ABANT İZZET BAYSAL ÜNİVERSİTESİ

ZİRAAT VE DOĞA BİLİMLERİ FAKÜLTESİ

ABANT IZZET BAYSAL UNIVERSITY

FACULTY OF AGRICULTURE AND NATURAL SCIENCES

ULUSLARARASI TARIM VE YABAN HAYATI BİLİMLERİ DERGİSİ

INTERNATIONAL JOURNAL OF AGRICULTURAL AND WILDLIFE SCIENCES

Cilt Volume	**2**	Sayı Number	**1**	**2016**

Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi	International Journal of Agricultural and Wildlife Sciences
Dergi web sayfası: http://dergipark.ulakbim.gov.tr/ijaws	Journal homepage: http://dergipark.ulakbim.gov.tr/ijaws

Ürün Bilgisi (Product Information)

Yayıncı Publisher	Abant İzzet Baysal Üniversitesi Abant Izzet Baysal University
Sahibi (AİBÜZDF Adına) Owner (On Behalf of AIBUZDF)	Prof. Dr. Vahdettin ÇİFTÇİ, Dekan (Dean)
Sorumlu Yazı İşleri Müdürü Editor-in-Chief	Yrd. Doç. Dr. Hakan KİBAR
Dergi Yönetimi Journal Administrator	Yrd. Doç. Dr. Faheem Shahzad BALOCH Yrd. Doç. Dr. Bahtiyar Buhara YÜCESAN Araş. Gör. Mehmet Zahit YEKEN
Yayın Dili Language	Türkçe, İngilizce Turkish, English
Yayın Aralığı Frequency	Yılda iki kez yayınlanır Published two times a year
Yayın Türü Type of Publication	Hakemli yaygın süreli yayın Double-blind peer-reviewed
Dergi e-ISSN Journal e-ISSN	2149-8245

Dergi Yönetim Adresi
Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi
Abant İzzet Baysal Üniversitesi
Ziraat ve Doğa Bilimleri Fakültesi
14280, Bolu-TÜRKİYE

Telefon: +90 0374 2534345
Faks: +90 0374 2534346
E-posta: ijawseditor@ibu.edu.tr

Journal Management Address
International Journal of Agricultural and Wildlife Sciences
Abant Izzet Baysal University
Faculty of Agriculture and Natural Sciences
14280, Bolu-TURKEY

Telephone: +90 0374 2534345
Fax: +90 0374 2534346
E-mail: ijawseditor@ibu.edu.tr

Tarandığı İndeksler

Indexed

Google-Scholar CiteFactor Cosmos DRJI ResearchBib

İÇİNDEKİLER-CONTENTS

Hakemler/Reviewers

Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi (UTYHBD), 2016, 2(1): 33 - 42
International Journal of Agriculture and Wildlife Science (IJAWS)

Research article

Determination of The Effect of Plant Density on Yield and Yield Components for Two Different Coriander Cultivars (*Coriandrum sativum* L.)

Duran Katar[1*] Nimet Katar[2]

[1]University of Eskişehir Osmangazi, Faculty Agriculture, Department of Field Crops, Eskişehir
[2]University of Eskişehir Osmangazi, Institute of Science, Eskişehir

Received: 25.03.2016 Accepted: 20.05.2016

Key words:

Coriander, cultivar, fruit yield, plant density

***Corresponding author**
e-mail: durankatar@gmail.com

Abstract. To study the effect of cultivars and plant density on yield, yield components and the essential oil yield of coriander (*Coriandrum sativum* L.), experiments were conducted as factorial experiments in the base of a randomized complete blocks design with eight treatments and three replications at an experimental field site of the University of Eskişehir Osmangazi, Faculty of Agriculture, Department of Field Crops in 2012 and 2013. The factors were cultivars (Arslan and Gürbüz) and plant density in four levels (20, 30, 40 and 50 plants m^{-2}). The results showed that higher plant height, essential oil rate and essential oil yield were obtained by using Gürbüz cv. rather than Arslan cv. Plant density also showed significant effects on all studied traits. The maximum plant height, essential oil rate and essential oil yield were obtained with 50 plants m^{-2}, and the highest umbel number per plant, weight of 1000 fruits and fruit yield were obtained with 20, 30 and 40 plants m^{-2}, respectively.

Bitki Sıklığının İki Farklı Kişniş (*Coriandrum sativum* L.) Çeşidinde Verim ve Verim Unsurları Üzerine Etkisinin Belirlenmesi

Anahtar Kelimeler:

