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Yield and oil composition of peppermint cultivars grown in the Isparta climate of Turkey

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Abstract: Peppermint, *Mentha piperita* L. belonging to the Lamiaceae family, contains a valuable essential oil known for its high menthol and menthone content. During the vegetation seasons of 2016 and 2017, field studies were conducted in Turkey's Isparta climate by using randomized blocks to examine the yield and oil composition of the new peppermint cultivars. In these studies, Multimentha produced the highest herb yield even though the quality of its essential oil is relatively poor due to its low menthol content. Yield levels of other cultivars were similar to each other with the same statistical group. In the study, Citaro, Tokat CL-8, and Chocolate varieties had high menthol contents and were within the same chemical group. Varieties reacted differently to years and harvesting seasons, including summer and autumn. The menthol content of Citaro and Tokat CL-8 cultivars was higher in the fall harvest compared to the summer harvest. On the other hand, the menthol content of the Chocolate cultivar remained stable throughout the seasons. The study has revealed that the yields of the varieties with high menthol are low, and the oils obtained from all these varieties except Multimentha conform to the European pharmacopoeia.

Key words: Cultivar, essential oil, *Mentha piperita*, menthone, menthol, yield

1. Introduction

Mints are members of the genus *Mentha* of the family Lamiaceae. There are 31 species of *Mentha* genus in the world (Tucker and Naczi, 2007). Some of these species, such as *Mentha arvensis* L., *Mentha x piperita* L. and *Mentha spicata* L., have commercial value as their essential oils are rich in menthol, menthone, carvone, pulegone, and piperitenone oxide, which are used in medicine, cosmetic, and food industries (Telci et al., 2010).

In developing countries, mint oil is produced with a ratio of 65%. Due to the high menthol content of its essential oil, *M. arvensis* is a widely cultivated plant in India, China, the United States, Brazil, Peru, Thailand, Korea, and Taiwan. With an annual production of 74,000 tons, the essential oil of *M. arvensis* is the second most-produced essential oil, right after that of *Citrus* (Telci et al., 2010). After *M. arvensis*, *M. piperita* is the world's second most widely cultivated *Mentha* species. *Mentha piperita* L., commonly known as "peppermint", is hugely popular throughout the world for its useful essential oil, which contains high levels of menthol and menthone. Western Europe and Japan are the main consumers of peppermint oil (World Merchandise Exports and Imports by Commodity, 2019) which is extensively used in the production of toothpaste, chewing gums, and pharmaceuticals.

Turkey's geographical structure and agricultural potential make it an excellent growing area for medicinal and aromatic plants. Yet, Turkey imports most of its mint oil requirement. Moreover, mint oil and menthol are the most imported essential oils in Turkey. In recent years, Turkey has paid four million dollars to import 100 tons of mint essential oil, and an additional seven million dollars to import 240 tons of menthol. The amount totals 11 million dollars spent for *Mentha* products (Turkish Statistical Institute, 2018).

Since mint can be grown easily in Turkey's climate, requirements can potentially be satisfied Turkey's menthol and peppermint oil needs by domestic production. Recent research, which aimed to identify yield levels of herb, oil, and major components of new peppermint cultivars, and was conducted with indigenous landraces, showed promising results for the cultivation of peppermint in Turkey. The research also revealed that the components of essential oils can vary to different ecological conditions (Telci et al., 2011). However, the data on the new cultivar's adaptability and yield potential for various ecologies and climates is limited. As Isparta, which is located in the Lake Region of Southwest of Turkey, is already a successful rose and lavender producer, local growers and manufacturers are looking for additional profitable essential oil plants.

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The aim of the research was, therefore, to determine profitable peppermint cultivars for the region's growers. For this reason, it was determined the yields of herb, oil, and oil composition of new peppermint commercial cultivars for Isparta ecological conditions.

2. Material and methods

2.1. Plant material and experimental area

In the study, five different peppermint (*Mentha x piperita* L.) clones were used, four of which were commercial cultivars, and one was a selected clone of Turkish mints. Fleurantalya Company provided the commercial cultivars (Multimentha, Chocolate, Citaro, and Swiss), and the fifth clone was selected from Turkish landraces of Tokat CL-8 (Telci and Şahbaz 2005, Telci et al., 2011).

