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ORIGINAL PAPER

Variation in Fatty Acid Compositions, Oil Content and Oil Yield in a Germplasm Collection of Sesame (*Sesamum indicum* L.)

Bülent Uzun · Çiğdem Arslan · Şeymus Furat

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Abstract The variation in oil content, oil yield and fatty acid compositions of 103 sesame landraces was investigated. The landraces varied widely in their oil quantity and quality. The oil content varied between 41.3 and 62.7%, the average being 53.3%. The percentage content of linoleic, oleic, palmitic and stearic acids in the seed oil ranged between 40.7–49.3, 29.3–41.4, 8.0–10.3 and 2.1–4.8%, respectively. Linolenic and arachidic acids were the minor constituents of the sesame oil. Linoleic and oleic acids were the major fatty acids of sesame with average values of 45.7 and 37.2%, respectively. The total means of oleic and linoleic acids as unsaturated fatty acids of sesame were about 83% which increases the suitability of the sesame oil for human consumption. The superiority of the collection was observed in oil content. The oil content of a few accessions was above 60%, proving claims that some varieties of sesame can reach up to 63% in oil content. The accessions with the highest oil content were relatively richer in the linoleic acid content while there were some landraces in which linoleic and oleic acid contents were in a proportion of almost 1:1. The results obtained in this study provide useful background information for developing new cultivars with a high oil content and different fatty acid compositions. Several accessions could be used as parental lines in breeding programmes aiming to increase sesame oil quantity and quality.

Keywords Gas chromatography · Germplasm · Fatty acid composition · Oil content · Sesame · *Sesamum indicum* L.

B. Uzun (✉) · Ç. Arslan · Ş. Furat
Department of Field Crops, Faculty of Agriculture, Akdeniz University, 07058 Antalya, Turkey
e-mail: bulentuzun@akdeniz.edu.tr

Introduction

Sesame (*Sesamum indicum* L.) belongs to the Tubiflorae order and Pedaliaceae family. The Pedaliaceae are a small family consisting of about 16 genera and 60 species [1, 2]. Of 60 species, about 37 species have been described in *Sesamum*. The predominant cultivated species worldwide is *S. indicum*. The origin of sesame has been disputed by several researchers [3–5]. Two possible centers of origin have been proposed; Ethiopia or the Indian subcontinent and sesame could have been taken either eastward from Africa or westward from India [6]. In both situations, Turkey played an important role in the spreading of sesame since it was a major crossroads of East and West trade in ancient times and it has many distinct sesame varieties that have been grown for thousands of years under a range of ecological conditions.

Sesame seeds and their oil have long been used for human nutrition and industrial uses such as pharmaceuticals, cosmetics, perfumery, soaps, paints and insecticides and it has still worldwide significance as an oilseed crop. Sesame seeds contain 60% oil and 25% protein. Since the oil and protein content had a strong negative correlation and sesame is primarily an oil and confectionary crop, no priority has been given to the protein content of its seeds [6]. Most of the world's sesame seed production is used for extracting oil which is used mainly for cooking [7]. As a culinary oil, it is free of unwanted odors, flavorful, very stable and resistant to oxidative deterioration. Oleic and linoleic acids are the predominant fatty acids of sesame oil, about 80% of its total [8, 9]. The high level of unsaturated fat increases the quality of the oil for human consumption.

The studies on fatty acid compositions of several germplasm collections of crop plants [10–14] have exposed

Table 1 Meteorological data for the field site during sesame growth in 2004 and 2005