Kişniş, çeşit, tohum verimi, bitki sıklığı

***Sorumlu yazar**
e-mail: durankatar@gmail.com

Özet. Çalışma; çeşitlerin ve bitki sıklığının kişniş (*Coriandrum sativum* L.) bitkisinin verim, verim unsurları ve uçucu yağ verimi üzerine etkisini belirlemek amacıyla; 2012 ve 2013 yıllarında Eskişehir Osmangazi Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü deneme tarlasında, Tesadüf Bloklarında Faktöriyel Deneme Desenine göre 8 uygulama ve 3 tekerrürlü olarak yürütülmüştür. Faktörler; çeşitler (Arslan ve Gürbüz) ve 4 farklı bitki sıklığı (20, 30, 40 ve 50 bitki m^{-2})'dır. Çalışma sonuçları; Arslan çeşidine kıyasla Gürbüz çeşidinden daha yüksek bitki boyu, uçucu yağ oranı ve uçucu yağ verimi elde edildiğini göstermiştir. Ayrıca bitki sıklığı değerlendirmeye alınan özelliklerin tümü üzerinde önemli etkiler göstermiştir. Maksimum bitki boyu, uçucu yağ oranı ve uçucu yağ verimi 50 bitki m^{-2}; en yüksek bitki başına şemsiye sayısı, 1000 tohum ağırlığı ve tohum verimi sırasıyla 20, 30 ve 40 bitki m^{-2} bitki sıklıklarından elde edilmiştir.

1. INTRODUCTION

Coriander (*Coriandrum sativum* L.) is one of the most important of all of the vegetable, spice and medicinal plants (Telci and Hisil 2008 and Akhani *et al*., 2012). Additionally, the crop, an annual herbaceous plant belonging to the Apiaceae (Umbelliferae) family, is an important seed used as a spice throughout the globe to add taste, flavor and pungency to various food items (Telci *et al*., 2006a; Sharangi and Roychowdhury 2014 and Yaldız and Kulak 2014). Coriander has been used in folk medicines for thousands of years, and various parts of this plant such as its' leaves, flowers, seeds, and fruits, possess diuretic, sedative, anti-diabetic, anti-mutagenic, antioxidant, anti-microbial and anthelmintic abilities (Nadeem *et al*., 2013).

The plant is a well-known spice plant is known as "aşotu" and "kişniş" in Turkish. It is grown in the Göller Region, Ankara, Eskişehir, Erzurum, Gaziantep and Konya in Turkey (Telci *et al*., 2006b and Duman *et al*., 2010). Maturated fruits and leaves (fresh and dried) are used as spices, and essential oil distillated from maturated fruit is used mainly as a flavoring agent in pharmaceutical preparations. Additionally, fruits are used as aromatics and carminatives and in laxative preparations to prevent griping (Inan *et al*., 2014; Yaldız and Kulak 2014).

Coriander fruits have essential oils that act as an active substance that is used in the pharmaceutical industry (Akhani *et al*., 2012). The fruits of the plant have an aromatic odor and taste that is due to an essential oil that is made up of hydrocarbons and oxygenated compounds (Abdelmajeed *et al*., 2013; Yaldız and Kulak 2014). The essential oil content of the dried fruits varies from very low (0.03%) to a maximum concentration of 2.7%. The predominant constituent of the essential oil of coriander is linalool, which comprises approximately two-thirds of the total essential oil (Shahwar *et al*., 2012, Inan *et al*., 2014). Additionally, the fruit contains 16.1% fatty oil, 14.1% protein, 21.6% carbohydrate, 32.6% fiber, 11.2% moisture and 4.4% mineral matters, and coriander leaves are very rich in vitamin A (Abdelmajeed *et al*., 2013).

Coriander yields can be affected by genetic traits of the cultivars, weather conditions and agronomic factors. Thus, coriander fruit yields reported from different experiments have been unstable and highly varied, from very high (over 3 t ha^{-1}) to very low (less than 0.5 t ha^{-1}) (Nowak and Szemplinski 2014). Proper agronomic management including the use of a suitable plant density, has a huge influence on the growth, yield and yield components of coriander. Previous studies in coriander in the countries of the world have reported that optimum plant density can increase the growth, yield components and the yield of individual plants. Ghobadi and Ghobadi (2010) reported that the highest fruit yield in coriander was produced at plant density of 50 plants m^{-2}. In the study conducted out on plant density of coriander in Iran, Mooosavi *et al*. (2012) indicated that the highest fruit ant essential yield was obtained at plant density of 60 plants m^{-2}. Also, the study of Mooosavi *et al*. (2013) recommended the plant density of 50 plants m^{-2} for production of coriander. The findings of the experiments performed on coriander in Turkey by Karadoğan and Oral (1994), Tuçtürk (2011) and Okut and Yıldırım (2005) showed that the most suitable row spacings were 30, 20 and 10 cm, respectively. However, there are no published research findings on the plant density of coriander in Eskişehir condition, Turkey.

The purpose of this study was to determine the effect of years, coriander cultivars and plant density as well as their interaction on coriander yield, yield components and the content of essential oil in coriander fruits.

2. MATERIAL AND METHODS

2.1. Plant Materials

Two coriander cultivars (Arslan cultivar improved from *Coriandrum sativum* var. *vulgare* and Gürbüz cultivar improved from *Coriandrum sativum* var. *microcarpum*), registered by the University of Ankara, Faculty of Agriculture, Department of Field Crops on 07 April 2005, were used as plant materials in this study.

