Turkish Journal of
Field Crops
2013, 18(1), 27-33

EFFECT OF SEEDING RATE ON YIELD AND QUALITY OF NON-CHEMICAL FENNEL (*Foeniculum vulgare* Mill.) CULTIVATION

*Ayse Betul AVCI

Ege University, Odemis Vocational School, Izmir, TURKEY
**Corresponding author: ayse.betul.avci@ege.edu.tr*

Received: 29.05.2012

ABSTRACT

This study was conducted to determine the effects of different seeding rates on yield and quality characteristics of fennel without using any chemical fertilizers and pesticides, in Atabey-Isparta ecological conditions during 2010 and 2011 vegetation periods. The experiment was established as randomized blocks design with three replications and three seeding rates (10, 15 and 20 kg ha^{-1}) were applied. Plant height, fruit yield and biological yield were significantly affected by seeding rate. Fruit yields ranged between 230.35 and 790.96 kg ha^{-1} and the highest yield was obtained from 15 kg ha^{-1} seeding rate. Essential oil contents ranged between 1.60 and 2.46%. The main constituent of the essential oil was identified as *trans*-anethole ranged between 84.48% and 97.79%.

Keywords: *Foeniculum vulgare*, fruit yield, essential oil, *trans*-anethole.

INTRODUCTION

From past to present, plenty of natural resources such as herbal products are used as medicine raw materials. However, natural components are not preferred by the manufacturers because of more expensive obtaining than that of their synthetics. Yet, using of synthetic products causes adverse effects on human health as well as they have therapeutic effects. In this regard, it can be said that increasing population and advancing technology threaten the human health and nature at an unpredictable extent. Due to such reasons, plants that are used in the medicine production are required to cultivate under organic conditions without using chemical inputs like fertilizer and pesticides, instead of collecting from nature or cultivated by using conventional agricultural practices. Therefore, herbal active ingredient can be obtained without undergoing any chemical change. Medicinal and aromatic plants such as sage, anise, thyme, carob, rosemary and fennel are organically grown either for domestic market or for foreign market although it varies on a yearly basis. Organic fennel consumption in Turkey is about 1243.39 tons (Bayram et al., 2010).

Fennel (*Foeniculum vulgare* Mill.) is commonly used as analgesic, anti-depressive, anti-inflammatory, digestive, treatment for disorders and spasmolytic (Basgel and Erdemoglu, 2006). In addition, fennel has carminative, flavoring, antioxidant, antibacterial, antifungal and mosquito repellent properties (Garg et al., 2010).

Fennel is a member of Apiaceae family and grows naturally in Northern (Davis, 1978; Baytop, 1999; Tanker et al., 2007), Western and Eastern Anatolia Regions of Turkey (Ozyilmaz and Yilmaz, 2009; Kizil et al., 2001). It can be annual or perennial (Ceylan, 1997). Although fennel agriculture is done in various provinces in our country such as Bursa, Denizli, Gaziantep, Manisa and Antalya, it is produced around Burdur province the most (Baydar, 2009). There are two important varieties of fennel which are *Foeniculum vulgare* var. *vulgare* (bitter fennel) and *Foeniculum vulgare* var. *dulce* (sweet fennel) (Akgul, 1993). Mentioned researcher reported that sweet fennel fruits contain 2-4% essential oil which the constituents are *trans*- anethole 60-80%, 5-10% fenchone, limonene, methyl chavicol, α- phellandrine, anisaldehyde, *cis*-anethole (due to the toxic effects, presence of *cis*-anethole is not desirable), anisic acid, anicketon, monoterpenes and alcohols.

Various studies were conducted on fennel by many researchers such as sowing methods and times (Ayub et al., 2008), N fertilization and plant density (Nakhaei et al., 2012), sowing date and seeding rate (Arabaci and Bayram, 2005) and sowing date and row spacing (Ahmad et al., 2004). Kandil (2002) also reported that generally fertilization with chemical fertilizers were given higher fennel growth parameters than organic fertilization, nevertheless essential oil content and the main components of the fennel fruit oil were not affected significantly by fertilization with organic and inorganic sources. Thus, the purpose of this study was to determine the effect of different seeding rate on some yield characteristics for fennel without using any chemical fertilizers and pesticides.