Months	Min. temperature (°C)		Mean temperature (°C)		Max. temperature (°C)		Rainfall (mm)		Relative humidity (%)	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
May	15.4	15.5	20.5	21.1	25.6	26.7	23.5	74.7	62.6	58.8
June	19.9	19.7	25.5	25.4	31.0	31.0	8.7	5.5	58.8	58.7
July	23.6	23.2	29.7	28.4	36.3	33.6	0.3	34.1	49.0	63.6
August	23.1	23.8	28.1	28.8	33.6	34.7	0.0	0.0	60.5	60.2
September	19.8	20.1	25.5	25.3	32.6	32.1	0.1	25.5	53.1	54.7

wide variations in the proportions of saturated and unsaturated fatty acids, offering possibilities of developing superior quality edible oils and specialized industrial oils [15]. The Turkish landraces of *S. indicum* should have considerable variation for oil content and fatty acid compositions by growing thousands of years under a range of ecological conditions. A survey of fatty acid compositions of this sesame germplasm would be useful to identify landraces of different seed oil content and compositions for improving varieties with better oil yield and superior quality edible oil. Also, the characterization and conservation of sesame germplasm for seed oil content and fatty acid compositions are essential for both safeguarding and the future use of the existing genetic resources of sesame. In this study, fatty acid compositions, oil content and oil yield were determined for 103 accessions of *S. indicum*.

Materials and Methods

The experimental material of this study was 103 cultivated sesame landraces collected from the sesame growing areas of Turkey. The collection covers all the regions of Turkey where sesame is grown. This collection was made available for oil content, oil yield and fatty acid compositions.

The accessions were maintained at the West Mediterranean Agricultural Research Institute in Antalya, Turkey in 2004 and 2005 growing seasons. The accessions were grown in two row plots of 5 m row length with a row to row spacing of 70 cm and plant to plant spacing of 10 cm. The experimental design was an augmented block design in five blocks of 21 accessions each with four controls, replicated and randomized throughout the blocks in 2004 and a randomized complete blocks design with two replications in 2005. Plants were furrow irrigated once on the 10th day after flowering. All the plants were harvested in the third week of September because there was no sharp maturity difference among the accessions. The characterization site is located at 36°52′N latitude, and 30°50′E longitude, and about 15 m above sea level. The experimental field can be characterized as having silty clay loam soils with pH 7.8. Temperature, rainfall and relative humidity of the experimental site during the crop growing periods are presented in Table 1.

The samples of 103 landraces grown in 2004 were subjected to oil extraction using a Soxhlet apparatus using a gravimetric method. In order to establish reproducibility, some of the accessions with high and low values in 2004 were again tested with the seed samples of 2005 for the studied traits. Seeds were bulked and 5 g clean and mature seed samples taken for oil content and fatty acid analysis. The oil content was determined by comparing the weights of 5 g seed samples before and after extraction by Soxhlet with petroleum ether for 4 h. After several time evaluations for the extraction, four hours using the Soxhlet apparatus was deemed sufficient to extract most of the oil and was thus selected for the study. The oil samples were then esterified according to the method of Marquard [16]. A 1-ml sample of oil was placed in a tube and 1 ml of Na methylate was added to the mixture. The sample was left at room temperature overnight, and then 0.25 ml isooctane was added. A 0.5-µl sample of the mixture was injected into the gas chromatograph. The composition of the fatty acids was determined by gas liquid chromatography (GC) performed on a Fison GC apparatus equipped with a flame ionization detector (FID), and fitted with a fused capillary column FFAP-DF (25 m × 0.25 mm ID). The detector was operated at 260 °C and the injector at 250 °C. The column was ballistically heated from 150 to 200 °C at the rate of 5 °C min^{-1}. The carrier gas (helium) inlet pressure was 0.15 MPa and the flow rate was 1 ml/min. Fatty acids were identified by retention time relative to an authentic standard (Sigma, 18918).

The data were analyzed for augmented design with five replications of four controls in 2004 and for randomized design with two replications in 2005. Treatments were separated using the least significant difference (LSD) test ($P < 0.05$). The analyses were performed using MINITAB and JMP statistical programs.

