands of sesame varieties are varied in size, form, and colors. The seed coat may be smooth or ribbed [5-6].

The origin of sesame is in the Indian subcontinent [7], while it is cultivated throughout the world in about 70 countries. It is grown worldwide over an area of 75 million hectares producing 6,111,548 t seed [8]. Sesame cultivation in Iran is widespread in many places with approximately 30,017 ha. The main cultivation area in Iran is in the south of Kerman (8,600 ha), Fars (6,000) and Khuzestan (4,300) provinces, which cover 71% of sesame production. Also, wide range of oilseeds including sesame and cottonseeds as well as colza, soybeans and safflower are cultivated in Iran [9].

Sesame seeds add a nutty taste and a delicate, almost in visible crunch to many Asian dishes [2]. The main reason why people use sesame seed in various ways around the world, is much high oil (about 50%), which is very stable against oxidative degradation, and superior nutritional value containing about 20% protein plus various minor nutrients such as calcium and iron [10]. Sesame seed contains a significant amount of vitamin B [11]. Furthermore, presence of vitamin E in sesame is very interesting in relation to the effectiveness of sesame seed as a health food. [12]. The medicinal effect of sesame seed as a source of energy was described in the Thebes Medicinal Papyrus (1,552 B.C.). Also, as describing Chinese book (300 B.C.) sesame useful for providing energy, a quiet frame of mind, and preventing aging when eaten over a long period. Further, sesame oil has been used as the basal oil for human body massage in traditional Indian medicine (13, 14, 10).

The knowledge of morphological and biochemical characters among different cultivar will help in the selection and breeding of high yielding, good quality cultivars due to increase production. Morphological and biochemical characters were used as to elucidate genetic variability among some sesame cultivars [15- 20].

The aim of this experiment is to get best cultivars with high yield and high quality of fatty acids. Wider variability among cultivars in this study can be profitably used in future breeding program of sesame.

Material and Methods

Fifteen different cultivars with different sources such as South Korea, USA, Japan, Yugoslavia and Iran were used in this study (Table 1). The seeds were obtained from Seed Production and Breeding Research Center in Islamic Azad University, (Khorasgan) Branch. Seeds were sown on 22 May 2018 in Agricultural Research Farm of Islamic Azad University, which located at Khatoon Abad village, at $32^{\circ}\ 38^{'}$ N latitude, $51^{\circ}\ 39^{'}$ E longitude and 1550 m elevation in sea level. This site has an arid climate where summers are dry and hot, and winters are cool. The soil texture was silty loam. Long-term average yearly precipitation and temperature of the site are 120 mm and 16°C, respectively.

The distance between rows was 70 cm and the seeds were sown at a depth of 0.5 to 1 cm and separated 10 cm in the planting row [21]. Some sesame morphological characters: maturity (M), sub branch (SB), leaf trichome (LT) and capsule trichome (CT), leaf uniformity (LU), seedling vigour (SV), leaf sheath (LS), plant height (PH), height up to the first capsule (HFC), capsule length (CL) and seed yield (SY) were evaluated. Biochemical characteristics including total oil percentages (TOP) and fatty acids compounds (FAC) were also assessed.

Morphological characteristics

Measuring vegetative traits: plant height, height up to the first capsule, capsule length was measured by a digital caliper.

Total seed yield: In order to evaluate seed yield, 20 plants in each cultivars were randomly selected, then measured and finally the total yield recorded as kg per ha.

Leaf sheath: The width of the leaf was measured in the range of 1 to 3. Number 3 indicates the widest leaf group, the number 2 indicating the middle leaf group and the number 1 indicating the narrowest leaf group [22].

Leaf uniformity: The homogeneity of the leaves was measured on a numerical scale as 1 (1 shape per plant), 2 (two shapes per plant) and 9 (combination number 1 and 2) [22].

Seedling vigour: The evaluation of seedling vigour assessed at 20 days after emergence in terms of

numerical index and in the range of numbers 3 (low), 5 (medium) and 7 (high) seedling vigour according to Descriptors for Sesame [22].
Furthermore, some of the morphological characters of sesame cultivar including maturity (1: early maturity, 2: average maturity and 3: late maturity), sub branch, leaf trichome and capsule trichome (1: present and 2: absent) were also evaluated as numerical index in this study [22].

