Turkish Journal of FIELD CROPS

Turk J Field Crops 2022, 27(1), 119-126 DOI: 10.17557/tjfc.1059664

COMPARISON OF OIL CONTENT AND FATTY ACIDS COMPOSITION OF SESAME (*Sesamum indicum* L.) VARIETIES GROWN AS MAIN AND DOUBLE CROP IN MEDITERRANEAN ENVIRONMENT IN TURKEY

Halil BAKAL[1]*

[1]Cukurova University, Faculty of Agriculture, Department of Field Crops, Adana-Turkey
**Corresponding author: hbakal@cu.edu.tr*

Received: 18.01.2022

ABSTRACT

This study was conducted during 2018 and 2019 growing seasons at the Experimental area of Cukurova University, Faculty of Agriculture in Mediterranean region (Adana, Turkey). The objective of this study was to compare of oil content and fatty acids composition of sesame varieties grown as a main and double crop. The experimental design was a Randomized Complete Block with three replications. Arslanbey, Batem-Aksu, Batem-Uzun, Baydar-2001, Boydak, Cumhuriyet-99, Golmarmara, Hatipoglu, Kepsut-99, Muganli-57, Orhangazi-57, Osmanli-99, Ozberk-82, Sarisu, Tan-99, Tanas and Sari Susam genotypes were used as a plant material in this study. These varieties were registered by the different Research İnstitutes and Faculties in Turkey. Oil content and fatty acids composition (oleic acid, linoleic acid, stearic acid and palmitic acid) of sesame varieties were investigated and compared in main and double crop growing seasons.
The results showed that the considerable variation was found in oil content and fatty acids composition among the sesame varieties grown in main and double crop growing seasons. Oil content, palmitic and oleic acid percentage of the sesame varieties were higher in main crop than in double crop growing season whereas, stearic and linoleic acid percentage of the sesame varieties were found higher in double crop than in main crop growing season.

Keywords: Fatty acid composition, Growing season, Oil content, Sesame

INTRODUCTION

Sesame (*Sesamum indicum* L.) is one of the important oilseed crops widely grown in different part of the world (tropical and subtropical areas) and it has been cultivated mainly in Asia and Africa (Jeon et al., 2012). Sesame seeds contain approximately 35-60% oil, 18-25% protein and 16-18% carbohydrate (Uzun et al., 2008). İt is a good source of vitamin E and B1 and minerals such as calcium, phosphorous, potassium, magnesium, iron, copper, zinc and manganese. The seed contains all essential amino acids and fatty acids (Alyemeni et al., 2011). For these reason, sesame seed plays an important role in human health due to its high oil content and proper quality (low cholesterol and have some antioxidants), as well as a good protein content (Gharby et al., 2017). The sesame seed is commonly known as the “Queen of oil seeds”, probably due to its high nutritional and therapeutic value, and resistance to oxidation and rancidity (Sukumar et al., 2008).

Sesame seeds have high nutritional quality due to its high oil and protein content. Sesame seed is mostly used for edible purposes such as oil and confectionery. It is also used for various food products such as tahini, halva, rolls, crackers, cakes, cookies, buns, chips, and margarine, cosmetics, perfumery, soaps, paints, insecticides and pharmaceutical products (Ogbonna and Umar-Shaaba, 2011).

The sesame oil shows high degrees of stability and resistant to oxidative rancidity due to the presence of a number of endogenous antioxidants such as sesamin, sesamolin and sesamol (Alpaslan et al., 2001). Bedigian (2004) and Sankar et al. (2004) indicated that the sesame oil contains phytosterols associated with reduced blood cholesterol levels and hypertension in humans and reduces the incidences of certain cancers. The antioxidant compound called lignan such as sesamin in sesame oil, inhibits human lymphoid leukemia cells by inducing apoptosis (Miyahara et al., 2000). Sesamin and tocopherols have shown benefits in the prevention of hypertension and stroke (Noguchi et al., 2004).

The quality of sesame oil is depending on the fatty acid composition. Fatty acid composition in sesame seeds consists of unsaturated fatty acids such as oleic (35.9-42.3%) and linoleic (41.5-47.9%) acids and saturated fatty acids, mainly palmitic (7.9-12%) and stearic acids (4.8-6.1%) (Hwang, 2005). In sesame oil, oleic and linoleic acids are the predominant fatty acids and constitute more than 80% of the total fatty acid content (Teres et al., 2008). The high level of monounsaturated (oleic acid) and polyunsaturated (linoleic acid) fatty acids increases the quality of the oil for human consumption (Jones et al., 2008 and Mondal et al., 2010). Fatty acids are important diet for healthy living. They have several functions in the body including helping in transportation of oxygen in the bloodstream, aiding cell membranes development and function, keeping the skin healthy, preventing early aging, and more importantly, preventing cholesterols build up in the articles (Mzimbiri et al., 2014).

Alpaslan et al. (2001), Mohammed and Mekonnen (2010), Shilpi et al. (2014) and El Harfi et al. (2019) indicated that the oil content and fatty acid composition in oilseed crops is affected by genotype, location, environmental conditions (temperature, photoperiod and moisture content), growing conditions, planting date, plant density, fertilization and the interaction of these factors. Uzun et al. (2002) reported that oil content of sesame can be varied by climate conditions and it can decrease by delaying planting time. In additionally, seed oil content may vary considerably between genotype and seasons, and oil percentage tends to rise with increasing length of photoperiod (Weiss, 2000).