To examine the ecological conditions of the province, field studies were conducted in Isparta, which is located on the meeting point of Central Anatolia, the Aegean and Mediterranean Regions, and the Lakes Region of Turkey. Isparta produces the majority of Turkey's essential oil production (especially rose oil). Faculty of Agriculture, Isparta University of Applied Sciences (ISUBU), which is in the central district of Isparta (37°45′N, 30°33′E), and at an elevation of 1035 m, was chosen as the experimental area for the studies conducted throughout 2016 and 2017. Isparta is known for its hot summers, and the climate of the area is classified as Mediterranean (Csa) according to Köppen Climate Classification (Peel et al., 2007). Temperature, precipitation, and humidity data of the experimental area are provided in Figure 1.

The soil of the experimental area is Clay loam and contains middle-level organic matter of 2.7%. The soil samples from the upper layer of 0–30 cm contained calcium carbonate with 22.2%, phosphorus 4.8%, and adequate potassium with 72%. Furthermore, it is medium alkaline with a pH of 8.07.

2.2. Field experiments

In the fall of 2015, the experiment was carried out with seedlings from rooted cuttings. The rooted clones were planted in plots by using a randomized block design with three replications. The plots were fertilized with 50 kg ha/da P_2O_5 and 50 kg/ha N, and the plants were planted in 30 cm rows. When needed, plots were irrigated with a drip irrigation system and protected from weeds by hand hoeing.

However, since the space between rows and midway between the rows began to close during the plant growth, cages with 0.5 m^2 were used to obtain data about the characteristics. At each developmental stage, 2.5 kg/ha of N fertilizer was applied and other requirements (irrigation, weed control, etc.) were handled regularly. The plants were then harvested in the flowering stage.

Plants were harvested twice (first in mid-July and later in the first week of October) during floral initiation by cutting the plants approximately 10 cm above the soil surface. For fresh herb yield, plants in each plot were weighed immediately after cutting, and 500 g of the fresh herb were uniformly dried at 35 °C in a drying cabinet to obtain dried herb and leaf yields.

2.3. Yields and essential oil contents

Plants were harvested twice each year to determine the total amount of fresh and dried herb yields and dried leaf yield. Essential oils were isolated using Clevenger distillation apparatus. Dried plant specimens were extracted with 500 mL of distilled water for two and a half h. Oil contents were calculated as mL/100 g. The oil phase was separated, dried over anhydrous sodium sulfate, and kept in a dark glass bottle at 4 °C for analysis.

2.4. Oil compositions

FID and GC/MS analyses of essential oil compositions were respectively performed by using a QP Shimadzu 5050 gas chromatography and mass spectrometer at SDU Experimental and Observational Student Research and Application Center. Samples were diluted in hexane, and then injected into the column CP-Wax 52 CB (50 m × 0.32 mm; film thickness = 0.25 µm) to separate the components. The initial temperature of the column was 60 °C and was increased 10 °C per min up to 250 °C. The temperature was kept at 220 °C for five min. The injection block temperature was 240 °C. The detector temperature was 250 °C, and the detector energy flow was set at 70 eV. The ionization method was EI, and Helium was used (20 mL/min). The flow rate was set at 10 psi. Essential oil components were identified by calculation of their retention indices under temperature-programmed conditions for n-alkanes (C_5-C_{20}) and the oil on the same column and conditions. Identification of all components was made by comparison of their mass spectral fragmentation patterns (WILLEY and NIST database/ChemStation data system). Quantitative data was obtained from FID area percentages without the use of correction factors.

2.5. Evaluation of data

1. Total yield obtained throughout the year (two cutting seasons) was analyzed according to the randomized block design with three replications. F values of the years and cultivars were calculated and compared with the F Table values ($p < 0.05$ and 0.01). The mean data of yield, which were statistically significant, were compared with the Duncan test. Statistical analyses were performed by using the SPSS statistical software.