Results and Discussion

Oil Content and Fatty Acid Composition

Variation in oil content, oil yield and fatty acid compositions of 103 accessions of *S. indicum* is presented in Table 2. Wide variation was observed in the germplasm for the investigated characters. The oil content of the seeds varied from 41.3 to 62.7%, the average being 53.3%. The magnitude and range of the values of seed oil were similar to those reported by Yermanos et al. [17] and Tashiro et al. [18]. The highest oil content in the germplasm was for 7/10-7-2 with a value of 62.7%. Four landraces, 87-AN, 28/9-4-2, Ant-26 and 7/10-10-1, had also the highest oil content with values of 62.5, 61.3, 60.6 and 60.1, respectively (Table 2). These results indicated that Turkish sesame germplasm contained some landraces with an oil content higher than 60%, consistent with the arguments of Weiss [2]. Weiss [2] stated that the oil content of some varieties from Central Asia, Afghanistan and Turkey were between 61 and 63%. In our study, five accessions had the highest oil content ranging from 60.1 to 62.7. These landraces offer great applicability as a starting point for future breeding studies aimed at improving the oil yield of sesame. In order to test the material one more season, the accessions were again grown in the growing period of 2005. Some accessions with low and high values for the investigated characters in 2004 were selected from this germplasm and analyzed for oil traits with the seed samples of 2005. The oil content and fatty acid composition of these accessions are shown in Table 3. The highest oil content was observed for Ant-26 with a value of 55.8% while Ant-31 had the lowest oil content with a value of 49.5% (Table 3). Indeed, 7/10-7-2 and Ant-26 were selected for higher oil content from the experiment of 2004 whilst Ant-31 and 13/10-3-1 for lower oil content. The mean oil content of Ant-26 as one of the highest oil accession was lower in 2005 than in 2004 but it still had high relative oil content in both growing years. Nevertheless, 7/10-7-2 and 13/10-3-1 showed no reproducibility with regard to oil content in the second year. Environmental fluctuations and the heterogeneous structure of some accessions played an important role in obtaining this result because oil content and fatty acid composition in sesame were greatly affected by environmental conditions [19–21].

The oils extracted from the accessions were analyzed to determine their fatty acid composition. Oleic and linoleic acids are the major fatty acids of sesame oil [8, 9] and they are found to be present in large amounts in the oils of all accessions. The percentage of oleic acid in seed oil ranged from 29.3 to 41.4% with an average value of 37.2%. Linoleic acid varied between 40.7 and 49.3% with the average being 45.7% (Table 2). Considering all the accessions together, the total means of oleic and linoleic acids as unsaturated fatty acids of sesame were about 83%. Same result was obtained in the selected accessions in the experiment of 2005 (Table 3). The high level of unsaturated fatty acids increases the quality of the oil for human consumption. The accessions with the highest oil content were relatively richer in the linoleic acid content. There were few landraces in which the linoleic and oleic acid contents were in a proportion of almost 1:1. These sources are also an important tool for improving new varieties with both high oleic and linoleic acid content. The amount of linolenic acid was negligible in all the accessions with a range of 0.06–0.75%.

Palmitic and stearic acids were the predominant saturated fatty acids of sesame oil with a range of 8.0–10.3 and 2.1–4.8%, respectively (Table 2). Arachidic acid was a minor constituent of sesame with a mean value of 0.09%. The selected material was again tested for fatty acids in the second year for reproducibility (Table 3). Regarding the highest oleic acid content, 29/9-6-2 and 3/10-2-2 were consistent with the values of 2004. Similar results were obtained for low linoleic acid content and the selected accession for this trait from 2004, 28/9-7-1 and 3/10-2-2, showed almost the same values with those of 2004.