Were et al. (2006), Mondal et al. (2010), Yol et al. (2015), Kurt (2018) and El-Harfi et al. (2019) reported that the oleic and linoleic acids varied between 35.67-53.96% and 30.40-51.65% respectively in oils of different sesame varieties. El-Harfi et al. (2019) indicated that the total unsaturated fatty acids percentage varied between 79.5-82.34% in sesame oils.

Weiss (1971) indicated that the air temperature effects on growth and development of sesame plant and seed quality. The oil content and quality of seed decreased at the lower temperature, specially sesamin and sesamolin content. High temperature during the growing period increased oil content of sesame seed.

Sekhon and Bhatia (1972) and Gupta et al. (1998) reported that sowing date also influenced fatty acid composition of sesame by decreasing linoleic acid and increasing oleic and stearic acid content as sowing was delayed. Not only these conditions affect fatty acid composition but also genotypic factors play an important role in the process, resulting in the fact that each genotype shows different fatty acid composition. Gupta et al. (1998) indicated that he sowing date is also known to influence fatty acid composition of sesame by decreasing linoleic acid and increasing oleic acid contents as the sowing gets delayed. Ali et al. (2015) reported that the oleic acid percentage was increased from 38.2 to 42.6% and linoleic acid percentage was decreased from 40.0 to 37.0% with delaying the sowing date from 20th June to 30th July.

Kurt et al. (2016) reported that the palmitic and stearic acids are the predominant saturated fatty acids in sesame oil. Unal and Yalcin (2008), Uzun et al. (2008), Savant and Kothekar (2011), Jeon et al. (2012), Yol et al. (2015), Kurt (2018), Thakur et al. (2018) and El Harfi et al. (2019) indicated that the palmitic and stearic acids percentage in sesame genotypes varied between 7.42-12.00% and 2.10-8.90% respectively in different part of the world.

In according to the “Turkish Food Codex” given limit values for sesame seed, palmitic, stearic, oleic and linoleic acids must be changed 7.9-12.0%, 4.5-6.7%, 34.4-45.5% and 36.9-47.9%, respectively (Anonymous, 2009). Uzun et al. (2002) reported that in general, sesame oil contains about 47% oleic acid 39% linoleic acid 9.0% palmitic acid and 4.1% stearic acid.

The Mediterranean climate has suitable temperature regimes for growth and development of sesame plants. Sesame is an important annual oil crop in Turkey. Environmental conditions are suitable for sesame growing as a main and double crop in Mediterranean region in Turkey. The environmental factor effects on growth and development of sesame plants, especially day and night temperature and photoperiod are the most effective environmental factors for the seed yield and seed quality. İt is important to know the content of sesame fatty acids for better quality and safety of its product. Fatty acid composition of sesame oils is not constant. The oil content and fatty acid composition of sesame oil varies depending on environmental factors (temperature and photoperiod), varieties, sowing dates and cultural factors. The objective of the study was to comparing oil content and fatty acids composition of sesame varieties grown as a main and double crop in Mediterranean environment in Turkey.

MATERIALS AND METHODS

Material

Field experiments was conducted during 2018 and 2019 growing seasons at Experimental Farm of Agricultural Faculty, Cukurova University (Southern Turkey, 36^{o}59^{l} N, 35^{o}18^{1} E and 23 m above sea level) as a main and double crop in Mediterranean region (Adana, Turkey). 16 different sesame cultivars such as Arslanbey, Batem-Aksu, Batem-Uzun, Baydar-2001, Boydak, Cumhuriyet-99, Golmarmara, Hatipoglu, Kepsut-99, Muganli-57, Orhangazi-57, Osmanli-99, Ozberk-82, Sarisu, Tan-99, Tanas and one local variety such as Sari Susam (Sari Susam was grown commonly in the Cukurova region) were used as a plant material in this study. These varieties were registered by the different Research İnstitutes and Faculties in Turkey. All of the varieties have indeterminate growth type and capsule dehiscence at ripening is completely shattering. Some of the seed and capsule characteristics of the sesame varieties were given at Table 1.

Table 1. Some seed and capsule characteristics of sesame varieties

Varieties	Seed Color	Capsule Type	Capsule number per leaf axil
Arslanbey	Dark brown	Small, long rectangle, bicarpellate	Tricapsulle
Batem-Aksu	Brown	Medium, long rectangle, bicarpellate	Monocapsulle
Batem-Uzun	Light brown	Wide, long rectangle, bicarpellate	Monocapsulle
Baydar-2001	Light brown	Wide, long rectangle, bicarpellate	Monocapsulle
Boydak	Brown	Wide, long rectangle, bicarpellate	Monocapsulle
Cumhuriyet-99	White	Small, long rectangle, bicarpellate	Monocapsulle
Golmarmara	White	Medium, long rectangle, bicarpellate	Monocapsulle
Hatipoglu	Dark brown	Small, long rectangle, bicarpellate	Monocapsulle
Kepsut-99	White	Small, long rectangle, bicarpellate	Monocapsulle
Muganli-57	Light brown	Wide, long rectangle, bicarpellate	Monocapsulle
Orhangazi-99	White	Medium, long rectangle, bicarpellate	Monocapsulle
Osmanli-99	White	Medium, long rectangle, bicarpellate	Monocapsulle
Ozberk-82	Light brown	Small, long rectangle, bicarpellate	Monocapsulle
Sari Susam	Yellow	Wide, long rectangle, bicarpellate	Monocapsulle
Sarisu	Yellow	Wide, long rectangle, bicarpellate	Monocapsulle
Tan-99	White	Medium, long rectangle, bicarpellate	Monocapsulle
Tanas	Yellow	Wide, long rectangle, bicarpellate	Monocapsulle