Biochemical Analysis

Total oil percent: Oil extraction was carried out using n-hexane solvent and the percentage of seed oil was determined by weighing extracted oil from 100 g of seed samples. Each sample was powdered and 10 grams placed inside a filter paper and wrapped in a special place inside the Soxhlet extractor. Then the required amount of n-hexane solvent was poured into the balloon and the temperature of the device was adjusted to 67 °C. Extraction operation continued for 8 hours [23].
Determination of fatty acid compositions: To determine the amount of fatty acids of sesame oil, oil must be extracted without high temperature (to avoid possible changes in fatty acid composition). Therefore, 50 grams of seed from each sesame cultivar was mixed. After mixing, hexane was added in a ratio of one to four and placed on a shaker (160 rpm) for 48 hours. After separating the solvent from the solution, 15 drops of each of the samples were poured into a test tube and 7 milliliters of 2 M methanol potassium were added. The test tube was placed in a batch 50-55°C. After shaking the solution, the contents were transferred to a smaller tube and placed at the same temperature for three minutes. After removing the supernatant from solution, the samples were injected into mass gas chromatography (GC-MS). The temperature of the injection site was 250°C, the detector temperature was 280°C, the gas flow rate of the helium carrier was 30 ml / min, and the injection rate was 0.5 µL [24].

Statistical Analysis

The experiment was conducted in randomized complete block design (RCBD) with three replications. The statistical analysis was done by MSTATC software (version 1.2, Michigan State University, East Lansing, MI). The comparison of means carried out by Duncan's multiple range test. Differences were considered significant at the level of $P \leq 0.05$. Pearson's correlation coefficients (r) were calculated using Microsoft Excel 2010 software.
The 22 morphological and biochemical traits were used to evaluate the variability of 15 sesame cultivars. A dendrogram was done using NTSYSpc v2.10e [25] software by unweighted pair-group method with arithmetic averages (UPGMA).

Results

Morphological Characteristics

In this study, the values of morphological parameters for cultivars are shown in Table 1. In terms of morphological growth trait; M (late to early), SB (present and absent), LT (present and absent), CT (present and absent) LU (1 to 3 shape), SV (low to high vigor), PH (70.67-130.67 cm), HFC (29.67-68.67 cm), CL (0.90-4.77 cm), SY (195.64-3070.20 kg/ha) and LS (0.87-3.03 cm) were measured.
According to the results, the highest PH was found in Esfahan × Pi161385 (130.67 cm) cultivar and lowest was in Pi161385 (70.67 cm) cultivar. The highest HFC value was observed at Sabzevar × Pi599457 and Borazjan 2 cultivar (68.67 cm) while, Pi234455 (29.67 cm) was the lowest one. In relation to CL, Sabzevar × Pi599457 (4.77 cm) and Sabzevar cultivar (0.90 cm) had the highest and lowest value, respectively. As state in SY, the highest and lowest values were detected in Esfahan (3070.20 kg/ha) and Pi599457 (195.64 kg/ha) cultivars, respectively. Also, the longest and the shortest LS were found in Esfahan (3.03 cm) and Pi2358371 cultivars (0.87 cm), respectively (Table 1).

Biochemical Characteristics

In terms of biochemical analysis, the range of oil percent was from 43.73% (Sabzevar) to 13.60% (Borazjan 2) (Table 2). Analysis of fatty acid compositions showed seven fatty acids including; 4 saturated and 3 unsaturated fatty acids: Palmitic acid (C16:0), Heptadecanoic acid (C17:0), Stearic acid (C18:0), Arachidic acid (C20:0), Oleic acid (C18:1), Linoleic acid (C18:2) and Linolenic acid (C18:3).
The range of total saturated and unsaturated fatty acids value was 80.29-84.24% and 14.29-17.64%, respectively.