MATERIALS AND METHODS

Sweet fennel (*Foeniculum vulgare* Mill.) seeds were obtained from village populations from the producers of Burdur province were used as the study material. The experimental design was randomized blocks with three replications on the experiment. Field research was conducted in Atabey Vocational School of Suleyman Demirel University during 2010 and 2011 vegetation periods. No agricultural activity has been done in the trial area for six years. Different seeding rates (1, 1,5, 2 kg da^{-1}) were applied in this study which was conducted for a two years period. The parcels were planned in six rows of 3 m length with 40 cm between rows. Sowing date of the first year was 2 April 2010 and the second year was 31 March 2011. Harvesting date of the first year was 16 September 2010 and second year was 7 September 2011. Additional nitrogen fertilization was not made due to the determined total nitrogen values were at a sufficient level (Lindsay and Norwell, 1969; FAO, 1990; Tovep, 1991; Gunes et al., 1996). Weed control and irrigation were made when necessary. In parcels 4 middle rows with 2.5 m length were harvested. Cuscuta (*Cuscuta sp.*) was encountered on some of the parcels in the first growing season, and contaminated plants were taken away from the parcels. In addition, *Graphosoma lineatum [italicum]* (L.) insect was encountered in fruit setting periods of both years, but biological and chemical control were not made.

Table 1. Results of soil analyze of the experiment field

	for 0-20 cm			for 20-40 cm		
Structure Analysis	**clay**	**silt**	**sand**	**clay**	**silt**	**sand**
	22.80%	16.89%	60.31%	20.20%	14.43%	65.37%
N		0.08316%			0.09576%	
P		9.66 ppm			9.83 ppm	
K		390 ppm			360 ppm	
pH		7.54			7.52	
eC		2.05 µs / 24.9°C			0.35 µs / 24.7°C	

Soil samples taken from 0-20 cm and 20-40 cm depth of the experiment field were analyzed in the laboratory of Soil Science Department of Agriculture Faculty of Suleyman Demirel University. According to that, soil structure of the experiment field was determined as sandy clay loam with low alkaline reactivity. Analysis results belonging to the experiment field were provided in the Table 1. Structure (texture) analysis was determined according to Day Hydrometer Method (Day, 1956), total Kjeldahl Method of Nitrogen Estimation (Kjeldahl, 1883), phosphorus sodium bicarbonate method (Olsen et al., 1954), potassium neutral 1 N Ammonium acetate method (Carson, 1980). pH and ec were determined by 1:1 soil:water mixture (Peech et al., 1947).

Table 2. Some of the climate data of Atabey district for 2010 and 2011 years

	Relative Humidity (%)		Temperature (°C)		Total Rainfall (mm)	
Month	2010	2011	2010	2011	2010	2011
March	60.1	68.7	8.3	5.9	33,2	50,4
April	59.9	67.8	11.5	10.0	47,0	54,7
May	55.4	65.9	16.4	14.0	32,4	43,1
June	61.4	56.2	19.2	19.3	64,5	62,2
July	47.1	40.5	24.6	24.9	40,1	1,8
August	37.8	37.2	26.4	24.4	0,2	0,6
September	54.0	40.2	20.3	19.8	30,0	-
October	72.5	57.0	11.9	10.9	79,1	-
Mean/Total	56.0	54.2	17.3	14.9	326.5	212.8

Climate data regarding the years during which the experiment was conducted were provided in Table 2. According to that, it was observed that the relative humidity, average temperature and total rainfall in 2010, which is the first year of the experiment, were higher compared to the second year. Additional irrigation was done due to lack of rainfall or no rain.

In the study, plant height (cm), number of fruited branches (units(s)/plant), number of umbels (units(s)/plant), number of umbellets (units(s)/umbel), number of fruits (units(s)/umbel), fruit yield (kg ha^{-1}) and biological yield (kg ha^{-1}) was calculated randomly chosen 10 plants without considering edge effect. The number of umbellets was calculated by counting the umbellets in all umbels of each plant and taking their averages (units(s)/umbel). The number of fruits was calculated by counting fruits in all umbels of each plant and taking their averages (units(s)/umbel). The thousand fruit weight (g) was calculated by counting and weighing 100 units of fruit with 5 replications from each parcel and comparing it with thousand fruit weight. In order to determine the essential oil content in both years, 10 g of air-dried fruits that were obtained from each parcel were weighed, crushed in the grinder and by adding 100 ml distilled water, calculated as milliliter/100 g (%) by water distillation with three replications in Neo-Clevenger apparatus (Wichtl, 1971). Essential oil constituents were analyzed by (%) gas chromatography method, and GC/MS analysis was carried out by utilizing Shimadzu GC/MS-QP 5050 A in Suleyman Demirel University Experimental and Observational Student Practice and Research Center. CP Wax 52 CB (50 m x 0.25 mm *i.d*., film thickness 1.2 µm) capillary column and Helium as a carrier gas were used. The temperature program reached from 60°C to 220°C with 2°C increases in temperature in a minute, and was applied by maintaining 220°C for 20 minutes. Temperature of the injector was 240°C. Mass spectra were used at 70 eV. After the compounds were ionized in gas chromatography column and separated, mass spectrum of each of them were obtained. Evaluation procedures were conducted by using "Wiley, Nist and Tutor" libraries.