The soil texture was clay loam. The soil tests indicated that pH of 7.36-7.40 with high concentrations of K_2O (748-730 kg ha^{-1}) and low concentrations of P_2O_5 (23-25 kg ha^{-1}). İn addition, the organic matter and nitrogen content of the soil were very low. The lime content was varied between 28.4-27.3% (2018 and 2019) in the soil. The soil is suitable for the sesame growing.

This study was conducted in Adana province **(**Mediterranean environment) in Turkey and in this region, winters are mild and rainy, whereas summers are dry and warm, which is a typical of a Mediterranean climate. The average monthly air temperature during the research period (March-November) was varied between 16.8 and 29.7 ºC in 2018, whereas it was 13.8 and 29.6 ºC in 2019. The average air temperature was the higher during the research period in both years than long term average temperature. The total rainfall was 212.4 mm and 243.8 mm during the growing period in 2018 and 2019, respectively. The average relative humidity was ranged from 58.6% to 71.6% in 2018 and 57.6% to 69.3% in 2019. The differences between the years and long term for the climate data were not found very significant

Method

The field trial was arranged in a Randomized Complete Block Design (RCBD) with three replications. 200 kg ha^{-1} of Di-ammonium phosphate (364 $kgha^{-1}$ N, 92 kg ha^{-1} P_2O_5) fertilizer was applied and incorporated to soil before planting. Urea (46%N) at the rates of 200 kg ha^{-1} was applied before first (beginning of flowering) irrigation in each two growing seasons. Plot size was 2.8 x 5.0 m (14.0 m^2) and spacing between row and plant was 70 and 10 cm, respectively. The seeds were sown by hand at the 6th May as a main crop and 22th June as a double crop in both years (Reserve seeds were used at the second years). During the growing period, recommended pesticides and fungicides were applied at proper time intervals to control insects and diseases. Furrow irrigation was applied at 15 days intervals to maintained soil moisture close to field capacity. The remaining cultural practices such as inter row cultivation and weed control were applied during the growing period. The plants were harvested by hand at the 6th September and 10th September for main crop and at the 22th October and 27th October for the double cropping in 2018 and 2019, respectively. After harvesting, the plants dried almost 15 days in the field and then they threshed by hand.

Data collection and analysis

The data belonging to oil content and oil quality characteristics such as fatty acids composition were recorded in each two growing seasons.

Determination of oil content; oil was extracted from sesame seeds using "Soxhlet", and oil percentage was estimated according to Association of Official Analytical Chemist (AOAC, 2010).

Determination of fatty acids composition: Fatty acid methyl esters were prepared according to AOAC (2010), method Ce 2-66 and analyzed with HP 6890 Series II Gas Chromatograph (GC) (Hewlett-Packard Company, Wilmington, DE, USA) equipped with a flame ionization detector and auto sampler.

The data were statistically analyzed by using JMP 8.1.0 package program with split plot design. The Least Significant Differences (LSD) test was used to compare the means of treatments at $p<0.05$ level (Caliskan et al., 2008; Steel and Torrie, 1980).

RESULTS AND DISCUSSION

According to two-year results, the data were statistical analyzed using repeated years split plot design by using variety and growing seasons factors. The variance analysis of the findings obtained from the study was shown in Table 2. İt can be seen in Table 2, only variety, season and season x variety factors were statistical significant for all the investigated characters, except oil content for the season.

Table 2. The F-values of the variance components of the investigated characteristics of sesame varieties grown in the field trial combined over two-years

Source of Variations	df	Oil Content	Palmitic Acid	Stearic Acid	Oleic Acid	Linoleic Acid
Year	1	ns	ns	ns	ns	ns
Season	1	ns	**	**	**	**
Year*Season	1	ns	ns	ns	ns	ns
Variety	16	**	**	**	**	**
Year*Variety	16	ns	ns	ns	ns	ns
Season*Variety	16	**	**	**	**	**
Year*Seasons*Variety	16	ns	ns	ns	ns	ns

df: Degree of freedom, ** $p < 0.01$, ns: not significant, O/L: Oleic acid/Linoleic Acid, İV: İodine value

Oil content

The data belonging to oil content of the sesame varieties at different growing seasons were shown in Table 3. According to two-year averages, the oil content of the sesame varieties varied between 42.9-51.1% in main crop and 43.7-50.8% in double crop growing season. The differences between the varieties for the oil content were statistically significant in both two growing seasons. The oil percentage was the highest in Cumhuriyet-99 (51.1% and 50.8%) and the lowest in Batem-Aksu (42.9% and 43.7%) among the sesame varieties in each two growing seasons. The oil content of the Boydak and Cumhuriyet-99 varieties were higher than Sari Susam (local variety) among the tested sesame varieties in each growing seasons. These differences between the genotypes for the oil content may have originated due to different genetic backgrounds and growing conditions (Baydar et al., 1999 and Uzun et al., 2002).