For a better classification of oil content and fatty acid composition of the germplasm, they were compared with those of a world collection in Table 4. The fatty acid profiles of the accessions conformed to the pattern described in the literature for sesame [2, 6, 17, 20, 22] The proportions of palmitic and stearic acids as saturated fatty acids of sesame were similar to those in the world collection (Table 4). The unsaturated fatty acids of sesame, oleic and linoleic acids had lower means than those of the world collection. This can be explained by heterogeneous populations collected from all over the world suited to different environment conditions. The superiority of the Turkish collection was observed in the oil content. The range of oil content was a bit higher than in the world collection. The maximum level of oil content was above 60% and proving to claims that some varieties can reach 63% in sesame. The development of sesame varieties suitable for commercial production of this type of oil would represent an interesting alternative within the general trend of promoting this neglected crop in both developing and developed countries.

The landraces were found to have considerable variability in their oil content, oil yield and fatty acid compositions. The landraces also varied widely in their quality. The major fatty acids in the seed oil on an average basis were linoleic and oleic acids. The results also showed that the highest oil content was found in Turkish varieties in agreement with the findings of Yermanos et al. [17] and

Table 2 Variation in oil content (%), oil yield and fatty acid composition (%) of sesame genotypes grown in 2004

Genotype	Oil content	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	Arachidic acid	Oil yield (kg/ha)
5/10-8-1	56.5	9.3	3.4	35.9	46.1	0.40	0.05	647.8
28/9-7-1	53.6	8.0	2.9	29.3	40.7	0.13	0.31	594.5
22/9-1-1	52.3	9.4	3.7	38.5	45.2	0.39	0.05	535.2
15/10-1-1	51.5	9.3	4.4	40.3	44.1	0.36	0.07	513.6
7/10-6-2	53.1	9.4	4.4	39.7	44.7	0.36	0.13	482.8