Every characteristic other than the essential oil constituents were subject to analysis of variance in TARIST packaged statistics software according to experimental design of randomized blocks. Differences were determined by F test and mean values were compared according to LSD test.

RESULTS AND DISCUSSION

Plant height

Significant differences were observed between seeding rates, years and their interactions (Table 3). Plant heights varied between 37.30 and 45.80 cm in the first year and 52.83and 56.43 cm in the second year. When the general averages of plant heights were investigated in terms of seeding rates, the highest values were recorded from 20 and 15 kg ha^{-1} seeding rates, respectively. In interaction, the highest plant heights were 45.80 and 44.47 cm from 15 and 20 kg ha^{-1} seeding rates in the first year, respectively. In the second vegetation year, the highest plant height was found as 56.43 cm in 20 kg ha^{-1} seeding rate. Arabaci and Bayram (2005) were obtained the highest plant heights from 25 and 15 kg ha^{-1} seeding rates, respectively. It was expected that plants grown densely were taller because of not to be found enough space for spreading (Ahmad et al., 2004) and it was clearly seen in the second year values. Ahmad et al. (2004) also reported that the maximum plant height was observed from 40 cm row spacing compared to 70 cm. The plant heights were compared in terms of the year averages, the first year value was 42.52 cm and the second was 54.60 cm. Plant heights of this study were similar with Kizil et al. (2001) and Tunçturk (2008); but lower than Karaca and Kevseroglu (2001), Ahmad et al. (2004) and Arabaci and Bayram (2005). Plant height is a genotypic characteristic and differences occurred between studies may be due to the seed materials from different origins, ecological conditions and agronomic practices.

Number of fruited branches

While different seeding rates were not affecting the number of fruited branches per plant, years and their interactions were affected (Table 3). Number of fruited branches varied between 5.30 and 6.55 branches per plant in the first year, and between 4.97 and 5.87 in the second year. According to two year averages, the highest number of fruited branches was obtained in the first year as 5.67 per plant. In interaction, the highest number of fruited branches was observed in the first year with 6.55 in 10 kg ha^{-1} seeding rate was the application of sparse sowing, in the second year there were no differences between the seeding rates. Arabaci and Bayram (2005) reported that seeding rates were not statistically significant on number of fruited branches per plant, but the interaction between seeding dates and seeding rates were significantly affected on number of fruited branches per plant. Mentioned researchers determined the highest number of fruited branches on 1 April sowing date in 5 and 15 kg seeding rates per hectare and these results were similar to the results of present study in terms of seeding rates. The values of number of fruited branches were in accordance with the findings of Kizil et al. (2001) and Arabaci and Bayram (2005).

Table 3. Mean values of plant height, number of fruited branches and number of umbels for fennel in different seeding rate

Seeding Rate (kg ha^{-1})	**Plant height (cm)**			**Number of fruited branches (unit(s)/plant)**			**Number of umbels unit(s)/plant)**		
Years	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
10	37.30 b	52.83 b	45.07 b	6.55 a	5.03 a	5.79	6.16 a	10.40 a	8.28
15	45.80 a	54.53 ab	50.17 a	5.15 b	4.97 a	5.06	5,90 a	7,95 b	6.93
20	44,47 a	56.43 a	50.45 a	5.30 b	5.87 a	5.59	4,90 a	9,83 a	7.37
Mean	42.52 b	54.60 a	48.56	5.67 a	5.12 b	5.40	5,99 b	9,08 a	7.54
LSD	$Y_{(5\%)}$: 1,88 $SR_{(5\%)}$: 2,31 $YxSR_{(1\%)}$: 3,26			$Y_{(5\%)}$: 0.50 SR: ns $YxSR_{(5\%)}$:0.86			$Y_{(5\%)}$: 0.88 SR: ns $YxSR_{(1\%)}$: 1.52		