2.2. Site Information

The experiments were carried out at the experimental field of the University of Eskişehir Osmangazi, Faculty of Agriculture, Department of Field Crops (39° 46´ N, 30° 32´ E, 732 m above sea level) during the crop growing period of 2012 and 2013. Meteorological data for the growing seasons is shown in Table 2. The total precipitation of the

2013. Meteorological data for the growing seasons is shown in Table 2. The total precipitation of the growing seasons (from April to July) were 171.0, 99.2 and 82.8 mm. Soil samples from a depth of 40 cm were taken before starting the experiment, and were subjected to a physicochemical analysis.

Soils from the 2012 and 2013 growing periods had organic matter concentrations of 1.55% and 1.53%, medium P_2O_5 (6.91 and 5.71 kg da^{-1}), medium K_2O (81.13 and 78.41 kg da^{-1}), an alkaline pH (7.3 and 7.1), a salt content of 0.048 and 0.063% and a $CaCO_3$ content 26.3 and 27.1%, respectively (Table 1).

Table 1. Some physical and chemical properties of analyzed soil in the experiment fields.
Çizelge 1. Deneme tarlası toprağının bazı fiziksel ve kimyasal özellikleri.

Structure	Lime (%)	Salt (%)	Plant-available phosporus (P_2O_5) (kg da^{-1})	Plant-available potassium (K_2O) (kg da^{-1})	pH	Organic Matter (%)
Clay-Loamy 2012	26.3	0.048	6.91	81.13	7.3	1.55
Clay-Loamy 2013	27.1	0.063	5.71	78.41	7.1	1.53

Source: Soil Fertilizer and Water Resources Research Institute.

Table 2. Some of the climatic data of the Eskişehir province for 2012 and 2013.
Çizelge 2. 2012 ve 2013 yıllarında Eskişehir ilinin bazı iklim verileri.

Years	January	February	March	April	May	June	July
			Total rainfall (mm)				
2012	52.4	46	50.4	23.7	50.6	12.6	12.3
2013	17.6	36.2	40.1	30.9	18.5	31.3	2.1
			Mean temperature (°C)				
2012	-2.5	-4.3	-2.6	12.8	15.5	21.7	24.0
2013	2.3	5.0	7.1	10.8	18.2	20.0	21.6
			Mean Humidity (%)				
2012	76.6	76.9	66.2	53.2	62.6	48.9	49.4
2013	67.7	88.0	59.8	63.2	51.5	53.9	51.9
	August	**September**	**October**	**November**	**December**	**Total/Mean**	
			Total rainfall (mm)				
2012	-	0.3	72.2	19.0	70.3	409.3	
2013	0	5.0	73.2	21.6	6.6	281.0	
			Mean temperature (°C)				
2012	21.7	19.1	14.5	7.8	3		
2013	22.4	16.7	9.8	6.7	-1.7		
			Mean Humidity (%)				
2012	48.4	51.1	62.3	74.1	81.0		
2013	53.1	55.1	64.8	74.1	77.6		

Data were taken from the Eskişehir Regional Meteorological Service.

2.3. Methods

The experiment was factorial, with two factors arranged in a randomized complete block design with three replications. Each block was divided into two whole plots, and two cultivars (Arslan cv. and Gürbüz cv.) were randomly assigned to the whole plots within each block. Each whole plot was divided into four split-plots, and four plant densities (20, 30, 40 and 50 plants m^{-2}) were randomly assigned to the split-plots within each whole plot (Ghobadi and Ghobadi 2010).

Each experimental sub-plot was 5 m long and consisted of 6 rows, 25 cm apart. Each sub-plot was 5 × 1.5 meters. There was a space of 2 meters between replications. Sowing was performed by hand, at a 25 cm row distance and 2-3 cm sowing depths, with a seed amount tuned to higher 20% than those of target densities on 01 April 2012 and 05 April 2013. Then, in bolting stages plants were thinned by hand for target plant densities. There was no incidence of pests or disease found on the coriander during the experiments. No fertilization, irrigation or chemicals were applied. Weeds were controlled effectively by hand, when needed.

When the fruits had ripened, the process of harvesting started. Harvesting was performed manually by pulling the dry plant out of the soil and removing the roots. The fruits were separated from the straw by means of a thresher on 25 July 2012 and 22 July 2013. At harvest, plant height (cm) and number the of umbel per plant were recorded on ten plants randomly chosen in each sub-plot, and thousand fruit weight (g) and fruit yield (kg ha^{-1}) were obtained from the whole sub-plot after the separated side rows.

2.4. Essential Oil Distillation

The fruits (50 g) of coriander ground in a blender separately were subjected to water-distillation using a Clevenger-type glass apparatus for 3 hours for the isolation of the essential oils in each sub-plot (Inan *et al.*, 2014). The results are presented in ml 100 g^{-1}.

2.5. Statistical Analysis

All analyses were performed with the MSTAT-C package program. The results of the experiments were also analyzed according to the factorial with two factors arranged in a randomized complete block design. Three years were analyzed using the split-split-plot design: the whole plot was the year, the split-plot was the cultivar, and the split-split plot was the sowing densities. The Fisher's least significant difference (LSD) test at a 5% level of probability was used to test for significant effects (Düzgüneş *et al.*, 1987).