38192	51.9	9.6	3.9	38.2	46.2	0.36	0.09	477.6
37486	53.4	8.7	4.1	38.4	45.2	0.31	0.27	473.0
Özberk-82	55.9	9.4	3.5	37.0	46.7	0.41	0.07	464.4
Yolcu	55.7	8.6	3.0	34.5	44.9	0.06	0.04	463.0
42259	55.3	9.5	2.8	34.9	49.3	0.41	0.05	459.7
Ant-32	57.7	9.6	4.6	39.1	43.8	0.35	0.18	456.1
Ant-51	55.4	9.9	4.7	39.4	44.6	0.36	0.14	452.6
H-10	57.3	9.1	3.1	34.1	48.8	0.35	0.04	443.0
38126	54.5	9.2	3.5	35.6	44.8	0.47	0.08	436.7
39700	53.0	9.3	2.7	34.5	48.3	0.48	0.13	429.7
Ant-8	54.3	9.2	3.1	36.3	47.2	0.40	0.06	419.6
H-7	50.5	9.6	4.2	39.4	45.4	0.36	0.12	410.7
B-3	53.5	9.5	3.3	37.3	47.0	0.34	0.13	400.5
Ant-49	52.8	9.4	3.7	37.7	43.9	0.37	0.10	399.3
1/10-2-2	53.5	9.1	3.0	35.6	47.8	0.40	0.03	396.5
Mug-57	52.8	9.0	3.5	37.0	43.8	0.43	0.08	396.0
39702	52.4	9.3	2.9	34.6	47.7	0.38	0.15	384.1
30/9-10-1	51.5	9.4	4.6	39.9	43.7	0.40	0.16	380.6
Ant-60	54.8	8.7	2.3	34.3	49.3	0.46	0.04	374.2
H-11	50.4	8.8	2.6	33.7	45.4	0.39	0.11	372.2
11/10-5-1	52.7	9.3	2.8	36.3	47.1	0.48	0.16	370.3
38816	55.5	9.6	4.2	38.2	45.1	0.42	0.07	369.9
Ant-57	51.4	9.2	3.4	38.1	45.4	0.44	0.09	369.7
28/9-4-2	61.3	9.2	3.1	35.1	46.2	0.45	0.07	365.2
Çamdibi	52.6	8.6	3.7	37.3	45.3	0.42	0.07	362.5
31594	53.2	9.5	3.0	36.3	47.0	0.44	0.05	353.3
38253	53.6	9.6	3.5	35.8	47.4	0.40	0.06	352.2
Ant-30	53.3	9.5	4.2	39.0	45.4	0.40	0.05	351.3
7/10-7-2	62.7	9.5	3.2	35.7	46.7	0.44	0.05	344.3
Tan	55.0	10.0	3.6	37.0	45.8	0.41	0.07	336.5
Ant-53	57.2	9.8	3.1	36.9	45.8	0.41	0.05	335.9
H-4	52.4	9.7	4.0	37.8	45.7	0.46	0.07	333.0
5/10-6-1	55.1	9.3	2.7	33.6	48.0	0.48	0.14	328.2
42569/2-2	55.9	9.3	3.7	37.4	45.1	0.48	0.24	318.1
30/9-7-1	52.9	9.7	4.5	40.0	43.7	0.38	0.08	317.5
17/10-10-2	48.9	9.3	3.5	37.2	46.1	0.41	0.19	315.6
Ant-75	54.0	9.5	3.6	38.1	44.2	0.41	0.05	315.3
42884	49.8	8.9	3.2	35.9	47.0	0.27	0.05	306.6
39700/26-6	53.4	8.7	3.3	37.2	46.9	0.44	0.03	306.2
30/9-5-1	54.7	9.6	3.4	37.1	46.0	0.48	0.08	304.4
29/9-6-3	55.9	10.1	4.3	39.5	44.1	0.38	0.12	302.5
H-1	56.7	9.9	4.2	38.8	45.6	0.39	0.08	301.2
H-2	51.5	9.0	2.5	33.1	48.6	0.48	0.11	286.3