Number of umbels

As it can be seen in Table 3, different seeding rates had insignificant effect on number of umbels per plant. On the other hand years and their interactions had significant effect on number of umbels. It was determined that the first year values ranged between 4.90 and 6.16 and in the second year it was between 7.95 and 9.83 per plant. Several researchers revealed that the number of umbels per plant is affected by plant density and when plant density increases, the umbel numbers decrease (Falzari et al., 2005; Ozyilmaz, 2007; Nakhaei et al. 2012). Similar results were obtained especially in the first year of the present study. It can be say that when plants are sowed densely they have competition with each others for unit area, nutrient elements, water and light, therefore the number of umbels decreases. The averages of umbel numbers were examined for years, the second year value was found higher than the first year with 9.08 and it was found statistically different from the first year. The reason of this may be due to the high amount of rainfall in July which probably affected pollination negatively, and therefore the number of umbels reduced. In interaction, there were no differences between the seeding rates for the first year, but in the second year the highest values were found in 10 and 20 kg ha^{-1} seeding rates with 10.40 and 9.83, respectively.

The results of this study were similar with Nakhaei et al. (2012) and lower than Tunçturk (2008) and Arabaci and Bayram (2005). These differences between the studies may be due to the different ecological conditions, agronomic practices and seed origins.

Number of umbellets

Seeding rates, years and their interactions had no significant effect on number of umbellets per umbel (Table 4). Number of umbellets varied between 6.35 and 7.37 in the first year and between 6.68 and 7.34 in the second year. Researchers revealed that when row spacing increases, number of umbellets was decreases (Ozyilmaz, 2007; Nakhaei et al., 2012). Different from these researchers, in present study this situation was not observed. Although there were no statistical differences between the number of umbellets, the highest value was found with an average of 7.27 from 15 kg ha $^{-1}$ seeding rate, and the second year value as 7.06 was found higher than the first year. Higher values were determined than present study by Ozyilmaz (2007) and Nakhaei et al. (2012). The differences between the other studies may be due to for similar reasons as number of umbels per plant.

Number of fruits

The effects of different seeding rates and year x seeding rate interaction were not found statistically significant on number of fruits per umbel, while year was effective. It was seen in Table 4, number of fruits per umbel ranged between 18.82 and 23.64 in the first year and between 37.11 and 42.58 in the second year. When the general averages of two years were compared; the highest number of fruits per umbel was obtained in the second year of the experiment with 39.91. The differences between the vegetation periods may be due to the rainfall in July had negative effects on pollination and consequently fruit set. Falzari et al. (2005) also revealed that fruit set was being reduced by a lack of synchrony between pollen production and stigma receptivity. It may be caused for this reason, number of fruits per umbel was determined lower than other researchers (Arabaci and Bayram, 2005; Ozyilmaz, 2007; Tunçturk, 2008).

Table 4. Mean values of number of umbellets, number of fruits and fruit yield for fennel in different seeding rate

Seeding Rate (kg ha^{-1})	**Number of umbellets (unit(s)/umbel)**			**Number of fruits (unit(s)/umbel)**			**Fruit yield (kg ha^{-1})**		
Years	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
10	6.90	6.68	6.79	23.64	37.11	30.38	343.9	557.3	450.6 b
15	7.37	7.16	7.27	24.55	42.58	33.57	397.4	799.6	598.5 a
20	6.35	7.34	6.85	18.82	40.03	29.43	263.5	587.5	425.5 b
Mean	6.87	7.06	6,97	22.34 b	39.91 a	31.13	334.9 b	648.2 a	491.53
LSD	Y: ns SR: ns YxSR:ns			$Y_{(5\%)}$: 4.21 SR: ns YxSR:ns			$Y_{(1\%)}$: 82.7 $SR_{(1\%)}$: 101.3 YxSR: ns		