2. Cultivars were analyzed through Cluster analysis and were classified according to their chemical compositions by using the Euclidean distance measure along with agglomerative and hierarchical methods (SPSS package software, Ver. 18).

3. Mean values of the major components were calculated with standard deviation.

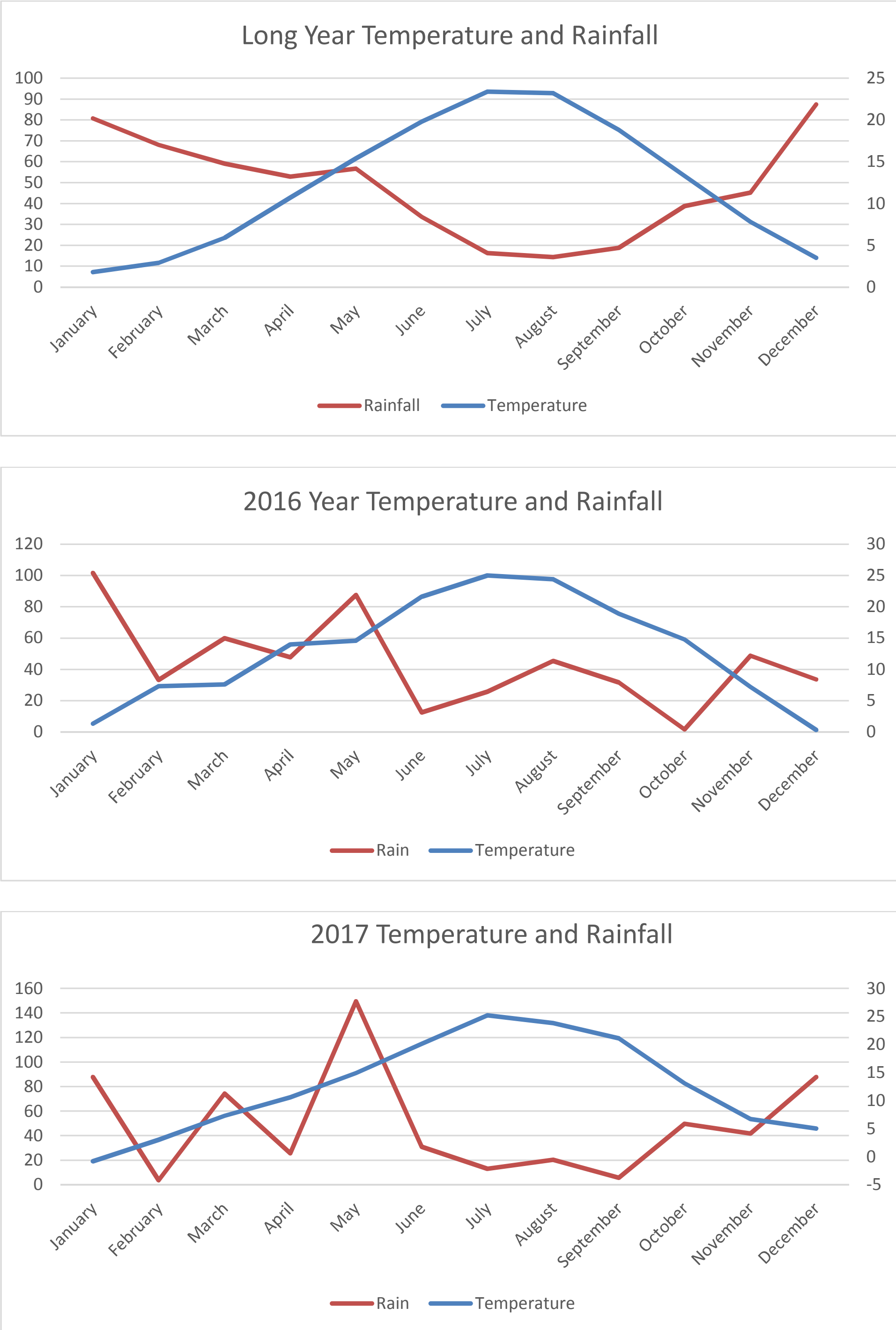

Figure 1. Climatic data (temperature and rainfall) of the research area.