3. RESULTS AND DISCUSSION

In this section, the parameters that were found to be significant are discussed. The non-significant parameters are not discussed, although these data were incorporated into the tables**.**

3.1. Plant Height (cm)

Plant height is mainly controlled by genetics; it can also be affected by environmental factors (Shahzad *et al.*, 2007, Balock *et al.*, 2010). Plant height varies according to the growing region's ecology and plant genotypes (Inan *et al.*, 2014). The data indicated that plant density, cultivar and their interaction significantly influenced plant height (Table 3). According to the mean of years, higher plant height (48.4 cm) was obtained in the Gürbüz cv. (Table 4). In the case of plant density, the maximum plant height (50.7 cm) was recorded in 50 plants m^{-2}, and the lowest plant height was recorded in 20 plants m^{-2} (Table 4). The high plant density resulted in greater plant height, which is in accordance with the observations of Akhani *et al.* (2012). In their interaction, the highest plant height (51.2 cm) was observed with Gürbüz × 50 plants m^{-2}. The plant height results are in close conformity with the results of Sharangi *et al.* (2014). These values, however, did not coincide with Mert and Kirici 1998; Kaya *et al.*, 2000; Inan *et al.* (2014) and Akhani *et al.* (2012) who reported higher plant height values. However, plant height values were not similar to the findings of Moniruzzaman *et al.* (2014) and Yousuf *et al.* (2014), who reported lower plant heights. This result could have occurred because of variable environmental conditions and the genotypes of the plant materials used in these studies.

3.2. Number of Umbels Per Plant

The results presented in Table 3 demonstrate that the umbel number per plant was influenced by the plant density and by the interaction effect between cultivar and plant density. An increase in plant density from 20 plants m^{-2} to 50 plants m^{-2} caused a 12.9, 24.5 and 35.5% reduction in the umbel number per plant (Table 4). The plant density significantly increased the umbels per plant, as was observed with an increase in plant density and competition, which decreased the umbel number per plant. This result is in agreement with the findings of Akhani *et al.* (2012) on coriander. In interaction effects between cultivars and plant density, as the highest number of umbels per plant (12.1) was observed with Gürbüz × 20 plants m^{-2}, the lowest number of umbels per plant (6.6) was observed with Gürbüz × 50 plants m^{-2}. It is obvious that increasing plant density significantly reduced the number of umbels per plant.

The number of umbels per plant was an important characteristic for fruit and essential oil yield (Inan *et al.*, 2014). The results presented in Table 4 are similar to the findings of some researchers (Inan *et al.*, 2014; Mert and Kirici 1998) that indicate that the number of umbels per plant varies between 7.9 - 23.5. Our values, however, did not coincide with Yousuf *et al.*, 2014 who reported higher values with regards to umbel numbers per plant.

3.3. Weight of 1000 Fruits (g)

The results demonstrated that the weight of 1000 fruits was significantly affected by the plant density, cultivar and their interactions (Table 3). The comparison of plant density indicated that the highest weight of 1000 fruits (10.5 g) was obtained in 30 plants m^{-2}. According to the mean of years, a higher weight of 1000 fruits (11.8 g) for cultivars was obtained in Arslan cv. (Table 4). This result could have occurred because of the variable genotypes of the cultivars used in this study (Abdelmajeed *et al.*, 2013).

In the interaction effect between cultivars and plant density, as the maximum weight of 1000 fruits (12.7 g) was recorded in Arslan × 30 plants m^{-2}, the minimum weight of 1000 fruits (8.0 g) was observed with Gürbüz × 20 plants m^{-2} (Table 4).

The results with regard to the weight of 1000 fruits were similar to the findings of Inan *et al.* (2014), Moosavi *et al.* (2012); Mert and Kirici (1998) and Kızıl (2002). These values, however, did not coincide with Inan *et al.* (2014) and Akhani *et al.* (2012) who reported higher plant height values. However, values of the weight of 1000 fruits did not agree with the results of Akhani *et al.* (2012) and Yousuf *et al.* (2014) who reported a lower weight of 1000 fruits. This discrepancy could be due to variable environmental conditions, fruit size and genotypes of the varieties used in these studies.

Table 3. Results of analyses of variance for the traits measured in the study.
Çizelge 3. Çalışmada değerlendirilmiş özelliklere ait varyans analiz sonuçları.

Source of variation	D.F	Plant height (cm)	Number of umbrella per plant	1000 fruit weight (g)
		Sum of means	Sum of means	Sum of means
Replication	2	10.049	0.715	1.601*
Years	1	16.055	0.653	0.207
Error$_1$	2	7.408	0.095	0.036
Cultivars	1	120.904*	3.413	160.345**
Year × Cultivar	1	44.545	0.003	1.095
Error$_2$	4	6.133	1.458	2.579
Plant Density	3	131.736**	36.769**	1.803**
Year × P.D.	3	9.678	0.345	0.055
Cultivar × P.D.	3	31.252*	4.443**	1.588**
Year × C. × P.D.	3	1.159	0.158	0.079
Error$_3$	24	7.443	0.530	0.259
Mean	47	20.023	3.179	4.086
C.V. (%)		9.555	18.984	20.235
Source of variation	**D.F**	**Essential oil content (%)**	**Fruit yield (kg ha^{-1})**	**Essential oil yield (l ha^{-1})**
		Sum of means	**Sum of means**	**Sum of means**
Replication	2	0.001	9423.970**	0.174
Years	1	0.003*	719957.041**	4.851**
Error$_1$	2	0.000	52.833	0.011
Cultivars	1	0.220**	7173.630	17.073**
Year × Cultivar	1	0.001	46950.030**	0.134
Error$_2$	4	0.000	1164.724	0.048
Plant Density	3	0.002**	96053.539**	1.050**
Year × P.D.	3	0.000	3851.350	0.081
Cultivar × P.D.	3	0.001	2147.923	0.197*
Year × C. × P.D.	3	0.000	1105.746	0.053
Error$_3$	24	0.000	4105.123	0.042
Mean	47	0.005	25653.017	0.591
C.V. (%)		21.926	19.448	28.673