Fruit yield

Significant differences were observed between seeding rates and year for fruit yield, whereas their interactions were insignificant (Table 4). It was seen in the table; values ranged between 263.5 and 397.4 kg ha^{-1} in the first year and between 557.3 and 799.6 kg ha^{-1} in the second year. The average of fruit yields was examined for seeding rates; the highest fruit yield was obtained from 15 kg seeding rate with 598.5 kg per hectare was found significantly different than the other applications. Arabaci and Bayram (2005) revealed that 15 kg seeding rate was provided the highest fruit yield with 206.8 kg ha^{-1} for fennel. The average of fruit yields were examined for years, the highest yield was determined in the second year with 648.2 kg ha^{-1} and it was found significantly different from the first year values. As it can be seen from Table 4, the second year values were found two times higher than the first year. This was an expected situation for fruit yield because number of fruits per umbel was lower in the first vegetation year as well. This difference can be explained due to the rainfall in July may have negative effects on pollination and consequently fruit set.

In previous studies, different results were determined for fennel with different seeding density applications. In this study, the fruit yield values were found parallel with Avci and Amir Nia (2007), Tunçturk (2008) and Nakhaei et al. (2012), lower than Kizil et al. (2001), Arabaci and Bayram (2005) and Ozyilmaz (2007), however higher than Ahmad et al. (2004).

Biological yield

Significant differences were observed between seeding rates and year for biological yield, whereas their interactions were insignificant (Table 5). The biological yields were varied between 901.6 and 1322.2 kg ha^{-1} for the first year and between 1340.5 and 2271.6 kg ha^{-1} for the second year. The average of biological yield was examined for different seeding rate; the highest yield was obtained from application of 15 kg per hectare with 1796.9 kg. The average of biological yield was investigated for years; the highest value was determined as 1719.4 kg ha^{-1} for second year.

In previous studies, different results were determined for fennel with different seeding rate and results of this study were found lower than others (Avci and Amir Nia, 2007; Ozyilmaz, 2007). It was may be due to the studies were conducted under different ecological conditions, agronomic practices and different origins of seed materials.

Thousand fruit weight

The different seeding rates and year x seeding rate interaction were insignificant effect on thousand fruit weight, while year was statistically significant (Table 5). Thousand fruit weights ranged between 6.27 and 6.57 g in the first year of the experiment and second year values varied between 7.87 and 8.72 g. The average of thousand fruit weight was obtained as 6.47 g for the first year and 8.10 g for the second year. These differences between the years may be due to the excessive July rainfall in the first year have negative effect on pollination and fruits may have not grown enough thus fruits may have been smaller than the second year. The thousand fruit yield values were found similar with Marotti et al. (1993), Ceylan (1997), Kizil et al. (2001), Arabaci and Bayram (2005) and Tunçturk (2008).

Table 5. The mean values of biological yield, thousand fruit weight and essential oil content for fennel in different seeding rate

Seeding Rate (kg ha^{-1})	Biological yield (kg ha^{-1})			Thousand fruit weight (g)			Essential oil content (%)		
Years	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
10	1205.1	1340.5	1273.5 b	6.57	8.57	7.57	1.72	2.46	2.09
15	1322.2	2271.6	1796.9 a	6.27	7.87	7.07	1.62	2.09	1.86
20	901.6	1544.6	1223.1 b	6.54	7.87	7.21	1.60	2.04	1.82
Mean	1143 b	1719.4 a	1431. 2	6.47 b	8.10 a	7.28	1.65 b	2.20 a	1.92
LSD	$Y_{(1\%)}$: 299.1 $SR_{(5\%)}$: 366.3 YxSR:ns			$Y_{(5\%)}$: 0.39 SR: ns YxSR:ns			$Y_{(1\%)}$: 0.36 SR: ns YxSR:ns		

Essential oil content

Different seeding rates and year x seeding rate interaction were not made significant effect on essential oil content, while year was effective (Table 5). Arabaci and Bayram (2005) also revealed that seeding rates were not made significant effect on essential oil content of fennel. Ozyilmaz (2007) stated that row spacing, sowing rates and their interactions were affected on essential oil content and emphasized that the highest content was obtained from 30 cm row spacing and 250 seeds/m^2. In this study, essential oil contents ranged between 1.60 and 1.72% in the first year and between 2.04 and 2.46% in the second year. The average of the essential oil contents was examined for vegetation periods; the first year content was found as 1.65% and the second was 2.20%. Essential oil of fennel fruits is related to fruit length (Ceylan, 1997) and essential oil is excreted from exudate canals present between costa (Zeybek, 1985). The difference between the years may be due to the fruit lengths. In the second year, fruit lengths may be taller and therefore thinner than the first year, because of the number of umbels and umbellets per plant and the number of fruits per umbel were higher.