3. Results and discussion

3.1. Location and climate

Isparta, the center of Turkey's essential oil industry, is a major agricultural and agro-industrial city located in the Lakes Region of Turkey. For thirty-five years now, Isparta has been one of the world's main producers of rose oil. Local growers are now searching for new essential oil plants in addition to the province's major essential oil plants, including rose and lavender. Additionally, oil companies have been trying to find a way to grow peppermint in the region to eliminate the dependency on imports of peppermint oil.

Studies have shown that peppermint can adapt to different climatic and soil conditions. However, climatic conditions dramatically affect the quality of its essential oil. Agricultural data shows that peppermint requires a temperate climate for proper growth, and it is mostly grown in the regions located north of the 40th parallel, areas considered the most suitable for proper oil quality (Green, 1963; Grulova et al 2015). However, various studies have revealed that peppermint can also be successfully grown in areas located south of the 40th parallel (Zheljazkov et al 2010). This study explores the adaptability of the new peppermint cultivar to the climate of the Isparta province located on the 37th parallel north, which is located south of the 40th parallel. Isparta is in the passing zone between the Mediterranean climate and the continental climate prevailing in Central Anatolia. Years-long climate data shows that July and August are the hottest months in the city (Figure 1). For this reason, regular irrigation is a must for the successful cultivation of plants that need relatively more water, such as mint. As can be seen from Figure 1, climate data shows that Isparta springs usually receive a sufficient amount of rainfall. During our study, however, the city did not receive enough rainfall until May and received relatively low rainfall in February and March. While the first harvest of the study was done in the hot summer season, the second harvest was done during mid-fall, when the temperature had gradually decreased.

3.2. Yields

In the second year of the study, all varieties produced higher yields than they did in the first year. Fresh and dry herb yields significantly differed between the two years. However, leaf yield levels remained almost stable throughout the years of the study, and the change was statistically insignificant (Table 1). Following the planting of *Mentha* plants, the soil surface was covered with rhizomes and stolons, which led to an increased number of plants per plot with high herb yields in the second year of the study. However, the increase in the number of plants per unit area caused lower leaves to fall during subsequent harvests. Therefore, leaf yield remained stable, while herb yields increased greatly in the second year. Despite the increase in herbal yields in the second year, essential oil yield also remained insignificant statistically due to the decrease in the number of leaves. The increasing number of plants per unit area has also led to similar results in the second years of previous studies (Telci and Şahbaz, 2005). In addition, vigorous stolons improved the growth of the plants after the first winter of the study, which, in turn, resulted in higher herb yields (Ruminska et al., 1984). Following the second year of the study, all yields began to decline due to physiological aging (Piccaglia and Marotti, 1993).

During the study, Multimentha gave the highest fresh herb yield with 27.0 t/ha in the first year and 41.4 t/ha in the second, and 34.3 t/ha in two years' mean. The yield of the Multimentha was so high compared to the other cultivars that it was in a statistically different group than the yields of other cultivars. After Multimentha, the Swiss cultivar produced the second-highest yields during the study. The results of the study showed that Multimentha has a strong habitus along with a capability to adapt to the climate of Isparta. In addition, the adaptability of Multimentha to different climatic conditions has been a subject to various other studies. The results of a series of studies conducted in four different regions of Egypt revealed that Multimentha produces the highest yields in warmer climates. In these studies, fresh herb yields of Multimentha varied between 33 and 38 t/ha (Hendawy et al., 2018). Fresh herb yields produced by Multimentha during our study were similar to the results of the aforementioned studies. Although only a limited number of studies have focused on the peppermint cultivar used in our experiment, the studies conducted by using peppermint genotypes and clones have shown that climatic and genetic conditions directly affect herb and leave yields. In a study conducted by Telci et al. (2011), two different clones were observed in four different ecologies. The results showed that peppermint produces high herb yields in Aydın and İzmir (37.0 and 36.8 t/ha, respectively), both of which have warm climates. The yields of the C-8 clone, referred to as Tokat CL-8 in the study, varied between 28.2 and 38.6 t/ha in different ecologies. However, these clones produced a lower yield in Isparta compared to the results of previous studies (Telci et al., 2011). The Multimentha cultivar, on the other hand, produced the highest yields and showed promising results regarding adaptability to the climate of the province.