Table 2 continued

Genotype	Oil content	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	Arachidic acid	Oil yield (kg/ha)
Gölmarmara	56.1	9.3	4.2	38.3	46.7	0.34	0.12	286.3
Ant-11	53.3	8.9	2.9	36.6	47.5	0.40	0.04	283.9
38128	57.6	9.4	3.4	37.4	45.4	0.39	0.07	282.2
Ant-25	48.2	9.6	3.8	38.0	44.9	0.39	0.08	280.8
Ant-29	56.5	8.4	3.3	36.4	47.0	0.75	0.02	279.3
Ant-21	56.7	9.4	3.7	38.3	44.3	0.40	0.07	260.3
Ant-17	54.3	9.1	3.1	36.6	47.3	0.45	0.17	258.4
4/10-10-1	49.0	9.9	3.0	37.0	44.2	0.44	0.13	256.1
Ant-37	50.7	9.0	3.5	37.8	46.8	0.41	0.04	250.7
30/9-2-1	49.8	9.3	2.9	35.5	46.7	0.36	0.08	243.6
Aksu	51.3	8.9	3.4	37.0	45.3	0.43	0.05	241.0
H-6	51.9	9.4	3.7	38.5	45.1	0.30	0.03	239.2
H-12	52.7	9.4	3.5	35.4	46.6	0.43	0.04	237.2
7/10-10-1	60.1	9.4	3.2	37.0	45.3	0.40	0.06	230.8
39710	52.2	9.5	3.3	36.4	48.2	0.48	0.05	224.0
5/10-5-2	48.7	9.5	0.1	36.3	47.3	0.41	0.05	222.7
H-8	53.6	9.7	3.8	38.0	45.8	0.44	0.02	222.1
Ant-66	41.3	9.6	3.3	34.9	46.1	0.28	0.02	215.0
Ant-64	52.9	9.3	2.7	35.9	47.0	0.41	0.13	213.6
B-2	58.8	9.7	4.0	38.2	45.5	0.38	0.05	213.6
87-AN	62.5	9.0	3.1	35.5	46.0	0.43	0.19	212.6
1/10-7-2	55.1	10.3	3.7	37.5	45.5	0.31	0.08	211.6
Ant-36	48.5	9.3	3.9	38.5	44.6	0.41	0.18	208.7
Ant-35	50.1	8.2	2.7	33.8	47.6	0.43	0.05	199.7
Ant-15	53.3	9.5	3.5	37.6	46.2	0.42	0.05	199.4
29/9-1-2	51.2	9.9	2.9	35.1	48.7	0.45	0.11	195.9
H-3	53.5	9.6	3.7	39.6	44.3	0.43	0.08	192.4
Ant-33	50.6	9.0	4.5	41.4	43.8	0.33	0.15	188.6
Ant-27	48.2	9.7	3.9	38.0	44.2	0.35	0.08	188.0
Ant-47	57.7	9.3	3.8	38.1	45.7	0.29	0.07	187.0
42498	54.1	9.6	3.5	37.0	46.6	0.45	0.01	186.2
13/10-3-1	47.5	9.2	2.8	34.6	45.5	0.32	0.10	185.1
Ant-31	48.0	9.3	4.1	38.4	44.7	0.47	0.23	183.9
Ant-22	56.1	8.2	2.1	33.9	49.3	0.44	0.03	183.6
3/10-2-2	57.8	9.8	4.8	40.9	42.1	0.35	0.21	181.0
28/9-2-3	56.4	10.1	4.0	38.0	46.7	0.40	0.08	180.5
Ant-62	52.4	9.4	3.4	38.5	45.1	0.46	0.05	160.3
Ant-71	53.8	9.4	3.9	40.2	44.4	0.42	0.11	158.2
42483	47.3	8.4	2.7	34.1	45.3	0.44	0.09	157.6
Ant-26	60.6	9.3	3.3	37.3	45.8	0.47	0.05	157.5
Ant-46	48.4	9.4	4.2	40.6	42.7	0.35	0.11	156.4
H-5	49.0	9.4	3.2	36.7	48.6	0.46	0.07	153.7
Ant-58	51.6	9.6	3.2	36.3	44.1	0.57	0.08	150.1
B-1	47.8	9.3	4.1	39.7	43.8	0.44	0.10	146.1
Ant-12	53.5	9.2	4.5	40.9	42.7	0.38	0.10	145.9
11/10-10-1	49.6	9.3	3.2	35.0	44.3	0.40	0.05	123.6
29/9-6-2	51.1	9.6	4.2	40.9	43.4	0.39	0.08	122.5
Ant-65	59.8	9.3	3.4	37.8	46.4	0.44	0.06	117.8

Table 2 continued

Genotype	Oil content	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	Arachidic acid	Oil yield (kg/ha)
Kundu	51.0	9.7	3.6	40.1	44.8	0.32	0.06	117.2
5/10-4-2	52.2	9.2	3.8	38.2	44.5	0.39	0.06	108.0
Ant-61	52.6	9.1	3.4	38.2	44.5	0.55	0.05	104.7
Ant-55	50.5	9.8	4.6	39.9	43.2	0.34	0.11	95.9
42518	53.6	9.4	3.1	36.2	48.9	0.40	0.03	83.6
Baydar-2001	54.6	9.4	2.6	34.2	45.9	0.53	0.04	74.9
Ant-67	49.7	9.1	3.5	39.0	44.4	0.34	0.05	72.6
Grand Mean	53.3	9.3	3.5	37.2	45.7	0.40	0.09	284.9
LSD (0.05)	3.0	NS	0.5	2.4	1.3	0.07	0.06	144.9

Table 3 Oil content (%) and fatty acid composition (%) of some accessions grown in 2005