Table 3. The oil content, Palmitic (C16:0) and Stearic (C18:0) acids percentages of sesame varieties as average of two years (2018 and 2019)

Varieties	**Oil content** (%)		**Palmitic acid** (%)		**Stearic acid** (%)	
	Main crop	Double crop	Main crop	Double crop	Main crop	Double crop
Arslanbey	49.8	49.6	9.74	9.66	3.65	4.08
Batem-Aksu	42.9	43.7	9.52	9.13	2.70	2.89
Batem-Uzun	48.1	47.0	10.04	9.62	2.48	2.56
Baydar-2001	49.1	48.3	9.46	9.35	2.28	2.72
Boydak	50.3	50.2	9.78	9.43	3.23	4.02
Cumhuriyet-99	51.1	50.8	10.88	9.65	2.86	3.95
Golmarmara	46.5	46.0	10.03	9.68	2.74	3.12
Hatipoglu	48.9	48.4	9.62	9.51	3.06	3.73
Kepsut-99	48.9	48.4	9.66	9.59	2.87	3.65
Muganli-57	49.1	48.7	9.49	9.40	1.79	2.50
Orhangazi-99	49.2	48.4	9.41	9.41	2.08	2.59
Osmanli-99	50.0	48.1	9.89	9.89	2.72	3.60
Ozberk-82	49.6	48.3	10.08	9.39	2.67	3.00
Sari Susam*	50.1	50.1	10.03	9.61	2.58	3.20
Sarisu	45.8	45.3	10.12	9.77	3.03	3.77
Tan-99	49.0	48.5	9.73	9.60	1.93	2.59
Tanas	48.8	46.3	10.31	9.48	2.66	2.74
Average	48.6	48.0	9.87	9.44	2.67	3.22
LSD (%5 $_{\text{Variety-A}}$)	0.233	0.295	0.035	0.025	0.020	0.056
LSD (%5 $_{\text{Seasons-B}}$)	NS		0.023		0.065	
LSD (%5$_{\text{A x B}}$)	1.568		0.235		0.226	

*Control variety (Local variety)

According to a two year average, the average oil content of the sesame varieties was 48.6% in main crop and 48.0% in double crop growing seasons (Table 3). The average oil content of the varieties was found higher in main crop (early sowing date) than in late sowing date (double crop growing seasons). But, the differences between the growing seasons for the oil content were not significant.

Early planting dates may not be feasible in some seasons or under some soil conditions. Early planting resulted in the apparently unfavorable combination of cool vegetative-stage temperatures and warm seed-fill-stage temperatures. Furthermore, genotypic differences for oil content have been reported with oil content displaying more genetic variability among cultivars than the other oil traits (Kane et al., 1997; Baydar et al., 1999 and Ashri, 2007).

Palmitic and Stearic acids

According to a two year average, palmitic acid percentage of the sesame varieties varied between 9.41-10.88% in main crop and 9.13-9.89% in double crop growing season. The differences between the sesame varieties for the palmitic acid percentage were statistically significant in both growing seasons. The highest palmitic acid percentage was obtained from Cumhuriyet-99 (10.88%) in main crop and from Osmanli-99 (9.89%) variety in double crop growing season (Table 3). The differences between the varieties must be due to difference in genetic constitution of sesame cultivars.

The average palmitic acid percentage of the sesame varieties were 9.87% in main crop and 9.44% in double crop growing season. The differences between the growing seasons for the palmitic acid percentage were significant. Palmitic acid percentage was decreased from 9.87% to 9.44% with the sowing date delayed from 6th May (main crop) to 22th June (double crop). The average palmitic acid percentage of the sesame varieties was found higher in main crop than in double crop growing season. İnteraction between the variety and growing season was found significant and the highest palmitic acid percentage was obtained from Cumhuriyet-99 (10.88%) in main crop growing season (Figure 1.).