The factors affecting the yield of peppermint are genotypes, plant age (Telci and Şahbaz, 2005), environmental conditions (Özgüven and Kırıcı, 1999; Telci et al., 2011), planting time (Özel and Özgüven, 1999), and cutting time (Zheljazkov et al., 2010). In our study, the Multimentha cultivar produced higher yields than it did in the studies in Adana (Özgüven and Kırıcı, 1999) and Egypt. (Hendawy et al. 2018). However, the yields of other cultivars used in our study were lower than those of other peppermint varieties which were studied in Adana.

Tokat CL-8 has also produced lower yields compared to the results of other studies conducted in four different locations (Telci et al., 2011). As the region, in which the study was conducted, has short vegetation periods and continental climate, vegetation period is considered an important factor for yield (Telci et al., 2011).

3.3. Essential oil contents

Variations in essential oil contents of cultivars have been examined for two years in different harvest seasons,

Table 1. Variation of yields in the peppermint (*Menthe piperita* L.) genotypes.

		Yields		
Variation sources		Fresh herb	Dried herb	Dried leaves
		(kg·ha^{-1})	(kg·ha^{-1})	(kg·ha^{-1})
Year	2016	18.0 b	5.1 b	3.4
	2017	23.8 a	6.6 a	3.8
Cultivar	Citaro	16.1 bc	4.6 bc	3.0 b
	Swiss	22.6 b	5.9 b	3.5 b
	Multimentha	34.3 a	9.4 a	5.5 a
	Chocolate	14.3 c	4.3 b	3.0 b
	Tokat CL-8	17.2 bc	5.1 b	3.1 b
Year × Cultivar interaction				
2016	Citaro	15.4	4.5	3.0
	Swiss	15.9	4.1	2.6
	Multimentha	27.0	7.9	5.3
	Chocolate	14.2	4.0	2.9
	Tokat CL-8	17.0	5.3	3.3
2017	Citaro	16.7	4.7	3.0
	Swiss	29.1	7.7	4.4
	Multimentha	41.4	11.0	5.7
	Chocolate	14.4	4.6	3.2
	Tokat CL-8	17.4	4.9	2.9
F values				
	Year (Y)	7.199*	4.408*	0.942^{ns}
	Genotypes (G)	10.799**	7.503**	4.82**
	YxG int	2.168^{ns}	1.382^{ns}	0.706^{ns}

$^{*}p < 0.05$, $^{**}p < 0.01$, ^{ns} not significant

summer and fall. According to the results, the mean data of essential oil content were statistically significant in terms of the years, cultivars, and year×cultivar interaction (Figure 2). The highest essential oil ratio was obtained from Multimentha with 2.8%, followed by Swiss with 2.4%. The essential oil ratios obtained from the other three cultivars were close to each other and within the same statistical group. During the study, the essential oil contents were higher in the first harvest seasons of both years due to climatic factors and vegetation periods of the region. But the conclusions have contradicted the result of the studies conducted in regions having long vegetation periods because the second cutting of the regions comes across the hot summer season. In ecologies where the vegetation period is long and the second cutting is taken in summer, essential oil contents are higher in the second harvest because of the effects of hot weather (Özgüven and Kırıcı, 1999; Telci et al., 2011). In this study, the first harvests were made in mid-July, and the second were made in early October. Our study has revealed that decreasing