Table 1 morphological characteristic of different sesame cultivars

Cultivars	Origin	Maturity[1]	Sub branch[2]	Leaf trichome[3]	Capsule trichome[4]	Leaf uniformity[5]	Seedling vigour[6]	Leaf Sheath (Cm)	Plant height (Cm)	Height up to the first capsule (Cm)	Capsule length (Cm)	Seed per plant (g)	Seed yield (kg/ha)
Pi161385	South Korea	1.00	2.00	2.00	1.00	2.00	5.00	1.87 c	70.67 g	34.00 fg	2.23 g	3.67 hi	524.08 hi
Pi599488	USA	1.00	2.00	1.00	2.00	9.00	7.00	2.07 c	123.33 a	46.67 c	3.40 bcd	5.67 f	809.68 f
Pi234455	Japan	2.00	1.00	1.00	1.00	2.00	5.00	1.07 e	93.67 de	29.67 g	3.23 cf	7.70 c	1099.56 c
Pi2358371	Yugoslavia	2.00	1.00	1.00	1.00	2.00	5.00	0.87 e	106.00 c	42.00 cde	2.93 ef	3.97 h	566.92 h
Pi599457	USA	3.00	1.00	1.00	1.00	9.00	5.00	2.40 b	91.67 ef	43.33 cd	3.80 b	1.37 j	195.64 j
USA	USA	2.00	2.00	1.00	1.00	2.00	3.00	1.87 c	76.67 g	35.67 f	1.70 h	3.23 i	461.24 i
Sabzevar × Pi599457	Iran	2.00	2.00	1.00	1.00	2.00	7.00	0.93 e	120.33 ab	68.67 a	4.77 a	4.97 g	709.72 g
Sabzevar × USA	Iran	3.00	2.00	1.00	1.00	2.00	7.00	2.00 c	128.00 a	52.33 b	3.00 def	9.27 b	1323.76 b
Esfahan × USA	Iran	3.00	2.00	1.00	1.00	1.00	7.00	2.10 bc	108.67 bc	53.67 b	3.33 cde	7.00 d	999.60 d
Esfahan × Pi599488	Iran	2.00	2.00	1.00	1.00	2.00	7.00	2.00 c	110.33 bc	38.33 ef	3.52 bc	6.30 e	899.64 e
Esfahan	Iran	3.00	2.00	1.00	1.00	1.00	7.00	3.03 a	109.00 bc	40.67 de	2.03 gh	21.50 a	3070.20 a
Sabzevar	Iran	2.00	2.00	2.00	1.00	9.00	5.00	1.53 d	80.33 fg	52.33 b	0.90 i	7.70 c	1099.56 c
Borazjan 2	Iran	3.00	1.00	2.00	2.00	1.00	3.00	1.03 e	105.33 cd	68.67 a	2.85 f	7.83 c	1118.12 c
Halil	Iran	2.00	1.00	2.00	2.00	1.00	5.00	1.87 c	82.00 efg	65.67 a	2.07 gh	4.13 h	589.76 h
Esfahan × Pi161385	Iran	2.00	2.00	1.00	2.00	9.00	7.00	1.87 c	130.67 a	45.33 cd	1.97 gh	9.33 b	1332.32 b
Max		-	-	-		-	-	3.03	130.67	68.67	4.77	21.50	3070.20
Min		-	-	-	-	-	-	0.87	70.67	29.67	0.90	1.37	195.64
Mean		-	-	-	-	-	-	1.77	102.44	47.80	2.78	6.91	986.65

Values in the columns followed by the same letter are not significantly different, $p \leq 0.05$, Duncan multiple range test.

[1] 1: early maturity, 2: average maturity and 3: late maturity

[2] 1: present sub branch and 2: absent sub branch

[3] 1: present trichome and 2: absent trichome in leaf

[4] 1: present trichome and 2: absent trichome in capsule

[5] 1 represented one shape per plant, 2 represented two shapes per plant and 9 represented combination shapes.

[6] represented to seedling vigour; 3: low, 5: medium and 7: high seedling vigor.

