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Effects of Growing Season and Root Presence on Some Yield Components and Fatty Acid Composition of Sesame in Cukurova Region

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Abstract
Sesame is harvested manually in Turkey. The traditional harvesting system which are ripped and bound in small bundles by labor and later dry plants are threshing. This system is being not only increases the cost of sesame, but also leads to a gradual decrease in planting area of sesame in Turkey. In the Turkey has been working on complete mechanization of sesame harvesting and threshing. Till now, the farmers do not prefer to mechanical harvest system because they are considering that the quality of seed are reduce by cutting the roots at the harvest. The main purpose of the study is to determine the relationship between root presence and seed quality in sesame. For this purpose, some quality parameters were compared to the seeds obtained from rooted and without root plants.It was carried out randomized complete split plot design, four replicates in Cukurova Region and for two years under main and second crops conditions. In the study, 1000 seed weight, fat-protein ration and fatty acid composition were determined in sesame seeds obtained from plants rooted and without root. As a result, this study found that root presence has no statistically significant effect on palmitic, stearic, oleic, linoleic acid. But, it was determined that root presence was a significant effect on seed weight ($P<0.05$). Despite could be determined that the growing season (main and second crop conditional) has statistically significant effect on stearic ($p<0.05$) and oleic acids ($p<0.01$), could not be determined this effect on palmitic and linoleic acid.

Keywords: Sesame, root presence, harvest, fatty acid composition.

INTRODUCTION

The sesame (*Sesamum inducum* L.) belongs to the family of *Pedaliaceae* and one of the oldest oil seeds known by humans. It contains about 50-60% seed oil with superior quality comparable to olive oil (Aslan *et al.,* 2007). Seeds of sesame are very rich in iron, magnesium, copper, calcium and vitamin B1 and E. It contain phytosterols associated with reduced levels of blood cholesterol (Bedigian, 2004). Sesame has an important place among oil plants with highest oil and containing an amount 25% of protein and sesame oil is remarkable stability to oxidation due to the present of lignins (Lee *et al*., 2008).

Sesame is grown in tropical zones as well as in temperate zones. Especially in Asia and Africa it is cultivated from centuries (Khan & *et al.,* 2016) and one of the traditional crops of Turkey, too. In Turkey Sesame genotypes has highest oil content changed between 40.0-61.8% (Tan, 2012). In despite of the nutritional value and oil quality of sesame seeds, research on this important crop has been not enough yet. Although seed yield in Turkey is higher than the world average, it is not satisfactory. Turkey sesame production at 289 332 da; and with 12.48% of this, which is 36 114 da, is total production of the Adana (TUİK, 2017). According to statistics between in 1966-1970 in terms of Turkey sesame planting area was ranked 4th in the World (İlisulu, 1973). The amount of sesame planting area in Adana (1970 s) was almost the same as total amount planting in Turkey in 2012. The production of sesame decrease year to year due to manual harvesting in Adana. Sesame is a highly profitable crop, but in order to reduce the cost of production even further, the mechanization of harvesting is essential. Mechanization of some aspects of sesame farming, such as forming a ridge, mulching, and seeding, have been developed, but weeding and harvesting operations are entirely dependent on manual labor (Yilmaz *et al.,* 2008). The most important expense is human work in the harvesting by hand. In a study conducted by Ugurluay (2002), the most consumption time in the total process time was determined in to be pulled up the plants and to be made brunches by hand (107 h ha^{-1}). Harvesting is the most costly input at sesame cultivation. This cost was found to be 59% by Flip (1988). In another study, the cost of harvest was determined 54.5% at the main crop and 41.0% at the second crop condition (Vurarak *et al.,* 2014). High priority must be given to the solution of manually harvesting issue, and as a potential alternative to it, mechanized or semi-mechanized harvesting systems must be presented to the farmers. Thus, the harvesting cost that is about 70% of the production input cost will be able to be reduced. Yet, while doing this to reduce the cost, it also must be remembered that crop quality must not be affected negatively. In Turkey it was done a few researches on sesame harvesting mechanization (Ugurluay, 2002). Generally, harvesting loss was determined in that research, however, effect of machine harvesting on seed quality and fatty acid composition was not determined earlier studies. This issue in sesame farming needs to be solved in order to increase the production areas. High priority must be given to the solution of manually harvesting issue, and as a potential alternative to it, mechanized or semi-mechanized harvesting system must be present to the farmers.

