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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Determination of fresh and dry herb yield and quality characterization of different coriander (*Coriandrum sativum* L.) populations grown under Eastern Mediterranean conditions

Doğu Akdeniz koşullarında yetiştirilen farklı kişniş (*Coriandrum sativum* L.) popülasyonlarında taze-kuru herba verim ve kalite karakterizasyonlarının belirlenmesi

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ABSTRACT

Coriandrum sativum L., an annual herb from the Apiaceae family, is widely distributed in Near Eastern countries, including the Middle East. Fresh herb and dry seeds have culinary and medicinal uses. In this study, ten different coriander seed samples, collected from various regions of Türkiye were cultivated under the same ecological conditions in the Eastern Mediterranean region. These samples were chosen based on seed size. The study employed samples obtained from Denizli, Hatay (Altınözü, Samandağ), Ankara, Burdur, in addition to five commercially available seed samples .The objective of this research was to assess herb yield and some quality characteristics within these populations. The cultivated populations were assessed for plant height, number of branches, fresh leaf rate, fresh herb yield, fresh herb essential oil (EO) yield, dry herb yield, and dry herb EO yield. Plant height varied between 29.0 and 40.6 cm; with the number of branches ranging from 3.4 to 5.0 per plant, and the fresh leaf rate was between 35.9% and 44.9%. The fresh herb yields of the samples were 687.93-1902.5 kg da^{-1}, while the fresh herb EO content was approximately 0.03%. Dry herb yield was ranged 89.7-279.9 kg da^{-1}, dry herb EO yield ranging 0.2 to 0.5 L da^{-1}. Samples originating from Altınözü exhibited superior results in terms of fresh herb yield, fresh herb EO content, dry herb yield and dry herb EO yield.

ÖZET

Ülkemizde genellikle kişniş olarak bilinen *Coriandrum sativum* L., Orta Doğu ülkeleri de dahil olmak üzere Yakın Doğu ülkelerinde doğal olarak bulunan Apiaceae familyasından tek yıllık bir bitkidir. Taze herba ve kuru tohumlar gıda, aroma verici ve ilaç olarak kullanılmaktadır. Bu çalışmada, Türkiye'nin farklı bölgelerinden temin edilmiş on farklı kişniş tohum örnekleri aynı ekolojik koşullarda (Doğu Akdeniz) yetiştirilmiştir. Denizli, Hatay (Altınözü, Samandağ), Ankara, Burdur illerinden temin edilen tohumlarla birlikte beş farklı ticari tohum örneği materyal olarak kullanılmıştır. Tohumlar boyutlarına göre seçilmiştir. Çalışmanın amacı aynı koşullarda yetiştirilen popülasyonlarda herba verimi ve bazı karakterlerin incelenmedir. Popülasyonlarda bitki boyu, dal sayısı, taze yaprak oranı, taze ot verimi, taze ot uçucu yağ (UY) oranı, kuru ot verimi, kuru ot UY verimi incelenmiştir. Bitki boyu 29.0-40.6 cm arasında; dal sayısı ise 3.4-5.0 adet arasında değişim göstermiştir. Taze yaprak oranı ise %35.9-44.9 arasında değişim göstermiştir. Taze ot verimi 687.9-1902.5 kg da^{-1} arasında değişirken, taze ot UY oranı genel olarak %0.03 değerinde bulunmuştur. Kuru ot verimi 89.7-279.9 kg da^{-1}, kuru ot UY verimi ise 0.2-0.5 L da^{-1} olarak bulunmuştur. Altınözü orijinli örneklerde taze ot verimi, taze ot UY miktarı, kuru herba verimi ve kuru herba UY verimi açısından yüksek sonuç alınmıştır.