P.D.: Plant Density; C.: Cultivar.

3.4. Essential Oil Content (%)

The results showed that the essential oil content was significantly affected by year, cultivar and plant density (Table 3). With respect to years, the highest essential oil content (0.333%) was obtained in 2013. With respect to cultivars, the highest value (0.393%) was found in Gürbüz cv. The content of the essential oils of coriander fruits from different plant densities varied from 0.317 to 0.342%. The highest essential oil content was obtained at a density of 50 plants m^{-2} while the lowest essential oil content was obtained at a density of 30 plants m^{-2} (Table 5). Some researchers reported that the essential oil content differed between 0.21-1.1% (Mert and Kirici 1998; Inan *et al.*, 2014). The results with regard to essential oil content for these two cultivars were similar to the findings of Inan *et al.* (2014). These values, however, did not agree with the findings of Sriti *et al.* (2009) who reported higher values with regard to the essential oil content.

The variations in essential oil content can be attributed to factors including climatic conditions, varieties used in different studies and growing conditions (Shahwar *et al.*, 2012; Inan *et al.*, 2014).

3.5. Fruit Yield (kg ha^{-1})

Fruit yield is a more important parameter than total biological yield which results from different combinations of many physiological processes based on the environment under which the crop was grown. Fruit yield depends upon the production of photosynthates and their distribution among various plant parts. The synthesis, accumulation, and translocation of photosynthates depends upon an efficient photosynthetic structure as well as sources such as soil, nutrients and water (Yousuf *et al.*, 2014). The physical environment and genetic make-up of the genotypes used in these studies have a profound influence on the growth, biomass partitioning and ultimately the yield of coriander. Temperature, humidity, rainfall and other meteorological factors may individually or collectively limit plant growth and production (Sharangi *et al.*, 2014). Plant density is an important management factor for almost all seed spices including coriander. A change in plant density leads to a significant change in the yield and yield components of coriander (Rassam *et al.*, 2007; Baloch *et al.*, 2010; Ghobadi *et al.*, 2010; Moosavi 2011; Moosavi 2012; Akhani *et al.*, 2012).

In this study, the fruit yield was significantly influenced by the different plant densities (Table 3). The fruit yield showed a linear response with increasing plant density from 20 plants m^{-2} to 40 plants m^{-2} and it then showed a decrease from 40 plants m^{-2} to 50 plants m^{-2}. The highest fruit yield (898.150 kg ha^{-1}) was detected at 40 plants m^{-2} while the lowest value (693.583 kg ha^{-1}) was obtained at a density of 20 plants m^{-2} (Table 5). This decreasing in fruit yield while decreasing density from 50 to 20 plant m^{-2} can be explained; although the fruit yield of a single plant increased in low densities, this increase could not compensate for the lack of plant numbers. In other words, the lowest leaf area index and the delay in the complete establishment of vegetation cover at a low density normally occurs; however, the use of environmental sources, especially radiation, has reduced, and therefore, there is a decrease in the total yield (Moosavi *et al.*, 2012).

The yields of coriander fruits during the experiments varied between 2012 and 2013 (Table 3). Two homogenous groups were distinguished with respect to fruit yield. Yields of both years consisted of two different groups. The higher fruit yields in both experimental years were obtained from the Arslan cv. as 965.025 kg ha^{-1} and 744.583 kg ha^{-1}, respectively. The lower values were detected from the Gürbüz cv. as 926.975 kg ha^{-1} in the first year and 657.583 kg ha^{-1} in the second year (Table 5).

The higher fruit yield values were obtained from the first year in both cultivars. The climatic differences between years could explain the responses of the coriander cultivars that obtained a high fruit yield to the conditions prevailing during the growing season of 2012.

Our results were consistent with the findings of Yousuf *et al.* (2014). These values were lower than the findings of some researchers who reported that the fruit yields varied between 965-2145 kg ha^{-1} (Kirici *et al.*, 1997; Mert and Kirici 1998; Kizil and İpek 2004; Inan *et al.*, 2014).