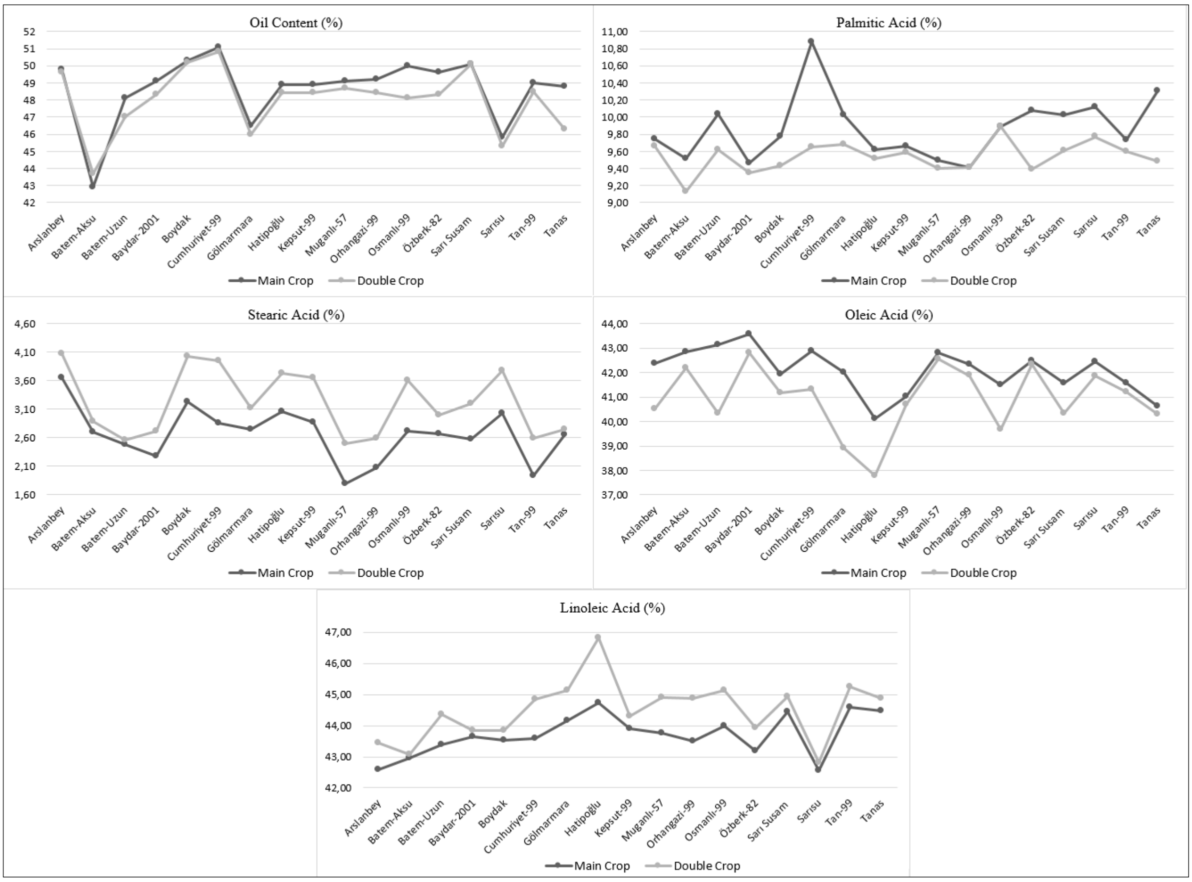

Figure 1. The comparison of average oil content, palmitic, stearic, oleic and linoleic acid of sesame varieties grown in main and double crop growing seasons

According to a two year average, stearic acid percentage of the sesame varieties varied between 1.79-3.65% in main crop and 2.50-4.08% in double crop growing season. The differences between the sesame varieties for the stearic acid percentage were statistically significant in both growing seasons. The differences between the varieties must be due to difference in genetic constitution of sesame cultivars. The highest stearic acid percentage was obtained from Arslanbey sesame variety (3.65% and 4.08%) in main and double crop growing season. The average stearic acid percentage of the sesame varieties were 2.67% in main crop and 3.22% in double crop growing season. The differences between the growing seasons for the stearic acid percentage were significant. Stearic acid percentage was increased from 2.67 to 3.22% with the sowing date delayed from 6th May (main crop) to 22th June (double crop). İnteraction between the variety and growing season was found significant and the highest stearic acid percentage was obtained from Arslanbey in both growing seasons (Table 3). These differences between the genotypes for the Palmitic and Stearic acids content may have originated due to different genetic backgrounds and growing conditions. The fatty acids composition in oilseed crops is affected by genotype, location, environmental conditions (temperature, photoperiod and moisture content), growing conditions, planting date, plant density, fertilization and the interaction of these factors (El Harfi et al., 2019). Similar results were reported by other researchers (Gupta et al., 1998; Uzun et al., 2008; Jeon et al., 2012; Ali et al., 2015; Yol et al., 2015; Kurt, 2016; Kurt, 2018; Vurarak et al., 2018 and El Harfi et al., 2019).

Oleic and Linoleic Acids

The data belonging to oleic and linoleic acids percentage of sesame varieties were shown in Table 4. According to a two year average, the oleic acid percentage of sesame varieties varied from 40.11 to 43.46% in main crop and from 37.78 to 42.81% in double crop growing seasons. The differences between the sesame varieties were statistically significant. The differences between the varieties must be due to difference in genetic constitution of sesame cultivars. The oleic acid percentage was the highest in Baydar-2001 (43.56% and 42.81%) and the lowest in Hatipoglu (40.11% and 37.78%) among the sesame varieties in each two growing seasons.