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INTRODUCTION

Coriandrum sativum L., commonly known as coriander, is an annual culinary herb and spice belonging to the Apiaceae family (Yousuf et al., 2014). This species is native to Middle East and Near East countries including Afghanistan, Iran, Lebanon, Syria, Pakistan, Palestine, Saudi Arabia, Sinai, Transcaucasia, and Türkiye. Furthermore, coriander has been cultivated almost in every continental (Nurzynska-Wierdak, 2013). Coriander is known as "Chinese parsley", "dhania", "cilantro" in English and "kişniş", "aş otu", and "kuzbara" in Turkish (Baytop, 2015; Naeem et al., 2022). The fresh leaf of this plant has a wide culinary use in Asia and America while its seeds generally used for culinary in Mediterranean region (Ciju, 2019). India is the largest producer and exporter of *C. sativum* with an estimated area of 468000 ha (Gantait et al., 2022). Russia, Bulgaria, Mexico, USA, Argentina, China, Romania, Italy, Japan, Hungary, Poland, Czechia, Morocco, and India are the main producer countries (Tiwari et al., 2002). Production areas of coriander in Türkiye were 2612 da and 1571 da in 2021 and 2022 (TUIK, 2023). Türkiye also contributes to the cultivation and consumption of *C. sativum*, primarily in regions such as Konya, Burdur, İzmir, Denizli and around Erzurum where it is grown and utilized as both fresh and dry herb.

The genus *Coriandrum* comprises two species found in the flora of Türkiye: *C. sativum* L. and *C. tordylium* (Fenzl) Bornm. Among these, *C. sativum* is the most widely utilized species from the flora. All aerial parts of the plant, including fresh and dried leaves and seeds, are employed in various applications, such as in food and beverages for flavoring and preservation, in perfumery for fragrances and in pharmaceutical productsfor therapeutic purposes (Mandal &Mandal, 2015). There are seven cultivars registered in Türkiye as Pel-Mus, Gamze, Erbaa, Kudret-K, Gürbüz, Arslan and Sancar Bey (TTSM, 2023). Studies showed that coriander plant parts and secondary metabolites have antioxidant, anti-bacterial and anti-fungal activities (Asgarpanah & Kazemivash, 2012; Mandal & Mandal, 2015). Seed essential oil from this plant mainly have linalool, nerol acetate, y-terpinene and α-pinene. On the other hand, fresh herb essential oil components were reported as cyclodecanol, 1-decanol, decanal, and 2-Dodecenal (Bahadirli et al., 2016).

Cultivation of coriander in different climatic conditions have also been investigated (Kaya et al., 2000; Kan & Ipek, 2002; Tuncturk, 2011; Katar et al., 2016; Kaplan and Cosge, 2021). In those studies, mainly Turkish varieties were investigated and compared.

The primary objective of this study was to cultivate various coriander seed samples of different origins and compare their herb yield and yield components under the climatic conditions of the Eastern Mediterranean region.

MATERIALS and METHODS

Plant material

In the experiment, ten different coriander seed samples (from Türkiye) were chosen according to their seed size and used as a plant material (Table 1). Field experiments were conducted in Hatay Mustafa Kemal University Telkalis Experimental Station fields in years of 2014 and 2015. Figure 1 shows the seed size and color of the selected materials. The seed samples of local species (Hatay) were obtained from farmers and the other samples were supplied from herbalists from other provinces. Seed size is a very important parameter for coriander to discriminate its varieties. In the present study, seed diameters lower than 3 mm were classified as small and larger than this value were classified as big.

Table 1. Coriander seed samples, source, and seed size

Çizelge 1. Kişniş tohum örneklerinin temin edildiği yerler ve tohum büyüklükleri

Population Codes	Description	Seed Size
1	Denizli	Big
2	Altınözü/Hatay	Big
3	Ankara	Small
4	Burdur	Small
5	Samandağ/Hatay	Big
6	Commercial-1	Big
7	Commercial-2	Big
8	Commercial-3	Small
9	Commercial-4	Big
10	Commercial-5	Big