3.6. Essential Oil Yield (l ha^{-1})

The data indicate that year, cultivar and plant density varied significantly at the 1% level and that the interaction of cultivar and plant density varied significantly at the 5% level which had a significant influence on the essential oil yield (Table 3). Essential oil yield is a function of fruit yield and essential oil content. An increase in these two parameters causes an increase in essential oil yield. The essential oil yield showed a linear response with increasing plant density. The highest essential oil yield (2.936 l ha^{-1})

Table 4. The mean values of plant height, number of umbels per plants, and 1000 fruit weight for coriander in different plant densities, years and cultivars.

Çizelge 4. Kişniş bitkisinin farklı bitki sıklıkları, yıllar ve çeşitler için bitki boyu, bitki başına şemsiye sayısı ve 1000 tohum ağırlığının ortalama değerleri.

Cultivars	Plant Density	Plant Height (cm)			Number of Umbels per Plant			1000 Fruit Weight (g)		
		2012	**2013**	**Mean**	**2012**	**2013**	**Mean**	**2012**	**2013**	**Mean**
Arslan	**P.D. 1**	42.000	43.500	**42.750** b	11.267	10.567	**10.917** A	11.800	12.167	**11.983** AB
	P.D. 2	41.033	45.033	**43.033** b	10.500	9.900	**10.200** AB	12.333	13.033	**12.683** A
	P.D. 3	43.800	45.900	**44.850** b	9.200	9.467	**9.333** BC	11.600	11.800	**11.700** BC
	P.D. 4	47.967	52.700	**50.333** a	8.100	8.267	**8.183** C	10.667	11.133	**10.900** C
Gürbüz	**P.D. 1**	44.177	41.323	**42.750** b	12.367	11.733	**12.050** A	8.010	7.903	**7.957** A
	P.D. 2	50.047	48.773	**49.410** a	9.833	9.767	**9.800** B	8.313	8.240	**8.277** A
	P.D. 3	51.000	49.693	**50.347** a	8.167	7.867	**8.017** C	8.257	8.240	**8.248** A
	P.D. 4	49.980	52.333	**51.157** a	6.633	6.633	**6.633** D	8.407	7.920	**8.163** A
Mean		**46.250**	**47.407**	**46.429**	**9.508**	**9.275**	**9.392**	**9.923**	**10.055**	**9.989**
Arslan		**43.700**	**46.783**	**45.242** b*	**9.767**	**9.550**	**9.658**	**11.600**	**12.033**	**11.817** A
Gürbüz		**48.801**	**48.031**	**48.416** a	**9.250**	**9.000**	**9.125**	**8.247**	**8.076**	**8.161** B
P.D. 1		**43.089**	**42.412**	**42.750** C**	**11.817**	**11.150**	**11.483** A	**9.905**	**10.035**	**9.970** AB
P.D. 2		**45.540**	**46.903**	**46.222** B	**10.167**	**9.834**	**10.000** B	**10.223**	**10.637**	**10.480** A
P.D. 3		**47.400**	**47.797**	**47.598** B	**8.684**	**8.667**	**8.675** C	**9.929**	**10.020**	**9.974** AB
P.D. 4		**48.974**	**52.517**	**50.745** A	**7.367**	**7.450**	**7.408** D	**9.537**	**9.527**	**9.532** B
L.S.D.(%)		**Cultivars:** 1.985			**Plant Density:** 0.832			**Cultivar:** 2.134		
		Plant Density: 3.115			**Cultivar × Plant Density:** 1.176			**Plant Density:** 0.581		
		Cultivar × Plant Density: 3.253						**Cultivar × Plant Density:** 0.822		

* Significant at 5%; ** Significant at 1%.

Table 5. The mean values of essential oil content, fruit yield and essential oil yield for coriander in different plant densities, years and cultivars.
Çizelge 5. Kişniş bitkisinin farklı bitki sıklıkları, yıllar ve çeşitler için uçucu yağ oranı, tohum verimi ve uçucu yağ veriminin ortalama değerleri.