Table 4. The effect of growing season on oleic (C18:1) and linoleic (C18:2) acids percentage of sesame varieties in two years average (2018 and 2019)

Varieties	**Oleic acid** (%)		**Linoleic acid** (%)	
	Main Crop	Double Crop	Main Crop	Double Crop
Arslanbey	42.36	40.52	42.58	43.44
Batem-Aksu	42.85	42.20	42.97	43.07
Batem-Uzun	43.15	40.33	43.39	44.35
Baydar-2001	43.56	42.81	43.64	43.85
Boydak	41.93	41.16	43.54	43.85
Cumhuriyet-99	42.89	41.31	43.59	44.86
Golmarmara	41.99	38.90	44.16	45.14
Hatipoglu	40.11	37.78	44.73	46.83
Kepsut-99	41.03	40.70	43.89	44.29
Muganli-57	42.80	42.57	43.75	44.90
Orhangazi-99	42.35	41.88	43.50	44.88
Osmanli-99	41.49	39.66	43.98	45.14
Ozberk-82	42.49	42.35	43.19	43.93
Sari Susam*	41.56	40.33	44.46	44.92
Sarisu	42.45	41.87	42.57	42.82
Tan-99	41.57	41.19	44.59	45.26
Tanas	40.62	40.28	44.47	44.88
Average	42.07	40.99	43.71	44.49
LSD (%5 $_{Variety-A}$)	0.139	0.157	0.070	0.098
LSD (%5 $_{Seasons-B}$)	0.583		0.168	
LSD (%5$_{A\ x\ B}$)	1.246		0.813	

*Control variety (Local variety)

As it can be seen in Table 4, while the linoleic acid percentage of the sesame varieties were ranging between 42.57 and 44.73% in main crop growing season and it was ranged between 42.82 and 46.83% in double crop growing season. The differences between the varieties must be due to difference in genetic constitution of sesame cultivars. According to a two year average data, the differences between the varieties for the linoleic acid percentage were statistically significant. Linoleic acid percentage was the highest in Hatipoglu (44.73% and 46.83%) among the sesame varieties in both growing seasons. The lowest linoleic acid percentage was obtained from Sarisu (42.57% and 42.82%) in each two growing seasons. In according to the “Turkish Food Codex” given limit values for sesame seed oleic and linoleic acids must be changed 34.4-45.5% and 36.9-47.9%, respectively (Anonymous, 2009). As seen in Table 4, oleic and linoleic acids percentage of the sesame varieties grown in Turkey were found in the limits specified by “Turkish Food Codex” declaration in this study.

The average oleic acid percentage of the sesame varieties were 42.07% in main crop and 40.99% in double crop growing season. The differences between the growing seasons for the oleic acid percentage were significant. Oleic acid percentage was decreased from 42.07% to 40.99% with the sowing date delaying from 6th May (main crop) to 22th June (double crop). Comparing the main and double crop for the oleic acid percentage of sesame varieties, it was higher in main crop than in double crop growing season. İnteraction between the variety and growing season for the oleic acid was found significant and the highest oleic acid percentage was obtained from Baydar-2001 (43.56%) in main crop growing season (Figure 1.).

The average linoleic acid percentage of the sesame varieties were 43.71% in main crop and 44.49% in double crop growing season. The differences between the growing seasons for the linoleic acid percentage were significant. Linoleic acid percentage was increased from 43.71% to 44.49% with the sowing date delayed from 6th May (main crop) to 22th June (double crop). Comparing the main and double crop for the linoleic acid percentage of sesame varieties, it was lower in main crop than in double crop growing season (Table 4). İnteraction between the variety and growing season for the linoleic acid was found significant and the highest linoleic acid percentage was obtained from Hatipoglu (46.83%) in double crop growing season. According to a two year average data, linoleic acid percentage of the sesame varieties was found higher than oleic acid percentage in both growing seasons in this study (Table 4).

It has demonstrated that unsaturated fatty acids are influenced by the environmental conditions, mainly air temperature during seed filling and oil biosynthesis. Thus, under low temperature conditions, there is an increase of unsaturated acid of seed oil, which leads to a higher proportion of linoleic and linolenic acids. Contrarily, under high temperature conditions, there is a low proportion of these acids and a high proportion of oleic acid in seed oil. İn addition to that, amplitude of maximum and minimum temperature as well as duration of plant exposure these temperature during seed filling effect significantly fatty acids compositions (Deng and Scarth, 1998). The climatic conditions are the main factors influencing the fatty acids composition such as oleic and linoleic acids, especially the variations in temperatures during seed filling stage (Andersen and Gorbet, 2002). The genetic components play an important role in the process, resulting in the fact that each genotype shows different fatty acid composition (Sekhon and Bhatia, 1972). Vurarak et al. (2018) reported that the oleic and linoleic acids percentage was varied between 41.09% and 40.38% in main crop and between 40.32% and 40.49%, respectively in double crop growing seasons. They also indicated that the oleic acid percentage was higher in main crop than in double crop, contrarily the linoleic acid percentage was higher in double crop than in main crop growing season.

As a result, the differences between the sesame varieties for the oleic and linoleic acids percentage were found statistically significant in both growing seasons. As it can be seen in Table 4, while the sowing date was delaying, the oleic acid percentage was decreased. On the other hand the linoleic acid percentage was increased. These results were in agreement with the findings of Were et al. (2006), Arslan et al. (2007), Uzun et al. (2007), Unal and Yalcin (2008), Mondal et al. (2010), Yol et al. (2015), Ali et al. (2015), Kurt (2018), Vurarak et al. (2018) and El-Harfi et al. (2019).

CONCLUSIONS

The results showed that the sesame varieties were registered by the different Research İnstitutes and Faculties in Turkey can be grown successfully as a main and double crop in Mediterranean region in Turkey. İn this study, considerable variation was found in oil content and fatty acids composition among the sesame varieties grown in main and double crop growing seasons. Oil content, palmitic acid and oleic acid of the sesame varieties were higher in main crop than in double crop growing season. On the other hand, stearic acid and linoleic acid of the sesame varieties were found higher in double crop than in main crop growing season.