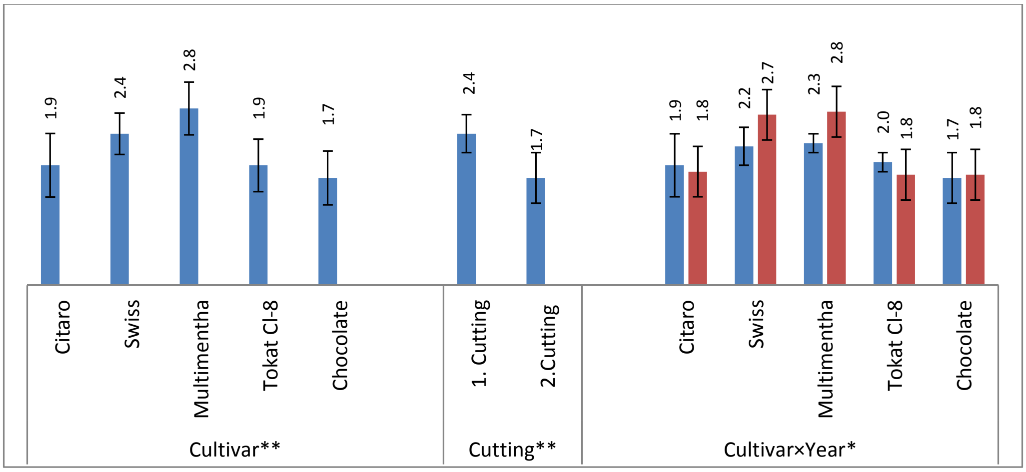

Figure 2. Variation of essential oil content (%) of the peppermint clone and cultivars according to cutting seasons (*: $p < 0.05$; **: $p < 0.01$).

temperature in the study location during autumn causes a decrease in oil ratios in the second harvest season. The increase in the essential oil ratio with temperature is known from previous studies (Duriyaprapan et al., 1986; Hendawy et al., 2018).

In this study, variations in the essential oil of the cultivars differed according to harvest seasons, and the cultivar-year interactions were statistically significant. While the essential oil contents of Multimentha and Swiss, both of which contain a high amount of essential oil, were dramatically higher in the second year, variations of the essential oil contents in the other three cultivars (Citaro, Tokat CL-8, and Chocolate) were similar throughout the study. It can be said that cultivars reacted differently to the changing climatic conditions throughout the years. The data on the essential oil content of the new cultivar (Ludwiczuk et al., 2016) and its adaptability to different climates are quite limited in the literature.

Studies on Tokat CL-8 and Multimentha have shown that climatic conditions affect the essential oil composition of the cultivars. In addition, various studies on Multimentha have revealed that ecological variations directly affect the essential oil content, and higher yields of essential oil are obtained in warm climates (Özgüven and Kırıcı, 1999; Hendawy et al., 2018). However, the response of varieties to different locations also depends on the genetics of the cultivars.

3.4 Essential oil composition

3.4.1. Chemical diversity between cultivars

In the study, 28 components were identified as a result of GC analysis, and the cultivars were grouped into two chemical groups according to their essential oil components by using Cluster Analysis (Figure 3). The research revealed a high similarity between the essential oil compositions of three cultivars, Citaro, Tokat CL-8, and Chocolate, and thus, these cultivars were classified within the same chemical group. It has also been observed that the menthone and menthol ratios of these three varieties are close to each other. During the study, the highest menthol content was found in Citaro (50.3%) and followed by Tokat CL-8 (48.3%), and Chocolate (47.4%). Menthone contents of these cultivars were 17.8%, 17.8%, and 19.2%, respectively. Although the Swiss has also a similar essential oil composition, it was clustered in a subgroup due to its partially low menthol ratio. Menthol and menthone contents of the cultivar were respectively 43.3% and 20.8%. In the study, the Multimentha was classified as a separate chemical group (chemotypes) as its main component is menthone, unlike the other cultivars. Besides, the menthyl acetate content of Multimentha is lower than those of other cultivars. Variations of menthol were more stable than menthone and menthyl acetate in all cultivars. With a standard deviation (cv) of 0.8%, the Chocolate cultivar was the most stable cultivar in terms of menthol (Table 2).

The commercial value of peppermint oil is heavily related to its menthone and menthol contents. In the European pharmacopeia, menthol and menthone contents of peppermint oil are expected to be between 30% to 55% and 14% to 32%, respectively (World Merchandise Exports and Imports by Commodity, 2019). The study has shown that the essential oils of all cultivars, except Multimentha, meet the standards of the European pharmacopeia in terms of menthone and menthol contents. Variations of oil composition in mint species depend upon the genetic structure of plants (Fejér et al., 2017), climatic conditions (Clark and Menary, 1980; Telci et al 2011), and agronomic practices (Piccaglia and Marotti, 1993; Telci and Sahbaz 2005). Studies on the essential oil composition of the new peppermint varieties are still very limited in number.