Cultivars	Plant density	Essential oil content (%)			Fruit yield (kg ha^{-1})			Essential oil yield (l ha^{-1})		
		2012	2013	Mean	2012	2013	Mean	2012	2013	Mean
Arslan	P.D. 1	0.263	0.260	**0.262**	803.800	627.000	**683.067**	2.113	1.463	**1.788** b
	P.D. 2	0.243	0.260	**0.252**	1013.100	771.667	**846.717**	2.461	1.770	**2.115** a
	P.D. 3	0.257	0.253	**0.255**	1050.000	807.667	**892.333**	2.697	1.863	**2.280** a
	P.D. 4	0.257	0.270	**0.263**	993.400	772.000	**823.200**	2.552	1.760	**2.156** a
Gürbüz	P.D. 1	0.377	0.407	**0.392**	781.200	562.333	**704.100**	2.944	2.557	**2.751** c
	P.D. 2	0.370	0.393	**0.382**	926.233	680.333	**848.950**	3.424	3.031	**3.228** b
	P.D. 3	0.360	0.400	**0.380**	1000.267	734.667	**903.967**	3.606	3.227	**3.417** b
	P.D. 4	0.420	0.420	**0.420**	1000.200	653.000	**886.100**	4.196	3.236	**3.716** a
Mean		**0.318** b	**0.333** a*	**0.326**	**946.025** A	**701.083** B	**823.554**	**2.999** A	**2.363** B	**2.681**
Arslan		**0.255**	**0.261**	**0.258** B**	**965.075** A	**744.583** A	**854.829**	**2.456**	**1.714**	**2.085** B
Gürbüz		**0.382**	**0.405**	**0.393** A	**926.975** A	**657.583** B	**792.279**	**3.543**	**3.013**	**3.278** A
P.D. 1		**0.320**	**0.334**	**0.327** AB	**792.500**	**594.667**	**693.583** B	**2.529**	**2.010**	**2.269** C
P.D. 2		**0.307**	**0.327**	**0.317** B	**969.667**	**726.000**	**847.833** A	**2.943**	**2.401**	**2.672** B
P.D. 3		**0.309**	**0.327**	**0.318** B	**1025.134**	**771.167**	**898.150** A	**3.152**	**2.545**	**2.848** AB
P.D. 4		**0.339**	**0.345**	**0.342** A	**996.800**	**712.500**	**854.650** A	**3.374**	**2.498**	**2.936** A
L.S.D.(%):		**Years:** 0.009			**Years:** 20.825			**Years:** 0.307		
		Cultivars: 0.017			**Year × Cultivar:** 64.147			**Cultivars:** 0.291		
		Plant Density: 0.017			**Plant Density:** 73.165			**Plant Density:** 0.235		
								Cultivar × Plant Density: 0.245		

* Significant at 5%; ** Significant at 1%.

was detected at a density of 50 plant m^{-2} while the lowest value (2.269 l ha^{-1}) was obtained at a density of 20 plants m^{-2} (Table 5). The yields of essential oil during the experiments varied between 2012 and 2013 (Table 5). The higher essential oil yields in both experimental years were obtained from Gürbüz cv. as 3.543 l ha^{-1} and 3.013 l ha^{-1}, respectively. The lower values were obtained from Arslan cv. as 2.456 l ha^{-1} in the first year and 1.714 l ha^{-1} in the second year (Table 5).

According to the mean of years, the higher essential oil yield (3.278 l ha^{-1}) for cultivars was obtained in Arslan cv., while the lower essential oil yield (2.085 l ha^{-1}) was found in Gürbüz cv. (Table 5). This result could be due to the variable genotype of the cultivars used in this study.

4. CONCLUSION

From this study, we conclude that coriander could be a suitable crop in our dry climatic conditions. The results clearly demonstrate the effectiveness of plant density for two different cultivars. Finally, we recommend a plant density of 40 plants m^{-2} to facilitate the highest fruit yield in both cultivars. Additionally, we suggest that plant densities of 40 and 50 plants m^{-2} be used to obtain the highest essential oil yield in Arslan cv. and Gürbüz cv., respectively.

REFERENCES

Abdelmajeed NA., Danial EN and Ayad HS., 2013. The effect of environmental stress on qualitative and quantitative essential oil of aromatic and medicinal plants. Archives Des Sciences, 66(4): 100-116.

Akhani A., Darzi MT and Hadi MHS., 2012. Effects of biofertilizer and plant density on yield components and seed yield of coriander (*Coriandrum sativum*). International Journal of Agriculture and Crop Sciences, 4(16): 1205-1211.

Baloch MS., Shah ITH., Nadim MA., Khan MI and Khakwani AA., 2010. Effect of seeding density and planting time on growth and yield attributes of wheat. The Journal of Animal and Plant Sciences, 20(4): 239-240.

Duman AD., Telci I., Dayisoylu KS., Digrak M and Demirtas İ., 2010. Evaluation of Bioactivity of Linalool-rich Essential Oils from *Ocimum basilucum* and *Coriandrum sativum* Varieties. Natural Product Communications, 5(6): 969-974.

Düzgüneş O., Kesici T., Kavuncu O ve Gürbüz F., 1987. Araştırma ve deneme metotları (istatistik metotları). Ankara Üniversitesi Ziraat Fakültesi Yayınları, Ankara.

Ghobadi M and Ghobadi M., 2012. Effects of late sowing on quality of coriander (*Coriandrum sativum*). World Academy of Science, Engineering and Technology, 6: 340-348.

Ghobadi ME and Ghobadi M., 2010. The Effects of sowing dates and densities on yield and yield components of coriander (*Coriandrum sativum* L.). World Academy of Science, Engineering and Technology, 70: 81-84.

İnan M., Kirici S., Giray ES., Turk M and Taghikhani H., 2014. Determination of suitable coriander (*Coriandrum sativum* L.) cultivars for eastern mediterranean region. Turkish Journal of Field Crops, 19(1): 1-6.

Karadoğan T and Oral E., 1994. Effect of different row spacings on yield, yield components and quality of coriander varieties. Journal of Atatürk University Agriculture Faculty, 25(3): 311-318.

Kaya N., Yılmaz G ve Telci İ., 2000. Farklı Zamanlarda Ekilen Kişniş (*Coriandrum sativum* L.) Populasyonlarının Agronomik ve Teknolojik Özellikleri. Turkish Journal of Agriculture and Forestry, 24: 355–364.