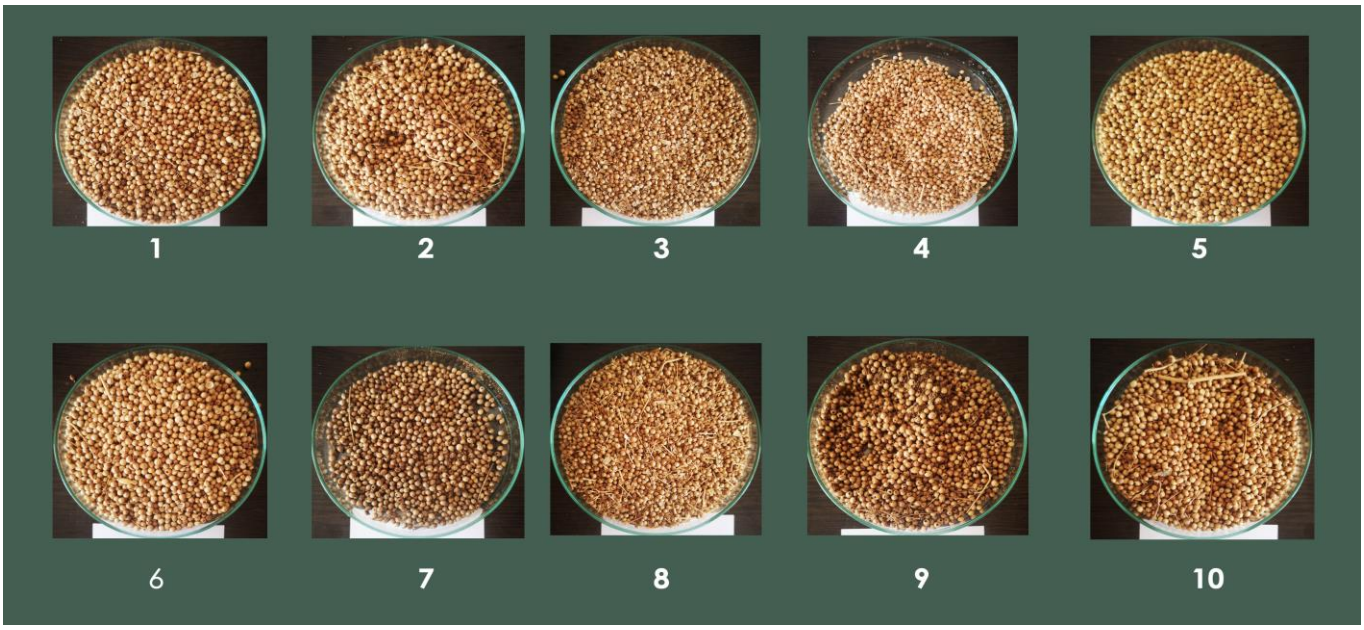

Figure 1. Seed size and colors of ten *C. sativum* seed samples

Şekil 1. C. sativum tohum örneklerine ait tohum büyüklüğü ve renkleri

Experimental design and evaluation of the experiments

Experiments were carried out over the research area of Hatay Mustafa Kemal University Agricultural Research Center (36°15'13.3"N, 36°30'08.7"E; 96 m) during the winter growing season in 2014-2015. Seeds were sown directly into the field on 18th November in 2014. Soil samples were taken from 0-30 cm of soils from different parts of the experimental area to determine some soil properties. Analysis of the soil samples revealed the following findings: pH: 7.63, organic matter: 1.58%, nitrogen (N): 0.079%, phosphorus (P): 19.7 kg da^{-1}, potassium (K): 104.5 kg da^{-1}, iron (Fe): 8.75 ppm, zinc (Zn): 0.21 ppm, lime: 21.66%, conductivity (EC): 942 µS/cm and soil type were found as clay-loam. Fertilizers were applied before sowing at the rate of 4 kg pure phosphorus and 4 kg pure nitrogen per decare.

Meteorological data observed near the experimental area by the Hatay Meteorology Directorate were summarized in Table 2. The experimental area has typical Mediterranean climate with hot dry summers and warm winters.

Experiments were conducted in in a "randomized complete block design'' with three replications.

The experimental plot size was 7.2 (m^2) with rows spacing of 0.30 m. The spaces between blocks were 3m and between plots were 1 m. Total experimental area was 228 m^2 and 2.5 kg da^{-1} seeds were calculated and used.

Table 2. Meteorological data of the experimental area between November 2014 andMarch 2015

Çizelge 2. Kişniş tohum örneklerinin yetiştirildiği yerlere ait Kasım 2014-Mart 2015 yılları arasındaki meterolojik verileri

Months	Maximum Temp. (°C)	Minimum Temp. (°C)	Humidity (%)	Precipitation (mm)
November	25.7	0.3	97.0	11.2
December	19.6	-3.1	99.0	45.1
January	17.7	-4.6	99.0	160.6
February	20.2	-0.6	99.0	14.8
March	26.5	2.1	97.0	145.3

Data were obtained from Hatay Meteorology Directorate.