The essential oil contents of the present study were lower than the other researchers values were found by Cosge et al. (2008), Arabaci and Bayram (2005) and Telci et al. (2009) but similar with Kizil et al. (2001), Ozyilmaz and Yilmaz (2009), Avci (2010), Tunçturk et al. (2011). The differences between the results of other researchers may be due to the seed materials of different origins, different ecological conditions under which the plants are cultivated, different sowing times, fertilizer applications, harvesting at different maturity stages and difference of agronomic practices conducted at growing stage.

Essential oil constituents

In the first year five constituents and in the second year nine constituents were identified in fennel essential oil (Table 6). The replications of essential oil were combined for determination of percentage of constituents, thus no statistical evaluation was made to determine the effects of different seeding rates and year on essential oil constituents. It was seen in Table 6; the main constituent of the fennel essential oil was *trans*-anethole and the average of the first year content (96.38%) was determined higher than the second year (86.44%). In the first year, the subsequent constituent was p-allyl anisole (2.46%) and it was limonene (6.35%) in the second year. α-pinene, sabinene, β-myrcene and β-cis-ocimene were not exist between the constituents of the first year while they were in the second year.

In previous *trans*-anethole was identified as the main constituent of the essential oil of fennel by the researchers (Avci, 2010; Telci et al., 2009; Cosge et al.,2008; Avci and Amir Nia, 2007; Kapoor et al., 2004; Kan, 2006; Anwar et. al, 2009). When *trans*-anethole values of previous studies were compared with present study Avci (2010) and Avci and Amir Nia (2007) were found similar values, but Telci et al. (2009), Cosge et al. (2008), Kapoor et al. (2004), Kan (2006), Anwar et. al (2009) were determined lower values. These differences between the results may be due to the seed materials of different origins, different ecological conditions, different sowing times, fertilizer applications, harvesting at different maturity stages and agronomic practices.

Table 6. Chemical composition of fennel essential oil in different seeding rates (%)

Constituents	**Rt**	**2010**				**2011**			
		Seeding Rate ($kg\ ha^{-1}$)				**Seeding Rate ($kg\ ha^{-1}$)**			
		10	15	20	Mean	10	15	20	Mean
α-Pinene	6.3	-	-	-	-	0.39	0.29	0.21	0.30
Sabinene	9.4	-	-	-	-	0.15	0.11	-	0.13
β-Myrcene	11.0	-	-	-	-	0.15	0.13	-	0.14
Limonene	13.0	0.31	0.10	0.11	0.17	7.49	6.45	5.11	6.35
β-cis-Ocimene	14.3	-	-	-	-	0.73	0.68	0.5	0.64
Fenchone	24.2	0.59	0.59	0.69	0.62	1.30	1.60	1.36	1.42
p-Allyl anisole	40.8	2.86	1.50	3.01	2.46	5.10	5.39	3.27	4.59
trans-Anethole	50.5	95.50	97.79	95.85	96.38	84.48	85.31	89.53	86.44
p-Anisaldehyde	62.7	0.71	-	0.31	0.51	-	-	-	-

CONCLUSION

Fennel is one of the important medicinal and aromatic plants because it is used in drug production and as herbal tea. Therefore, cultivation of this plant without using any chemical fertilizers and pesticides is very essential. Otherwise, active ingredients and compositions may change and some chemical residues may occur. For this reason, this study was intended to determine the appropriate seeding rate for fennel cultivation without using any chemicals. In present study, the fruited branch, umbel, umbellet and fruit numbers per plant, thousand fruit weight and essential oil content values were not adversely affected on seeding rates; whereas plant height, fruit yield and biological yields were influenced. In conclusion, the highest fruit yield was obtained on 15 kg ha^{-1} seeding rate and organic fertilizers could be recommended for increasing of fruit yield.

ACKNOWLEDGEMENT

The author would like to thank Ebru FITIL KAVUT and Onder OZAL for seeding and soil analyses.

LITERATURE CITED

Ahmad, M., S.A. Hussain, M. Zubair and A. Rab, 2004. Effect of different sowing seasons and row spacing on seed production of fennel (Foeniculum vulgare). Pakistan Journal of Biological Sciences. 7(7): 1144-1147.