Sesame cultivars grown all over the world have dehiscent capsules; therefore, 99% of the fields are harvested manually (Georgiev *et al.,* 2009). A lot of sesame varieties and ecotypes which have been grown for hundreds of year are distributed in various ecological regions of Turkey (Baydar *et al.,* 1999). Sesame is commonly grown in small-scale farms with less input and less mechanization in most of major sesame producing countries as well as in Turkey. Sesame yield is low, mainly attributed to low yield of the cultivars with an indeterminate growth habit, pest and diseases occurrence, insufficient weed control, uneven ripening of capsules, seed shattering, susceptibility to environmental stress, lack of mechanized harvest and lack of adequate research (Furat & Uzun, 2010). Sesame harvesting takes 5-8 days and lack of labor during the harvest period give rise to high cost and low yield (Tan, 2012). Together with that shed their seed. It is very important to harvest in sesame seeds if not timely harvested causing yield losses. Sesame yield could be improved by using better management practices and adapt to crop to the mechanical agricultural systems (Calıskan *et al.,* 2004).

It is very important that the sesame harvesting at time is correctly determined. The rightest harvest moment occurs when the seeds in the base of the stem start to open. A common feature in most variety, especially in dehiscent ones, is the speedy process of natural dehiscence of capsules, with eventual seed fall. This happens right after the best maturity stage, which, in case of late harvests, can mean great losses in production (Queiroga *et al.*, 2008). It is noteworthy that determining the ideal harvest moment for dehiscent sesame is hard because capsule maturity is uneven, for it is a plant that has indetermined growth (Banerjee & Kole, 2009). In Turkey, there is not a breeding program for the development of a new type of sesame cultivars with in dehiscent capsules and suitable for mechanized harvesting. According to mechanical harvesting of sesame, the cultivars should have an upright habitus with a limited number of branches, strong and lodging resistant stem. In order to decrease the losses in mechanized harvesting, the height at first branch and pod should be 25–30 cm from soil surface.

Harvesting by machine or used combine harvester is limited in the world. Generally, in Turkey sesame harvest method is to pull up maturity plants in the field two or three times. Sesame plants are pulled up from the roots of the sesame plants and ten of fifteen plants banding together are made bunch in the field. Bunches are pressed about seven or ten days

(Yilmaz *et al.*, 2008) and fallowing the bundles are then inverted, and the seed falls out (thresing). In the Turkey has been working on complete mechanization of sesame harvesting and threshing. In an effort to mechanize the harvest of sesame, have introduced recently the use of binders in Turkey. The binders were used to cut and bundle the sesame plants, manual labor was used to shock the cut plants, and combines were brought in to thresh the shocks. This methodology is very little used in Turkey and is considered "semi-mechanized harvest" because it still requires some manual labor. Till now, the farmers do not prefer to mechanical harvest system because they are considering that the quality of seed are reduce by cutting the roots at the harvest.

The fatty acids, as the other elements that from oil, are found in different forms of compositions in each of oil plants (Baydar, 1999). That's why, the factors that effect the amount of oil and fatty acids in the plant should be done accordingly in order to meet the need for the consuming purpose, whatever it is (Karaca & Aytaç, 2007). Tahini is widely used in foods in the Middle East and its quality related to oil and fatty acid contents (Ozcan, 1993). Quality of sesame seed rooted and without root of bunched plant is important both sesame farmers. Farmers can be easily prefer to mechanical harvesting if they know the impact of the harvest on quality.

One purpose of this research examined whether it is or not change seed oil and fatty acid composition. If this goal can be proved, the harvest of sesame in Turkey can quickly become using mechanization. Farmers can be easily prefer to mechanical harvesting if they know the impact of the harvest on quality.

The main purpose of the study is to determine the relationship between root presence and seed quality in sesame. For this purpose, some quality parameters were compared to the seeds obtained from rooted and rootless plants. It was carried out randomized complete split plot design, four replicates in Cukurova Region (in Adana province) and for two years under main and second crops conditions. In the study, 1000 seed weight, fat ration, protein ration and fatty acid composition were determined in sesame seeds obtained from root and without root plants.

MATERIAL AND METHOD

Source of plant material and climate values of region

Orhangazi-99 sesame variety was used as material in the experiment. This variety was preferred because it drops its lower leaves completely at the stage ripeness, and because it also has a slight lodging. The average yield of this variety change from 1 420 to 2 690 kg ha^{-1}. Average flowers is change 28-45 day, vegetation duration is between 92-100 days depending on environmental conditions. Additionally, it has a suitable number of side branches for harvesting, and its height is very suitable for harvesting the early capsules.