Kizil S., 2002. The effects of different seed rates of selected coriander (*Coriandrum sativum* L.) lines on yield, yield components and essential oil rate. Turkish Journal of Field Crops, 7(2): 99-105.

Kizil S and Ipek A., 2004. The effects of different row spacing on yield, yield components and essential oil content of some coriander (*Coriandrum sativum* L.) lines. Journal of Agricultural Sciences, 10(3): 237-244.

Mert A and Kirici S., 1998. To determine the yield and yield charecters of coriander (*Coriandrum sativum* L.) populations. In: Proceedings of XIIth International Symposium on Plant Originated Crude Drugs, New Trends and Methods in Natural Products Research. Ankara pp: 112.

Moniruzzaman M., Rahman MM., Hossain MM., Karim AJMS and Khaliq QA., 2014. Response of coriander foliage to different rates and methods of nitrogen application. Bangladesh Journal of Agricultural Research, 39(2): 359-371.

Moosavi SGR., 2011. Effects of different sowing dates and plant densities on yield and agronomic traits of fennel, isabgol and roselle in Birjand, Iran. Final report of research design in Islamic Azad University, Birjand Branch, Birjand, Iran.

Moosavi SGR., 2012. Yield and yield components of *Coriandrum sativum* L. as affected sowing date and plant density. Technical Journal of Engineering and Applied Sciences, 2(4): 88-92.

Moosavi G., Seghatoleslami M., Ebrahimi A., Fazeli M and Jouban Z., 2013. The effect of nitrogen rate and plant density on morphological traits and essential oil yield of coriander. Journal of Ornamental and Horticultural Plants, 3(2): 95–103.

Nadeem M., Anjum FM., Khan MI., Tehseen S., El-Ghorab A and Sultan JI., 2013. Nutritional and medicinal aspects of coriander (*Coriandrum sativum* L.). British Food Journal, 115(5): 743-755.

Nowak J and Szemplinski W., 2014. Influence of Sowing date on yield and fruit quality of coriander (*Coriandrum sativum* L.). ACTA Scientiarum Polonorum Horticulture, 13(2): 83-96.

Okut N and Yıldırım B., 2005. Effects of different row spacing and nitrogen doses on certain agronomic characteristics of coriander (*Coriandrum sativum*). Journal of Biological Sciences, 8(6): 901-904.

Rassam GA., Naddaf M and Sefidkan F., 2007. Effects of sowing date and plant density on seed yield and yield components of *Pimpinella anisum*. Research and Scientific Journal of Iranian Ministry of Agriculture, 20(75): 127-133.

Shahwar MK., El-Ghorab AH., Anjum FM., Butt MS., Hussain S and Nadeem M., 2012. Characterization of coriander (*Coriandrum sativum* L.) seeds and leaves: volatile and non-volatile extracts. International Journal of Food Properties, 15: 736-747.

Shahzad MA., Din WU., Sahi ST., Khan MM., Ehsanullah and Ahmad M., 2007. Effect of sowing dates and seed treatment on grain yield and quality of wheat. Pakistan Journal of Agricultural Sciences, Faisalabad, 44(4): 581-583.

Sharangi AB and Roychowdhury A., 2014. Phenology and yield of coriander (*Coriandrum sativum* L.) at different sowing dates. Journal of Plant Sciences, 9(2): 32-42.

Sriti J., Talou T., Wannes WA., Cerny M and Marzouk B., 2009. Essential oil, fatty acid and sterol composition of Tunisian coriander fruit different parts. Journal of the Science of Food and Agriculture, 89: 1659-1664.

Telci I and Hisil Y., 2008. Biomass Yield and Herb Essential Oil Characters at different Harvest Stages of Spring and Autumn Sown *Coriandrum sativum*. European Journal of Horticultural Science, 73(6): 267-272.

Telci I., Toncer OG and Sahbaz N., 2006a. Yield, essential oil content and composition of *Coriandrum sativum* varieties (var. *vulgare* Alef and var. *microcarpum* DC.) grown in two different locations. Journal of Essential Oil Research, 18(2): 189-193.

Telci I., Bayram E and Avci B., 2006b. Changes in yields, essential oil and linalool contents of *Coriandrum sativum* varieties (var. *vulgare* Alef. and var. *microcarpum* DC.) harvested at different development stages. European Journal of Horticultural Science, 71(6): 267-271.

Tunçtürk R., 2011. Effects of different row spacings on the yield and quality in coriander (*Coriandrum sativum* L.) cultivars. Yuzuncu Yil University Journal of Agricultural Sciences, 21(2): 89-97.

Yaldız G and Kulak M., 2014. Assessment on adaptation of some selected medicinal and aromatic plants to the northern parts of Turkey: Agricultural and chemical property based evaluation. Medicinal and Aromatic Plant Research Journal, 2(3): 50-56.

Yousuf MN., Brahma S., Kamal MM., Akter S and Chowdhury MEK., 2014. Effect of nitrogen, phosphorus, potassium and sulphur on the growth and seed yield of coriander (*Coriandrum sativum* L.). Bangladesh Journal of Agricultural Research, 39(2): 303-309.