Harvesting was carried out before stem elongation period of plants in March 2015. Populations 5 and 6 were harvested in 4th of March while Populations 1, 2, 3, 7, 9, 10 were harvested in 8th of March and the remaining Populations (4 and 8) were harvested in 20th of March in 2015.

Investigated traits;

- **Plant height:** Taken as the average of heights of the ten plants per plot measured from the soil surface to the top-most growth point of plants.
- **Number of branches per plant**: The numbers of branches on the main stem were counted from ten plants in each plot
- **Fresh leaf rate**: 100 g of herbs were weighed, and later leaf and branches were separated, and leaves were weighed again, and then fresh leaf rate were calculated
- **Fresh herb yield:** Calculated as the sum of the herbs harvested from the net plot area and transformed to kg per da.
- **Fresh herb essential oil content:** 200 g of fresh herbs were water distilled with Clevenger type apparatus and essential oil contents were measured as percentages.
- **Dry herb yield**: Calculated as the sum of dried herbs (dried in room conditions at 24 °C) from the net plot area and transformed to kg per da.
- **Dry herb essential oil (EO) yield:** Dry herbs were water distilled with Clevenger type apparatus and essential oil (EO) contents were calculated as L per da in dry herb.

The experimental data were subjected to analysis of variance with SPSS 22.0 (SPSS Inc., Chicago, IL, USA) statistical program. The comparison of the means was carried out with the Duncan's multiple comparison test. According to the results, all sample groups were lettered, and the results were interpreted.

RESULTS and DISCUSSIONS

In the present study, 10 different seed samples, obtained from different geographic regions of Turkey, were cultivated in Amik Plain (Hatay, Türkiye) and some of their properties were determined. All of the investigated properties were found statistically significant ($p \leq 0.05$) (Table 3). Plant height of the samples were ranged between 29.0 and 40.6 cm The samples from Ankara province were found to have lowest plant height while Commercial-4 had the highest plant height. On the other hand, Denizli, Altinözü, Burdur, Samandag, Commercial-2 ,3, 4, 5 samples were found to have similar plant heights. There were several studies on plant height of coriander. Kan and Ipek (2002) found reported a plant height of 40.8-58.5 cm; Gumuscu et al. (2007) 49.7- 68.7 cm; Tuncturk (2011) 36.7-52.2 cm; Katar et al. (2016) 36.9-75.6 cm, Ozyazici and Bektas (2021) 64.3-75.9 and Kaplan and Cosge Senkal (2021) 46.7-51.9 cm. In addition, it was generally observed that large-fruited and early ecotypes produced shorter plant heights while small-fruited and

late-fruited ecotypes produced longer plant heights (Telci et al., 2006). Furthermore, the higher plant height results obtained in previous studies may be due to longer growth period for seed maturity for harvest. In the present study, there were no correlation between plant height and seed size.

Number of branches is another parameter that correlated with plant yield. Numbers of branches were found between 5.03 and 3.40 per plant. The highest numbers of branches per plant were observed from Samandağ and Commercial 1 samples while the lowest result was determined from Commercial-5 samples. Number of branches also varied according to different previous studies such as Kaya et al. (2000) with 3.7-7.7; Kan and Ipek (2002) with 5.03-13.8; Tuncturk and Tuncturk (2008) with 5.3-5.9; Tuncturk (2011) with 5.0-6.5; Katar et al. (2016) with 4.3-7.6 and Kaplan and Cosge Senkal (2021) with 4.5-5.1. These results shows that the number of branches could be affected by ecology and genotypes. On the other hand, different harvesting times could be effective on variations of the results.

Coriander fresh leaf and herb can also be used in culinary. Therefore, fresh leaf yield and herb yield are important parameters to observed samples differences. Fresh leaf rate of the samples was ranged between 35.9 and 44.9%. The highest fresh leaf yield was found in Denizli originated samples, while the lowest result was found in Commercial-5 samples.