Genotype	Oil content	Palmitic acid	Stearic acid	Oleic acid	Linoleic Acid	Linolenic acid	Arachidic acid
Ant-26	55.8	8.9	5.52	43.5	40.3	0.64	0.3
13/10-3-1	55.7	8.8	5.49	41.6	42.2	0.62	0.4
28/9-7-1	54.7	9.0	5.51	42.3	41.3	0.62	0.4
29/9-6-2	53.5	8.5	5.59	43.2	40.9	0.65	0.4
Ant-60	54.3	8.5	5.55	42.8	41.0	0.64	0.4
Mug-57	54.0	9.0	5.47	42.9	40.4	0.63	0.5
H-2	53.1	9.0	5.33	42.2	41.7	0.60	0.4
3/10-2-2	53.1	9.1	5.56	42.6	40.8	0.63	0.4
Ant-46	52.8	8.5	5.63	43.2	40.8	0.64	0.4
Ant-22	51.8	9.0	5.19	42.3	41.6	0.57	0.4
7/10-7-2	51.0	8.6	5.53	43.6	40.4	0.62	0.4
Ant-31	49.5	8.6	5.97	43.1	40.5	0.60	0.4
LSD (0.05)	1.4	0.2	0.05	NS	0.4	0.02	NS

Table 4 Oil content and fatty acid composition of sesame landraces grown throughout Turkey together with those reported for the word collection

Constituent	Turkish collection (%)	World collection (%)[a]
Oleic acid	29.3–41.4	32.7–53.9
Linoleic acid	40.7–49.3	39.3–59.0
Linolenic acid	0.06–0.75	–
Palmitic acid	8.0–10.3	8.3–10.9
Stearic acid	2.07–4.8	3.4–6.0
Arachidic acid	0.01–0.31	–
Oil content	41.3–62.7	40.4–59.8

[a] Yermanos et al. (1972)

Weiss [2]. The results obtained in this study provide useful background information for developing new cultivars with a high oil content and different fatty acid compositions. However, it will be necessary to perform more thorough testing of the landraces in replicated years.

Relationships among Fatty Acid Compositions, Oil Content and Oil Yield

The results of correlation analyses among oil content, oil yield, and fatty acids of the accessions examined are shown in Table 5. The correlation between oil content and oil yield was positive and significant as expected. Palmitic acid was significantly positively correlated with stearic and oleic acid. This result agrees with the previous report on opium poppy by Bajpai et al. [15]. However, it is inconsistent with the report of Were et al. [20]. This difference is perhaps indicative of inherent differences in the degree of branching and relative activities of the different steps in the fatty acid biosynthesis pathways in different plants such as in the opium poppy [15]. Stearic acid was significantly positively correlated with oleic and arachidic acid while it was significantly negatively correlated with linoleic and linolenic acids. The oleic acid content had significant negative correlation with the linoleic acid and oil yield. The linoleic acid content had significant positive correlation with the linolenic acid but a negative correlation with

Table 5 Relationships among oil content (% in seed), oil yield (kg/ha) and fatty acid compositions (% in oil) in sesame landraces

	Oil content	16:0	18:0	18:1	18:2	18:3
16:0	0.055					
18:0	0.057	0.389**				
18:1	−0.045	0.481**	0.763**			
18:2	0.126	−0.134	−0.599**	−0.520**		
18:3	0.113	−0.001	−0.194*	−0.040	0.313**	
20:0	−0.039	−0.058	0.238*	0.049	−0.360**	−0.191
Oil yield	0.205*	−0.119	0.021	−0.214*	0.070	−0.231*

* and ** are statistically significant at 0.05 and 0.01, respectively

arachidic acid. Linolenic acid was negatively correlated with the oil yield as well as oleic acid.

Linoleic acid had a strong negative correlation with oleic acid (Table 5). This association is well documented and reported in sesame [17, 20, 22]. Similar results have been observed in the seed oil of other oilseed crops such as in crucifer species [23], soybean [24, 25], peanut [26], and safflower [27]. One reason for the inverse relationship between these fatty acids could have been dependent on the environment where the genotypes were grown [14]. However, correlations between oleic and linoleic acids in many crop plants were always strongly negative. There should be a genetic contribution for the related fatty acids. Thus, Knowles [28] determined the genes involved in the inverse relationship between oleic and linoleic acid in safflower as pointed out by Johnson et al. [11].

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