Table 2 Oil percent and fatty acids compositions of different sesame cultivars

Cultivars	Oil Percentage (%)	Σ Saturated fatty acid (%)	Σ Unsaturated fatty acid (%)	Palmitic acid (%)	Heptadecanoic acid (%)	Stearic acid (%)	Arachidic acid (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)
Pi161385	29.20 i	16.93	82.43	8.23 bc	0.09 e	7.78 a	0.83 ab	49.42 cd	32.62 cde	0.39 bc
Pi599488	37.70 de	15.90	84.19	7.67 de	0.09 e	7.34 ab	0.81 ad	52.01 b	31.81 ef	0.37 cd
Pi234455	33.17 h	15.38	83.67	7.37 ef	0.12 bcd	7.14 bc	0.75 cf	52.84 b	30.46 fg	0.37 cd
Pi2358371	38.83 cd	15.14	84.19	7.08 f	0.17 a	7.06 bc	0.84 a	56.23 a	27.62 h	0.34 cd
Pi599457	35.37 f	16.48	82.13	7.82 cd	0.10 de	7.78 a	0.79 ad	52.83 b	28.98 gh	0.32 cde
USA	33.83 gh	15.82	83.43	7.88 cd	0.11 cde	7.06 bc	0.77 be	49.11 d	34.05 bcd	0.27 e
Sabzevar × Pi599457	36.73 e	16.62	82.72	8.42 b	0.12 bcd	7.30 ab	0.78 ae	50.48 c	31.91 ef	0.33 cde
Sabzevar × USA	39.53 bc	16.06	82.15	8.01 bcd	0.19 a	7.12 bc	0.75 def	49.56 cd	32.25 def	0.34 cd
Esfahan × USA	35.43 f	15.75	83.04	7.84 cd	0.13 bc	7.01 bcd	0.77 be	50.03 cd	32.64 cde	0.37 cd
Esfahan × Pi599488	34.53 fg	15.73	84.00	8.33 b	0.14 b	6.54 d	0.72 efg	49.97 cd	33.69 be	0.34 cd
Esfahan	40.20 b	17.64	80.29	10.87 a	0.13 bc	5.96 e	0.69 fg	44.40 f	35.45 ab	0.44 b
Sabzevar	43.73 a	15.60	84.15	7.85 cd	0.13 bc	6.80 cd	0.82 abc	49.06 d	34.55 abc	0.54 a
Borazjan 2	13.60 j	16.53	82.47	8.24 bc	0.14 b	7.32 ab	0.84 a	49.79 cd	32.36 def	0.32 de
Halil	39.70 bc	14.29	84.24	8.05 bcd	0.12 bc	5.46 f	0.66 g	51.93 b	31.98 def	0.33 cde
Esfahan × Pi161385	39.40 bc	14.86	83.70	8.04 bcd	0.06 f	6.01 e	0.75 def	47.03 e	36.33 a	0.34 cd
Max	43.73	17.64	84.24	10.87	0.19	7.78	0.84	56.23	36.33	0.54
Min	13.60	14.29	80.29	7.08	0.06	5.46	0.66	44.40	27.62	0.27
Mean	35.40	15.92	83.12	8.11	0.12	6.91	0.77	50.31	32.45	0.36

Values in the columns followed by the same letter are not significantly different, $p \leq 0.05$, Duncan multiple range test.

Therefore, the percentage of total unsaturated fatty acids (TUFA) was higher than total saturated fatty acids (TSFA) in all cultivars (Table 2). The predominant saturated fatty acids (SFA) in current study were palmitic acid (7.08-10.87%), heptadecanoic acid (0.06-0.19) and stearic acid (5.46-7.78%) followed by arachidic acid (0.66-0.84%). The high value of palmitic acid was reported in Esfahan cultivar, while Pi2358371 cultivar had the lowest. The high and low value of heptadecanoic acid was observed in Sabzevar × USA and Esfahan × Pi161385 hybrids, respectively. Pi599457 and Pi2358371 cultivars showed the high value of stearic acid and arachidic acid, respectively, While Halil cultivar had the low value of stearic acid and arachidic acid.

In terms of unsaturated fatty acids (UFA), oleic (44.40-56.23%), linoleic (27.62-36.33%) and linolenic (0.27-0.54%) acids were found as major unsaturated fatty acids. Pi2358371 cultivar and Esfahan cultivar showed the high and low value of oleic acids, respectively. Whereas, high value of linoleic acid was detected in Esfahan × Pi161385 cultivar and Pi2358371 cultivar showed the lowest. Linolenic acid had the highest value in Sabzevar cultivar while USA cultivar had the lowest value (Table 2).

Correlation coefficients between all morphological and biochemical traits in the sesame cultivars was done. Seedling vigour had the positive correlation with plant height ($r = 0.67$; $p < 0.05$) and oil percent ($r = 0.66$; $p < 0.05$). In current study, saturate fatty acid and unsaturated fatty acid ($r = -0.84$; $p < 0.05$) is clearly negative correlated each other. According to SFAs, arachidic acid was positively correlated with stearic acid ($r = 0.8$; $p < 0.05$). As stated by USFAs, oleic acid was negatively correlated with linoleic acid ($r = -0.92$; $p < 0.05$). In addition, palmitic acid was negatively correlate with oleic acid ($r = -0.78$; $p < 0.05$).

Two different cluster analyses were performed for 15 sesame cultivars using all morphological and biochemical traits. Cluster analysis by 11 morphological traits showed six main clusters. Cluster II had the highest total seed yield and also had the average maturity plant type. Cluster IV reported the high seedling vigour and highest leaf sheath were recorded in cluster VI (Fig1, Table 1).

Cluster analysis by biochemical characters also showed six main groups which observed cultivars were separated base on saturated and unsaturated fatty acids. The highest saturated fatty acids were verified in cluster VI while the highest unsaturated fatty acid verified in cluster V. Cluster II had the highest oleic acid. Also, Cluster VI reported maximum value of palmitic acid (Fig1, Table 2).