The experimental area Adana province which is located in Eastern Mediterranean Region of Turkey, soils are classified as clay. The region has warm and humidity climate in summer and the mean annual rainfall is between 650-800 mm, most of which fall in a major cropping season which extends from December to June. 2011 and 2012 climate data of experimental area are given in Table 1. Second year temperatures are higher than first year temperatures as shown in the Table 1.

Method

The study was conducted in the farming fields of Eastern Mediterranean Agricultural Research Institute for two years under main and second crop conditions in Adana province, Turkey (latitude 36° 51′ N, longitude 35° 20′ E and altitude 11.0 meter above sea level). It was carried out randomized complete split plot design with four replicates. Growing seasons (main and second crop conditions) were assigned to the main-plots and root presence (rooted and without root) to the sub-plots during the 2011-2012. The size of each plot was 2.8 m x 5 m, row spacing (four rows) was 0.7 m and the distance between plants in the row was 0.15 m, and 2-3 cm of depth. Seed rate was kept 2.5 kg ha^{-1} and agronomic practices were carried out consistently for all the experimental units during the growing season. The crop was fertilized with an amount of 70 kg N, and 50 kg of P_2O_5 ha^{-1} applied as basal dose prior to sowing. Right after sowing, irrigation was performed, and then, when plant height reached 10-15 cm, hoeing was performed for the first time, and right after that, irrigation was performed for the first time. Later on, irrigation was performed for three times and pesticide control against whitefly pest was performed for four times along sesames grown for second crop conditions. For main and second crop conditions sowing and harvesting dates are given Table 2. While main crop was sowing at the end of April, second crop was sowing at the end of June after wheat harvest. The main crop was harvested on August, second crop on September, 2011 and 2012. The traditional harvesting, after the plants were pull up from the roots of the sesame plants, ten or fifteen plants banding together are made bunched in the field. But at the alternative harvesting, before sesame plants are made bunched in the field, plant roots were cut, namely, they are made bunched without root. Bunches are pressed about 5-10 days. Bunches which including to dry and open capsules and grain are hit with thick stick to be provide the spilled of the grain from inside the capsule in threshing by hands is done.

Plant height (cm), number of branches per plant (branches $plant^{-1}$), stem thickness (mm) and height of first capsules (cm) were recorded on ten plants randomly chosen before harvesting. Biological yield of plant have given as mean. The following methods were applied to the seeds obtained from each of the parcel and replication to determine the 1000 seed weight, protein rate, oil rate and fatty acid compositions.

1000 seed weight (g): At maturity, the seed obtained from all the randomly selected five plants were weighed and calculated on the basis of number of plants threshed to get average weight of seeds plant.

Protein rate (%): It was determined with Kjeltec method by using the Kjeltec appliance (Anonymous, 1977).

Oil rate (%): Oil rates were determined an NMR appliance that work with Nuclear Magnetic Resonance system, within a level of 0 % moisture (Granlund & Zimmerman, 1975). Measurements for oil rates were done for each parcel in two parallels and then the average was calculated.

Fatty acid contents (Oleic, Linoleic, Palmitic, Stearic): The composition of fatty acid was determined by gas liquid chromatography (GC) (Christie, 1973) In according to the Turkish Food Codex given limit values for sesame seed, palmitic, stearic, oleic and linoleic acid must be changed 7.9-12.0%, 4.5-6.7%, 34.4-45.5%, and 36.9-47.9% respectively (Anonymous, 2009). Obtained data is compared to this codex limits.

Data analyzed

The data collected were statistical analyzed by using the computerized statistical programme JUMP7. Data were subjected to analyses of variance for the combination of two years, growing season and root presence. Analysis of variance was used to test the significance of treatment effects (Steel and Torrie, 1980) and Least significance difference (LSD) test at P = 0.05 was used to compare the treatment means.

RESULTS AND DISCUSSION

Some of the general parameters measured for the main and second crops of sesame between 2011 and 2012 are given in Table 3. According to Table 3, seed yield was higher by 14.5% at the main crop conditions than at the second crop conditions. Also, it was seen that second year of seed yield is increased in the second crops conditions. Number of branches per plant changes between 4.7 and 5.4 for two years. Its showed that effect of growing season on height of plant and height of first capsules. Second crop condition gave the shortest height to first capsule compared to main crop condition. It can be said that height of first capsules is related to total temperature and environment. Differences due to environmental (total temperature and others) and growing season were significant. Brigham (1985), Karaca & Aytac (2007) reported that sesame yield is highly variable depending upon the growing environment, cultural practices and cultivars.