LITERATURE CITED

Ali, S., A. Jan, A. Sohail, M. Habibullah, J. Zhikuan, A. Z. Kahan and K. Akhtar. 2015. Agro-Management effects on fatty acid composition of sesame (*Sesamum indicum* L.). Pure Appl. Bio. 4(1):43-49.

Alpaslan, M., E. Boydak, M. Hayta, S. Gercek and M. Simsek. 2001. Effect of row spacing and irrigation on seed composition of Turkish sesame (*Sesamum indicum* L.). Journal of the American Oil Chemists' Society. 78(9):933-935.

Alyemeni, M. N., A.Y. Basahy and H. Sher. 2011. Physico-chemical analysis and mineral composition of some sesame seeds (*Sesamum indicum* L.) grown in the Gizan area of Saudi Arabia. J. Med. Plants Res. 5(2):270-274.

Andersen, P. C and D. W. Gorbet. 2002. Influence of year and planting date on fatty acid chemistry of high oleic acid and normal peanut genotypes. J. Agric. Food Chem. 50:1298-1305.

Anonymous. 2009. Regulation on Turkish food codex. http:/ www.tarim.gov.tr/ sayfalari/EN/ mevzuat. Aspx?Ogeld.

AOAC. 2010. Official and recommended methods. American oil Chemists’ Society Press. Champaings İL, USA.

Arslan, C., B. Uzun, S. Ulger and M. I. Cagirgan. 2007. Determination of oil content and fatty acid compositions of sesame mutants suited for intensive management conditions. Journal of the American Oil Chemists' Society. 84:917-920.

Ashri, A. 2007. Sesame (*Sesamum indicum* L.). İn: Singh, R.J. (ed.) Genetics Resources, Chromosome Engineering and Crop Improvement. Vol. 4, Oilseed Crops, CRC Press, Boca Raton, FL. 231-289.

Baydar, H., I. Turgut and K. Turgut. 1999. Variation of certain characters and line selection for yield, oleic and linoleic acid in the Turkish sesame (*Sesamum indicum* L.) populations. J. Agr. and Forest. 23:431-441.

Bedigian, D. 2004. History and lore of sesame in southwest Asia. Economic Botany. 58(3):329-353.

Caliskan, S., M. E. Caliskan, M. Arslan and H. Arioglu. 2008. Effects of sowing date and growth duration on growth and yield of groundnut in a Mediterranean-type environment in Turkey. Field Crops Res. 105:131-140

Deng, X. and R. Scarth. 1998. Temperature effects on fatty acid composition during development of low linolenic oilseed rape (*Brassica napus* L.). J Am Oil Chem' Soc. 75:759-766.

El-Harfi, M., A. Nabloussi, H. Rizki, S. Ennahli and H. Hanine. 2019. Proximate composition and fatty acid composition, phytochemical content of sesame (*Sesamum indicum* L.) seeds landrace from Morocco. Advances in Crop Science and Technology. 7(3):426.

Gharby, S., H. Harhar, Z. Bouzobaa, A. Asdadi, A. El-Yadini and Z. Charrouf. 2017. Chemical characterization and oxidative stability of seeds and oil of sesame grown in Morocco. Journal of Saudi Society of Agricultural Sciences. 16:105-111.

Gupta, S. K., T. P. Yadava, K. Parkash, N. K. Thakral and P. Kumar. 1998. Influence of date of sowing on oil and fatty acid composition in sesame (*Sesamum indicum* L.). An. of Biol. 14:67-68.

Hwang, L. S. 2005. Sesame oil. In Bailey’s Industrial Oil and Fat Products, 6th ed.; Shahidi, F., Ed.; John Wiley and Sons Inc.: New York, NY, USA, pp. 538–577. ISBN 047167849X.

Jeon, H., I.H. Kim, C. Lee, H. D. Choi, B. H. Kim and C. C. Akoh. 2012. Discrimination of origin of sesame oils using fatty acid and lignin profiles in combination with canonical discriminant analysis. J. Am. Oil Chem. Sci. DOI 10.1007/s11746-012-2159-y

Jones, P. J., S. Jew and S. Abu Mweis. 2008. The effect of dietary oleic, linoleic, and linolenic acids on fat oxidation and energy expenditure in healthy men. Metabolism. 57:1198-1203.

Kane, M. V., C. C. Steele and L.J. Grabau. 1997. Early-maturing soybean cropping system: I. Yield responses to planting date. Agronomy Journal. 89(3):454-458.

Kurt, C. 2018. Variation in oil content and fatty acid composition of sesame accessions from different origins. Grasas y Aceites. 69(1):241

Kurt, C., H. Arioglu, T. Erdem and M. R. Akkaya. 2016. A comparatives study of fatty acid extraction methods of sesame (*Sesamum indicum* L.) varieties grown under Mediterranean. Journal of Experimental Biology and Agricultural Sciences. 4(V-Suppl):588-593.