Discussion

A wide range of variability was observed for all morphological and biochemical traits. According to morphological characters such as: plant height, Abate *et al*., [26] reported higher (Mean=140.25 cm) value of plant height than this study (Mean=102.44 cm). The mean of plant height of Pham *et al*., [16] experiment was 126.44 cm while Begum *et al*., [19] reported 94 cm and Rathod *et al*., [27] observed 74.01 cm. The value of capsule length in this study (Mean=2.78 cm) was higher than Abate *et al*., [26, Mean= 2.7 cm], Begum *et al*., [19, Mean= 2.7], Pham *et al*., [16, Mean= 2.6] as well as Valamathi *et al*., [15, Mean= 2.18]. High level of capsule length in this study can be related to genetic diversity of these cultivars. The yield per plant, in Pham *et al*., [16, Mean= 32.30 g] study, showed the higher yield per plant in sesame than current study. Begum *et al*., [19] reported the mean of yield per plant 9.56 g. Also, Valarmathi *et al*., [15] and Abate *et al*., [26] observed the mean of yield per plant 5.09 g and 5.75 g, respectively. These variations may be related to the geographical source and different genome of the sesame cultivars used in this study [18,19].

High level of variability of morphological characters within different sesame collections was reported by Bisht *et al*. [28]. This study was also observed the high variability among sesame cultivars. Selection based on phenotypic performance was the primary factor which would be effective to bring about considerable improvement in those characters [29].

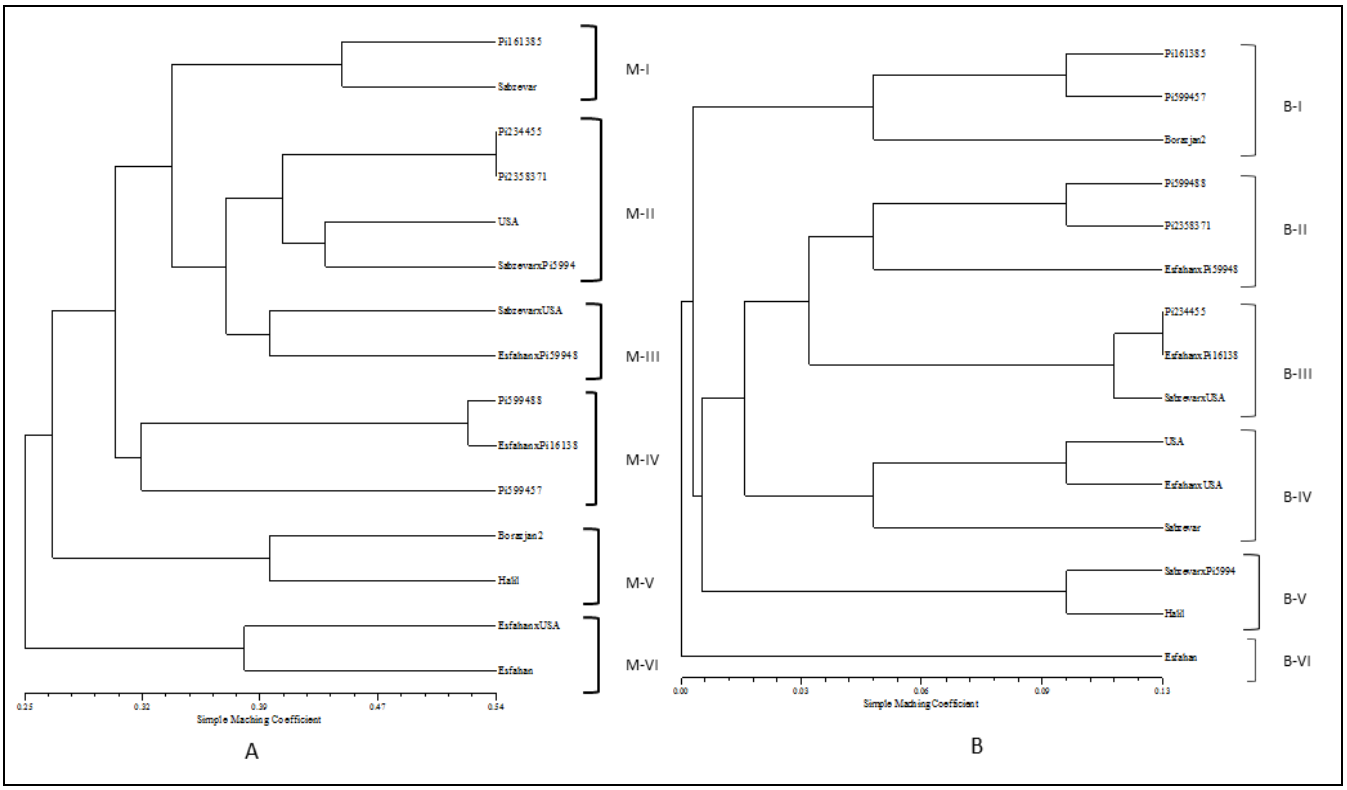

Fig. 1 Cluster analysis for 15 Sesame using morphological and biochemical traits. "A" represented the morphological traits and "B" represented the biochemical traits.