1000 seed weight

Statistical analysis indicated that growing season had a highly significant effect on 1000 seed weight. Data in Table (4) revealed that 1000 seed weight was significantly affected by growing season ($p<0.01$) and root presence ($p<0.05$). According to data of growing season and root presence, 1000 seed weight is the highest at main crop and without root conditions. 1000 seed weight ranged from 2.94 g to 3.07 g in growing season. But according to study of Mandi *et al.* (2007) found that second crops (3.11 g) had heavier seed than main crops condition (2.87 g).

Oil content

A perusal of Table 4 exhibits that there is no effect of growing season and root presence on oil content statistically. However, the oil content ranged from 54.10% to 55.98%. Different references reported that the total amount of temperature required to grow a sesame crop ranges from 2500°C to 3500°C (İlisulu 1973; Tan 2012). In this study, while total 2714°C average temperature measured during growing season for the main crop conditions, 2508°C average temperature measured during growing season for the second crop conditions. It can be said that temperature differences between main and second crop conditions is not effect on oil rate. But, oil content ranged from 54.10% to 55.83%.According to İlisulu (1973) sesame seeds contain average 40-60% oil. Tan (2012) reported that oil content of Orhangazi-99 variety has been changed between 55.3-57.9%. As seen in Table 3, oil contents were higher in main crop conditions (by 55.83%) than second crop conditions but these variations were not significant for growing season. 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). Our results showed that oil content is inversely related to growing season.

Protein content

It is a fact that, both oil and protein raters for all oil plants are desired to be high, and that applies for sesame as well (Smith, 1991). It is determined that growing season was effective at ($p<0.01$) importance level on protein rate statistically. Protein content ranged from 18.39% to 21.17%. It was higher by 13.3% at the second crop conditions than at the main crop conditions. There is an inverse relation between oil and protein values (Wilcox & Shibles, 2001). Similar results are found in this study. However, root presence was not effective statistically on protein rate (Table 4).

Oil fatty acid composition

Results which are related oil fatty acid compositions according to the cases were given Table 5. According to combined variation analysis, an important level of a difference the effect of growing stages on the palmitic and linoleic fatty acid was not found statistically. On the other hand, growing season was found to be effective on the stearic fatty acid $p<0.05$ importance level, on oleic fatty acid $p<0.01$. There was no significant and statistically effect of root presence on fatty acid compositions. When these results are evaluated, it is possible to say that growing season is more effective on fatty acid composition compare to root presence.

Statistical analysis indicated that the effects on palmitic fatty acid neither growing season nor root presence. Palmitic fatty acid ranged from 10.77% to 10.84%. According to statistical analysis, it was determined that growing season is effective on stearic fatty acids statistically. The stearic acid is reduced 3.75 % at the second crop conditions compare to main crop conditions. Stearic acid ranged from 6.40% to 6.65%. Growing season is effective on oleic acids statistically. Oleic acid is reduced 1.72% at the main crop conditions compare to second crop conditions. Oleic acid ranged from 40.38% to 41.09%. It was determined that the cases was no effects on linoleic acid statistically. There was no significant and statistically effect of root presence on linoleic acid compositions. Linoleic acid ranged from 40.32% to 40.49% (Table 5)**.** Genetic structure, development stages and fruit formation is effect of fatty acid content of cultivars (Karaca & Aytac, 2007). Oil quality is determined to its fatty acid compositions which is palmitic, stearic, oleic and linoleic fatty acid content percentage. Those values may change under different genetic, morphological, ecological, physiological, and cultural factors (Beatrice *et al*., 2006)

CONCLUSION

In the end of this study, it was determined that stearic and oleic fatty acid content may change under main and second crop conditions. This situation is thought to be related to the climate of the country.However, it was determined that root presence was not effective on fatty acid content. At the Turkish Food Codex declaration, palmitic fatty acid is ranged between 7.9-12.0%, stearic fatty acid 4.5-6.7%, oleic fatty acid 34.4-45.5%, linoleic fatty acid 36.9-47.9% (Anonymous, 2009). In our study, all results were found in the limits specified by Turkish Food Codex declaration.