Akgul, A., 1993. Spice Science and Technology. Association of Food Technology Publ. 15, Ankara.

Arabaci, O. and E. Bayram, 2005. The effect of different sowing date and seeding rate on yield and some important characteristics of fennel (Foeniculum vulgare Mill.). 6th Turkish Field Crops Congress. 5-9 September 2005, Antalya, 529-534.

Anwar, F., M. Ali, A.I. Hussain and M. Shahid, 2009. Antioxidant and antimicrobial activities of essential oil and extracts of fennel (Foeniculum vulgare Mill.) seeds from Pakistan. Flavour Fragr. J. 24: 170-176.

Avci, A.B. and R. Amir Nia, 2007. The effect of different line interval and seeding rate on some yield and quality characteristics of fennel (Foeniculum vulgare mill.). 7th Turkish Field Crops Congress, 25-27 June 2007, Erzurum, 793-797.

Avci, A.B., 2010. Organic farming opportunities of anise, coriander and fennel in Burdur region. Book of Proceedings, International Conference on Organic Agriculture in Scope of Environmental Problems. 03-07 February 2010, Famagusta, Cyprus Island, 290-291.

Ayub, M., M.A. Nadeem, A. Tanveer, M. Tahir, M.T.Y. Saqib and R. Nawaz, 2008. Effect of different sowing methods and times on the growth and yield of fennel (Foeniculum vulgare Mill.). Pak. J. Bot., 40(1): 259-264.

Basgel, S. and S.B. Erdemoglu, 2006. Determination of mineral and trace elements in some medicinal herbs and their infusions consumed in Turkey. Science of The Total Environment, 359: 82– 89.

Baydar, H., 2009. Medicinal and Aromatic Plants Science and Technology. 3. ed. Suleyman Demirel University Publ. 51, Isparta.

Baytop, T., 1999. Phytotherapy in Turkey. From past to present. 2. ed. Nobel Medical Publ İstanbul.

Bayram, E., S. Kirici, S. Tansi, G. Yilmaz, O. Arabaci, S. Kizil and I. Telci, 2010. Enhancement possibilities of production of medicinal and aromatic plants. 5th Turkish Technical Congress of Agricultural Engineering, 11-15 January 2010, Ankara.

Carson, P.L., 1980. Recommended potassium test. in: Recommended chemical soil test procedures for the North Central Region. Rev.ed. North Central Regional Publication 221. North Dakota Agric. Exp. Stn.North Dakota State University, Fargo. USA.

Ceylan, A., 1997. Medicinal Plants-II (Essential Oil Plants). Agriculture Faculty of Ege University Pub 481. İzmir.

Cosge, B., B. Gurbuz, H. Kendir and A. Ipek, 2008. Composition of essential oil in sweet fennel (Foeniculum vulgare mill. var. dulce) lines originated from Turkey. Asian J. Chem. 20 (2): 1137-1142.

Davis, P.H., 1978. Flora of Turkey and The East Aegean Islands, vol.4. Edinburgh University Press, Edinburgh, pp 352-377.

Day, P.R., 1956. Report of the Committee on Physical Analysis, 1954-1955. Soil Science Society of America. Soil Sci. Soc. Am. Proc. 20: 167-169.

Falzari, L.M., R.C. Menary and V.A. Dragar, 2005. Reducing fennel stand density increases pollen production, improving potential for pollination and subsequent oil yield. HortScience. 40 (3): 629-634.

FAO., 1990. Micronutrient, assessment at the country level: an international study. FAO Soils Bulletin 63. Rome.

Garg, C., S.A. Khan, S.H. Ansari and M. Garg, 2010. Efficacy and safety studies of Foeniculum vulgare through evaluation of toxicological and stadardisation parameters. Int J Pharm Pharm Sci. 2 (2): 43-45.

Gunes, A., M. Aktas, A. Inal and M. Alpaslan, 1996. Physical and chemical characteristics of Konya Closed Basin territories. Agriculture Faculty of Ankara University Pub 1453. Ankara.

Kandil, M.A.M.H, 2002. The effect of fertilizers for conventional and organic farming on yield and oil quality of fennel (Foeniculum vulgare Mill.) in Egypt. Braunschweig: FAL, 94 p, Landbauforsch Volkenrode SH 237.