Furthermore, the differences among cultivars support to select promising plants during breeding programs for special purpose.

Generally genetic variation of plants changes in time and place. The development of genetic diversity in plant species depends on the evolution and regimen of species, ecological factors, geography and some human's role in changes in the natural environment [30].

In this study the mean of oil percentage was 35.40%, which similar to Valarmathi *et al*., [15] research, whereas lower than Nabloussi *et al*., [31, Mean=48.24], Rathod *et al*., [27, Mean= 46], Abat *et al*., [26, Mean=45.3] and Baydar *et al*, [32, Mean=44.1]. In all cultivars, the percentage of total unsaturated fatty acids (TUFA) was higher than total saturated fatty acids (TSFA). The high amounts of UFA, might be a health-promoting nutrient and to be interested in diet [33]. The percentages of oleic and linoleic acids in sesame oil were very close to each other, and with this characteristic sesame oil was appeared to be different from other seed oils [32]. The mean of oleic acid composition in this research was higher than Baydar *et al*., [32], Nabloussi *et al*., [31] and Devarajan *et al*., [34] reports, while the mean of linoleic acid had the highest value in Devarajan *et al*., [34, Mean= 42] report. One of the most important fatty acids characteristics of edible oils is the ratio of unsaturated fatty acids to saturated fatty acids, which is imperative of nutritional quality. In addition, fatty acids with one or more unsaturated bands, can be effective in reducing blood cholesterol levels. Also, unsaturated fatty acids such as linoleic acid and linolenic acid are effective in reducing heart disease, seizures, diabetes and cancer [35, 36]. Negative correlation between linolenic acid and oleic acid in sesame cultivars in this study was also reported by Were *et al*., [37] which can be reason to ecological and geographical factors as same as human's role in changes in the natural environment [30].

The climate variability has a small effect on saturated and unsaturated fatty acids. In warm regions, palmitic acid content of soybean oil was observed higher than cold regions [38]. In cold and high altitude regions, the amount of palmitic acids decreased, while it

increased in warm high altitude regions [39]. Therefore, the proper maintenance and management of cultivars is not possible, because the material may contain valuable genes are important for future activities [40].

In this research, a wide range of changes were observed among the sesame cultivars for measured traits, indicating a high genetic potential among native and non-native cultivars. According to these two cluster, Esfahan cultivar located in a separate cluster alone. Esfahan cultivar and Pi161385 cultivar had the most distance in both cluster. The morphological and biochemical characters of Sabzevar cultivar was very close with USA origin cultivars. Morphological characters of Borazjan 2 cultivar was same as Russian cultivar (Pi2358371) and placed in the same sub-cluster, while it had the same biochemical value as same as USA origin cultivars. This analysis shows that cultivars have different relationships in biochemical and morphological traits.

Conclusion

The hybrids cultivars had higher value of seedling vigour rather than local cultivars in general. It is worth mentioning that among local cultivars; only Esfahan cultivar was similar to hybrid cultivars. Iranian local cultivars have acceptable amount of seed yield and the highest seed yield were measured in Esfahan cultivar. Surprisingly, this yield was also higher than other studied cultivars. In regard to the fatty acid profile in the sesame oil, the main components were oleic and linoleic acid. The composition of the oil samples obtained an average of 50.31% oleic acid, 32.45% linoleic acid, 6.91% stearic acid, and 8.11% palmitic acid. The Iranian local cultivar, namely Sabzevar was the best cultivar for oil percent, total unsaturated fatty acids and linoleic acid while, Halil cultivar was the best cultivar in terms of the lowest amount of total saturated fatty acids and the highest oleic acid percent. Also Pi2358371 cultivar has the highest amount of oleic acid and the lowest amount of linoleic acid, Arachidic acid and heptadecanoic acid. The high levels of unsaturated fatty acids and little amounts of saturated fatty acids are beneficial for human health. In this study Iranian local cultivars had the highest value of oil percent and total unsaturated fatty acids in comparison to other cultivars. Ultimately, according to obtained results of this study, it is suggested that Iranian local cultivars with possess of diverse morphological and biochemical characteristics, can be used in sesame breeding programs to improve qualitative and quantitative characteristics of this valuable medicinal plants.