At the end of this study, it can be said to sesame growers that seed quality of with root and without root is same. This result supported that sesame can be harvested with machine instead of harvest with hands. Therefore, the effect of different harvesting method on sesame quality were determined that can be potentially an alternative harvesting process which is the most difficult, time consuming and costly one is sesame farming.

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Table 1. Temperature ($^{\circ}$C), relative humanity (%), total rainfall (mm), and wind speed (m s^{-1}) for 2011 and 2012 in the experimental area

Months	Mean of temperature		Mean of relative humidity		Total rainfall		Mean of wind speed	
	2011	2012	2011	2012	2011	2012	2011	2012
April	16.5	18.1	65.4	68.3	117.3	36.0	0	9.7
May	20.1	20.8	70.2	74.0	30.0	97.0	0	9.7
June	24.5	26.7	72.4	66.2	0	35.5	9.4	7.5
July	27.9	29.3	71.5	65.3	0	18.3	8.8	10.6
August	28.8	29.3	68.6	62.5	0	0	9.7	10.2
September	26.9	27.0	65.7	64.9	0	0	9.6	10.0
October	20.7	22.6	49.7	61.9	6	51.9	11.7	35.0

Table 2. Experimental area sowing and harvest dates for main and second crop

Years	Process	Main crop	Second crop
2011	Sowing	04.05.2011	29.06.2011
	Harvest	12.08.2011	26.09.2011
2012	Sowing	28.04.2012	19.06.2012
	Harvest	06.08.2012	21.09.2012

Table 3. Some of plant parameters for main and second crop conditions

Parameters	Main crop			Second crop		
	2011	2012	Average	2011	2012	Average
Plant height (cm)	189.1	179.6	184.3	145.3	170.7	158.0
Stem thickness (mm)	13.3	12.5	12.9	11.9	14.2	13.1
Branches (per plant)	4.7	5.0	4.8	4.8	5.4	5.1
Height of first caps. (cm)	73.5	51.0	62.3	48.0	53.0	50.5
Seed yield (kg ha^{-1})	1728.2	1437.3	1582.8	1151.7	1553.8	1352.2

Table 4. Summary of the variation from average 1000 seed weight, oil content, protein content

Parameters	1000 seed weight (g)	Oil content (%)	Protein content (%)
Growing season			
Main crop	3.07±0.09a	55.83±3.36	18.39±3.03a
Second crop	2.94±0.38b	54.10±2.12	21.17±2.49b
$LSD_{(0.05)}$	0.0016	-	0.006
Root presence			
Rooted	2.98±0.30b	54.95±3.40	19.69±2.90
Without root	3.03±0.27a	54.98±2.40	19.86±3.29
$LSD_{(0.05)}$	0.0009	-	-
CV(%)	0.65	6.67	4.10
Growing season	0.0077^{**}	0.174^{ns}	$<.0001^{**}$
Root presence	0.021^{*}	0.968^{ns}	0.725^{ns}
Growing season*Root presence	0.94^{ns}	0.242^{ns}	0.548^{ns}

Means followed by similar letters in columns or rows are not significantly different according to least significant difference (LSD). * and ** significant at 0.05 and 0.01 level of probability, respectively.

Table 5. Summary of the variation from average palmitic, stearic, oleic and linoleic fatty acid.

Parameters	Palmitic (%)	Stearic (%)	Oleic (%)	Linoleic (%)
Growing Season				
Main crop	10.79±0.62	6.40±0.43b	41.09±0.47a	40.32±1.16
Second crop	10.82±0.43	6.65±0.74a	40.38±0.53b	40.49±1.21
$LSD_{(0.05)}$	-	0.004	0.0042	-
Root Presence				
Rooted	10.77±0.50	6.53±0.62	40.81±0.60	40.44±1.14
Without root	10.84±0.60	6.51±0.61	40.62±0.64	40.36±1.21
$LSD_{(0.05)}$	-	-	-	-
CV(%)	0.99	2.47	0.93	0.73
Growing season	0.708^{ns}	0.023^{*}	0.0001^{**}	0.431^{ns}
Root presence	0.462^{ns}	0.834^{ns}	0.173^{ns}	0.674^{ns}
Growing season*Root presence	0.201^{ns}	0.388^{ns}	0.845^{ns}	0.060^{ns}

Means followed by similar letters in columns or rows are not significantly different according to least significant difference (LSD). * and ** significant at 0.05 and 0.01 level of probability, respectively.