Miyahara, Y., T. Komiya, H. Katsuzaki, K. Imai, M. Nakagawa, Y. Ishi and H. Hibasami. 2000. Sesamin and episesamin induce apoptosis in human lymphoid leukemia Molt 4B cells. İnt. J. Mol. Med. 6:43-46.

Mohammed, H. and Z. Mekonnen. 2010. Study on Genotype X Environment İnteraction of Oil Content in Sesame (*Sesamum indicum* L.). World Journal of Fungal and Plant Biology. 1:15-20.

Mondal, N., K. V. Bhat and P. S. Srivastava. 2010. Variation in fatty acid composition in İndian germplasm of sesame. J. Am. Oil Chem. Sci. 87:1263-1269.

Mzimbiri, R., A. M. Shi, H. Liu and Q. Wang. 2014. A Review: peanut fatty acids determination using hyper spectroscopy imagine and its significance on food quality and safety. Food Science and Quality Management. 28:90-97.

Noguchi, T., K. Ikeda, Y. Sasaki, J. Yamamoto and Y. Yamori. 2004. Effects of vitamin E and sesamin on hypertension and cerebral thrombogenesis in stroke-prone spontaneously hypertensive rats. Clin Exp Pharmacol Physiol. 2:24-26.

Ogbonna, P. E and Y. G. Umar-Shaaba. 2011. Yield responses of sesame (*Sesamum indicum* L.) to rates of poultry manure application and time of planting in a derived savannah ecology of south eastern Nigeria. African Journal of Biotechnology. 10(66):14881-14887

Sankar, D., G. Sambandam, M. R. Rao and K. V. Pugalendi. 2004. Impact sesame oil on nifedipine in modulating exudative stress and electrolytes in hypersensitive patients. Asia Pac. J. Clin. Nutr. 13:107.

Savant, K. D. and V. S. Kothekar. 2011. İnduction of variability in fatty acid profile in sesame (*Sesamum indicum* L.). Journal of Phytology. 3(12):01-03.

Sekhon, K. S. and I. S. Bhatia. 1972. Fatty acid changes during ripening of sesame (*Sesamum indicum* L.), Oleagineux. 27:371–373.

Shilpi, S., M. Nuruzzaman, F. Akhter, M. N. Islam and G. N. C. Sutradher. 2014. Response of Nitrogen and Sulfur on the Oil Content of Sesame and Nutrient Status of Soil. Intern J. of Bio-res Stress Management. 5:041-046.

Sogut, T. 2009. Effect of main and second cropping on seed yield, oil and protein content of sesame (*Sesamum indicum* L.) genotypes. Turkish Journal of Field Crops 14(2):64-71.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. McGaw-Hill Book Company, Inc. N.Y.

Sukumar, D., R. Arimboor and A. C. Rumughan. 2008. HPTLC fingerprinting and quantification of lignans as markers in sesame oil and its polyherbal formulations. Journal Pharmaceutical and Biomedical Analysis 47:795-801.

Teres, S., G. Barceloi-coblijn, M. Mener, R. Ailvarez, R. Bressani, J. E. Halver and P. V. Escribai. 2008. Oleic acid content is responsible for the reduction in blood pressure induced by olive oil. Proc. Natl. Acda. Sci. 105:13811-13816.

Thakur, V., S. Paroha and R. P. Mishra. 2018. Free Fatty Acid Profile of Seven Sesame (*Sesamum İndicum* L.) Verities. İnt. J. Curr. Microbiol. App. Sci. 7(7):3439-3453.

Unal, K. and H. Yalcin. 2008. Proximate Composition of Turkish Sesame Seeds and Characterization of their Oils. Grasas Y Aceite. 59(1):23-26.

Uzun, B., C. Arslan and S. Furat. 2008. Variation in fatty acid compositions oil content and oil yield in a germplasm collection of sesame (*Sesamum indicum* L.). Journal of the American Oil Chemists' Society. 85:1135-1142.

Uzun, B., C. Arslan, M. Karhan and C. Toker. 2007. Fat and fatty acids of white lupin (*Lupinus albus* L.) in comparison to sesame (*Sesamum indicum* L.). Food Chem. 102:45–49.

Uzun, B., S. Ulger and M. I. Cagirgan. 2002. Comparison of determinate and indeterminate types of Sesame for oil content and fatty acid composition. Turkish J. Agric. 26:269-274.

Vurarak, Y., M. E. Bilgili and P. Cubukcu. 2018. Effects of Growing Season and Root Presence on Some Yield Components and Fatty Acid Composition of Sesame in Cukurova Region. Eurasian Journal of Agricultural Research. 2(1):13-21.

Weiss, E. A. 1971. Castor, sesame and safflower. LEONARD Hill Books, London, pp 311-526

Weiss, E. A. 2000. Oilseed Crops. 2nd ed. Blackwell Science, Oxford, pp.131-164.

Were, B. A., A. O. Onkware, S. Gudu, M. Velander and A. S. Carlson. 2006. Seed oil content and fatty acid composition in East African sesame (*Sesamum indicum* L.) accessions evaluated over 3 years. Field Crops Res. 97:254–260.

Yol. E., R. Toker, M. Golukcu and B. Uzun. 2015. Oil Content and Fatty Acid Characteristics in Mediterranean Sesame Core Collection. Crop Science. 55:2177-2185.