On average, evaluation of genetic diversity in the sesame cultivars is the first step for breeding programs of this plant. As there are many sesame cultivars in Iran, collection and evaluation of both qualitative and quantitative traits of these valuable germplasm is highly recommended. According to our finding, although it is impossible to introduce a cultivar as an elite cultivar, the cultivars of Esfahan, Sabzevar and Halil possess specific traits among studied ones. For instance, one of the main objectives of sesame breeding programs is the production or improvement of cultivars with high yields. In current study, Esfahan cultivar was found applicable as a parent in breeding programs for improving yield related traits. Also Halil or Sabzevar cultivars with appropriate amounts of oil composition can be grate potential as a parents in breeding programs for release of sesame cultivar in terms of fatty acids compositions. For future breeding programs it can be recommended that a research project should be performed for regions consist: Kerman (arid and dry environment), Fars (semi-arid and temperate environment) and Khuzestan (hot and humid environment) for the cultivars which have high yield and fatty acids compositions for considering local environmental variation and adaptation for each conditions.

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References

1. Ashri A. Sesame breeding. Plant Breed Rev. 1998;16:179-228.

2. Anilakumar KR, Pal A, Khanum F, Bawa AS. Nutritional, medicinal and industrial uses of sesame (*Sesamum indicum* L.) seeds-an overview. Agric Conspec Sci. 2010;75:159-168.
3. Xu J, Chen S, Hu Q. Antioxidant activity of brown pigment and extracts from black sesame seed (*Sesamum indicum* L.). Food Chem. 2005;91:79-83.
4. Vittori Gouveia LDA, Cardoso CA, de Oliveira GMM, Rosa G, Moreira, ASB. Effects of the intake of sesame seeds (*Sesamum indicum* L.) and derivatives on oxidative stress: A systematic review. J Med Food. 2016;19:337-345.
5. Devarajan S, Singh R, Chatterjee B, Zhang B, Ali A.. A blend of sesame oil and rice bran oil lowers blood pressure and improves the lipid profile in mild-to-moderate hypertensive patients. J Clin Lipidol. 2016;10:339-349.
6. Hsu DZ, Chu PY, Jou IM. Enteral sesame oil therapeutically relieves disease severity in rat experimental osteoarthritis. J Food Nutr Res. 2016;60:1-6.
7. Bedigian D. History and lore of sesame in Southwest Asia. Econ Bot. 2004;58:329-353.
8. FAOSTAT. Food and Agricultural Organization of the United Nations. 2016. Available at: http://faostat.fao.org.
9. Anonymous. Statistical book of agricultural of Iran. 2017. Ministry of Agriculture Jihad. Tehran, Iran.
10. Namiki M. Nutraceutical functions of sesame: a review. Crc Cr Rev Food Sci. 2007;47:651-673.
11. Brito OJ, Nunez N. Evaluation of sesame flour as a complementary protein source for combinations with soy and corn flours. J Food Sci. 1982;47:457–460.
12. Speek AJ, Schrijver J, Schreurs W. Vitamin E composition of some seed oils as determined by high-performance liquid chromatography with fluorometric detection. J of Food Sci. 1985;50:121-124.
13. Weiss EA. Oilseed crops. Longman Group. 1983.
14. Joshi AB. Sesame, 1st ed. Collier-Macmill an:London. 1961. 109pp.
15. Valarmathi G, Surendran C, Vanniarajan C, Kumar M, Saravanan NA. Morphological and biochemical characterization of sesame (*Sesamum indicum* L. and *S. mulayanum* L). Sesame and Safflower Newsletter. 2003; (18), pp.42-46.
16. Pham TD, Thi Nguyen TD, Carlsson AS, Bui, TM. Morphological Evaluation of Sesame (*'Sesamum indicum*' L.) Varieties from Different Origins. Aust J Crop Sci. 2010;4:498-508.
17. Alege GO, Akinyele BO, Osekita OS. Phytochemical studies and genetic diversity in sesame (*Sesamum indicum* L.). In Proceedings of the World Congress on Engineering London. 2014.
18. Kiranmayi SL, Roja V, Padmalatha K, Sivaraj N, Sivaramakrishnan S. Genetic diversity analysis in sesame (*Sesamum indicum*) using morphological, biochemical and molecular techniques. Int J Appl Biol Pharm. 2016;7:95-110.
19. Begum T, Iqbal A, Dasgupta T. Genetic Variability and Divergence among Cultivars of Sesame (*Sesamum Indicum* L.). Bangl J Bot. 2017;46:955-962.
20. Iqbal A, Pati PK, Akhtar R, Begum T, Dasgupta T. Diversity in Sesame Accessions. IJEAB. 2018;11:725-731.
21. Miraj S, Kiani S. Bioactivity of Sesamum indicum: A review study. Der Pharmacia Lettre. 2016;8:328-34.
22. IPGRI and NBPGR. Descriptors for Sesame (*Sesamum* spp.). International Plant Genetic Resources Institute, Rome, Italy; and National Bureau of Plant Genetic Resources, New Delhi, India. 2004.76pp.
23. AOAC (Association of Official Analytical Chemists). Official Methods of Analysis. 15 ed. Washington D.C. 2000.
24. Metcalfe LD, Schmitz AA, Pelka JR. Rapid preparation of fatty acid esters from lipids for gas chromatographic analysis. Anal Chem. 1966;38:514-515.
25. Rohlf FJ. NTSYS-pc: Numerical taxonomy and multivariate analysis system, ver. 2.1. Applied Biostatistics, NY. 2001.
26. Abate M, Mekbib F, Ayana A, Nigussie M. Genetic variability and association of traits in mid-altitude sesame (*Sesamum indicum* L.) germplasm of Ethiopia. Am J Exp Agric. 2015;9:1-14.
27. Rathod RS, Manapure PR, Banginwar AD, Kumar BS, Patil SR, Jogdande PN. Genetic diversity studies for yield and yield contributing traits in sesame (*Sesamum indicum* L.). JSC. 2017;27:136-142.
28. Bisht IS, Mahajan RK, Loknathan TR, Agrawal RC. Diversity in Indian sesame collection and stratification of germplasm accessions in different diversity groups. Genet Resour Crop Ev. 1998;45:325-335.