Kan, Y., M. Kartal, S. Aslan and N. Yildirim, 2006. Composition of essential oil of fennel fruits cultivated at different conditions. J. Fac. Pharm, Ankara, 35 (2): 95–101.

Kapoor, R., B. Giri and G. Mukerji, K. 2004. Improved growth and essential oil yield and quality in Foeniculum vulgare mill on mycorrhizal inoculation supplemented with P-fertilizer. Bioresource Technology, 93: 307–311.

Karaca A. and K. Kevseroglu, 2001. The research of some important phenology and morphology characters of coriander (Coriandrum sativum L.) and fennel (Foeniculum vulgare Mill.). 4th Turkish Field Crops Congress, 17-21 September 2001. Tekirdag, 243-248.

Kizil, S., N. Arslan and A. Ipek, 2001. The effect of different sowing dates on yield and yield components of fennel (Foeniculum vulgare Mill. var. Dulce). 4th Turkish Field Crops Congress, 17-21 Eylul 2001, Tekirdag, 331-334.

Kjeldahl, J. 1883. Neue Methode zur Bestimmung des Stickstoffs in organischen Korpem. Z. Anal. Chem. 22: 366-382.

Lindsay, W.L. and W.A. Norwell., 1969. Development of a DTPA micronutrient Soil Test. Soil Sci. Am. Proc. 35: 600-602.

Marotti, M., V. Dellacecca, R. Piccaglia and E. Giovanelli, 1993. Agronomic and chemical evaluation of three “Varieties” of Foeniculum vulgare Mill.. ISHS Acta Horticulturae 331, pp. 63-69.

Nakhaei, A., S. G., Moosavi, R., Baradaran and A.A., Nasrabad, 2012. Effect of nitrogen and plant density levels on yield and yield components of fennel (Foeniculum vulgare L.). IJACS. 4 (12), 803-810.

Olsen, S.R, C.V. Cole, F.S. Watanabe and L.A. Dean, 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. US.Dept. of Agric.Cric. 939 p.

Ozyilmaz, B., 2007. Effect of different row spacing and seeding rate on yield, yield component and some quality properties of fennel (Foeniculum vulgare Mill. var. dulce). Gaziosmanpasa University, Graduate School of Natural and Applied Sciences Master Thesis, 84 p.

Ozyilmaz, B. and G. Yilmaz, 2009. The effects of row spacing and seeding rate on yield, yield component and some quality properties of fennel (Foeniculum vulgare Mill. var. dulce). 8th Turkish Field Crops Congress, 19-22 October 2009, Hatay, 69-72.

Peech, M., L.T. Alexander, L.A. Dean and J.F. Reed, 1947. Methods of soil analysis for soil fertility investigations. U.S. Dept. Agr. Circ. 757 p.

Tanker, N., M. Koyuncu and M. Coskun, 2007. Pharmaceutical Botany. 3rd Ed. Pharmacy Faculty of Ankara University Pub 93, Ankara.

Telci, I., E. Bayram and B. Avci, 2006. Changes in yields, essential oil and linalool contents of Coriandrum sativum varieties (var. vulgare Alef. and var. microcarpum DC.) harvested at different development stages. Europ. J. Hort. Sci. 71(6): 267–271.

Telci, I., I. Demirtas and A. Sahin, 2009. Variation in plant properties and essential oil composition of sweet fennel (Foeniculum vulgare Mill.) fruits during stages of maturity. Industrial Crops and Products. 30: 126–130.

Tovep., 1991. Productivity Inventory of Turkey Soils. T.C. The Ministry of Agriculture and Rural Affairs.

Tuncturk, M., 2008. Effects of different nitrogen doses on the agricultural and chemical properties of fennel (Foeniculum vulgare Mill.). Asian J. Chem. 20 (4): 3209-3217.

Tuncturk, R., M. Tunçturk and D. Turkozu, 2011. The effects of different phosphorus and nitrogen doses on the yield and quality of fennel (Foeniculum vulgare Mill.) in Van ecological conditions. YYU J Agr Sci. 21(1):19-27.

Wichtl, M., 1971. Die Pharmakognostisch-Chemische Analyse Akad. Verlagsgesellschaft, Frankfurt, 479 p.

Zeybek, N., 1985. Pharmaceutical Botany, Seeds Indoor Plants (Angiospermae) Systematics and Important Substance. Pharmacy Faculty of Ege University 1. Izmir.