The results of the fresh herb yield, fresh herb essential oil (EO) content, dry herb yield and dry herb EO yield obtained from field experiment were given in Table 4. Fresh herb yields of the samples were found between 687.9 and 1902.5 kg da^{-1}. The highest result was obtained from Altınözü samples while the lowest was obtained from Commercial-1 samples.

Table 3. Results of plant height, number of branches and fresh leaf rate according to coriander samples
Çizelge 3. Kişniş populasyonlarına ait bitki boyu, dal sayısı, taze yaprak oranı sonuçları

Populations	Plant height (cm)	Number of Branches (per plant)	Fresh Leaf Rate (%)
1	39.8 a	3.7 cd	44.9 a
2	38.8 ab	4.0 bcd	42.1 ab
3	29.0 c	4.3 abcd	43.4 ab
4	38.7 ab	4.4 abc	38.7 bc
5	39.5 a	5.0 a	41.8 abc
6	35.1 b	5.0 a	43.3 ab
7	37.8 ab	4.1 bcd	43.9 ab
8	36.7 ab	4.7 ab	38.7 bc
9	40.6 a	4.3 abcd	39.2 abc
10	39.9 a	3.4 d	35.9 c

* The means given in each column followed by different letters are significantly different (p≤0.05).

In a previous study, fresh herb weights were found between 12.9 and 34.8 g from the sample cv. Santo in America (Meyering et al., 2019). Comparing to the results of fresh herb yield from Inan et al. (2007) as found as 845.6-906.5 kg da^{-1}, most of our results were found to be higher. Fresh herb EO contents were found to be very similar in all populations changing between0.027-0.030%. Many of the previous EO studies were focused on the seed EO. Inan et al. (2007) found fresh EO content as 0.04% while Bhuiyan et al. (2009) reported an EO content of 0.10%. These different results could be the outcomes from different ecology and genotypes. Dry herb yields were divided into four groups between 89.7 and 279.9 (kg da^{-1}), the highest yield was observed in Altınözü while the lowest result was obtained from Commercial-1 sample. Similar to our results, Inan et al. (2007) found dry herb yield between 201.8-220.5 kg da^{-1}. In the present study, dry herb EO yields of the samples were also calculated from dry herb essential oil contents. The highest dry herb EO yields were observed from population 2 and population 9.

Table 4. Fresh herb yield, fresh herb EO content, dry herb yield and dry herb EO yield results of different populations
Çizelge 4. Taze herba verimi, taze herba UY oranı, kuru herba verimi ve kuru herba UY verimi

Populations	Fresh Herb Yield (kg da^{-1})	Fresh Herb EO Content (%)	Dry Herb Yield (kg da^{-1})	Dry Herb EO Yield (L da^{-1})
1	1511.2 ab	0.027 ab	224.4 ab	0.380 abcd
2	1902.5 a	0.030 a	279.9 a	0.507 a
3	1091.2 bc	0.023 ab	151.3 bc	0.257 de
4	1815.7 a	0.023 ab	195.1 ab	0.360 bcd
5	1567.2 ab	0.027 ab	199.3 ab	0.363 bcd
6	687.9 c	0.030 a	89.7 c	0.207 e
7	1660.0 a	0.027 ab	239.8 a	0.397 abc
8	1743.8 a	0.020 b	202.6 ab	0.283 cde
9	1729.7 a	0.027 ab	214.7 ab	0.423 ab
10	1566.8 ab	0.027 ab	229.6 ab	0.383 abcd

* The means given in each column followed by different letters are significantly different (p≤0.05).

In summary, among the studied populations, Populations 2, 4, 7, 8, and 9 exhibited noteworthy performance in terms of fresh herb yield, while only Population 2 displayed a higher essential oil (EO) yield. Populations 2 and 9 were found to possess elevated EO content compared to the remaining populations. The findings suggest that Hatay, located in Türkiye, is well-suited for the cultivation of coriander intended for fresh herb consumption. It is worth noting that the EO contents observed in this study were comparatively lower than those reported in previous research, which may be attributed to ecological and varietal factors.

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STATEMENT OF CONFLICT OF INTEREST
The authors declare no conflict of interest for this study.

AUTHOR'S CONTRIBUTIONS
The contribution of the authors is equal.

STATEMENT OF ETHICS CONSENT
Ethical approval is not applicable because this article does not contain any studies with human or animal subjects.

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