29. Sharma AK, Sharma RN. Genetic variability and character association in early maturing rice. ORYZA. 2007;44:300-303.
30. Magss-Kolling GL. Variability in Namibian landraces of watermelon (*Citrullus Lanatus*). Euphytica. 2003;132: 251-258.
31. Nabloussi, A., Hanine, H., Harfi, M.E. and Rizki, H., 2018. Moroccan sesame: an overview of seed and oil quality. Science within Food: Up-to-date Advances.
32. Baydar H, Turgut I, Turgut K.. Variation of certain characters and line selection for yield, oil, oleic and linoleic acids in the Turkish Sesame (*Sesamum indicum* L.) Populations. Turk J Agric For. 1992;23:431-441.
33. Fernandes L, Casal S, Cruz R, Pereira JA, Ramalhosa, E. Seed oils of ten traditional Portuguese grape varieties with interesting chemical and antioxidant properties. Food Res Int. 2013;50:161-166.
34. Devarajan S, Chatterjee B, Urata H, Zhang B, Ali A, Singh R, Ganapathy, S. A blend of sesame and rice bran oils lowers hyperglycemia and improves the lipids. Am J Med. 2016;129:731-739.
35. Gercekcıoglu R, Yilmaz N, Bayrak OF, Sahin F. Variation in Fatty Acid Composition of 'Tulameen' Red Raspberry Seed Oil by the Application of Nitrogen Fertilizers and Organic Manure.IJNES. 2007;1.
36. Simopoulos AP. The omega-6/omega-3 fatty acid ratio, genetic variation, and cardiovascular disease. Asia Pac. J Clin Nutr. 2008;17(1):131–134.
37. Were BA, Onkware AO, Gudu S, Welander M, Carlsson AS. Seed oil content and fatty acid composition in East African sesame (*Sesamum indicum* L.) accessions evaluated over 3 years. Field Crop Res. 2006;97:254-260.
38. Rebetzk GJ, Plantalone WR, Burton JW, Carter JR, Wilson RF. Genetic background and environment influence palmitate content of soybean seed oil. Crop Sci. 2001;14:1731-1736.
39. Wilcox JR, Cavins JF.Normal and reduced linoenic acid soybean strains: Crop Sci. 1992;32:1248-251.
40. Lotti C, Marcotrigiano AR, Giovanni C, Resta P, Ricciardi A, Zonno V, Fanizza G, Ricciardi L. Univariate and multivariate analysis performed on bio-agronomical traits of *Cucumis melo* L. germplasm. Genet Resour Crop Ev. 2008;55:511-522.