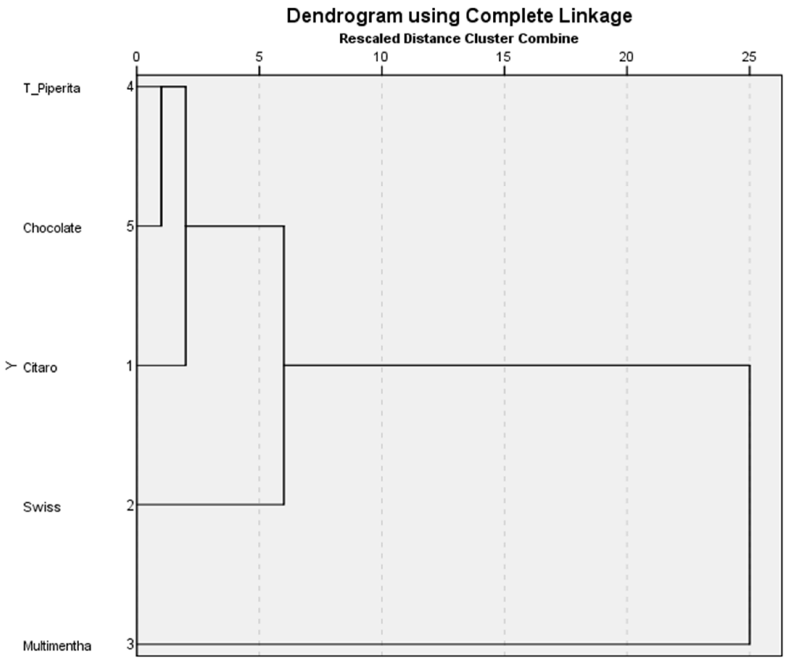

Figure 3. Dendrogram of clusters resulting from the chemical composition of peppermint clone and cultivars.

Consistent with our findings, Ludwiczuk et al. (2016) stated that menthol contents of Citaro and Swiss cultivars (51.8%) are higher than that of Swiss (41.5%), and Multimentha has the lowest menthol content with 28.0%.

3.4.2. Variation of major components (menthol, menthone, and menthyl acetate)

In our study, we have examined the variation of the major components of the cultivars over the years and harvesting seasons (summer and autumn). Menthol contents of the cultivars were generally higher at the second harvesting in autumn than the first harvesting in summer. Menthol contents of Citaro and Tokat CL-8 increased significantly in the second cuttings of both years. Similarly, the menthol content of Swiss increased in the second harvest of the first year. However, it remained almost the same in the second year. Although the Chocolate cultivar had a relatively high menthol content in the second cutting of both years, the differences between the two cutting seasons were negligible and insignificant (Figure 4).

The study has also shown that menthone contents were higher in the summer harvests. The highest menthone content (58.6%) was obtained in the summer harvest of the first year during the two-year studies. Menthone contents of all cultivars gradually decreased in the subsequent harvests. While newly-formed leaves had higher menthone contents than mature leaves, menthol contents of the leaves increased following their maturation (Rohloff, 1999). In other words, the menthone content in young leaves is higher than in mature leaves (Verma et al., 2010). During our study, the ability of young plants to produce more side branches and grow horizontally led to more young leaves and thus, a high amount of menthone in the summer cutting of the first year. Unlike menthone, menthyl acetate contents of all cultivars reached the highest in the autumn harvest of the second year. In the second year, strong rhizomes and stolons helped plants grow more uniformly, accelerated the biosynthesis of menthol, and increased menthyl acetate ratios.

It is known that the biosynthetic pathway of essential oil synthesis in peppermint continues from pulegone in the form of menthone menthol and menthyl acetate and the enzymes involved in this pathway play roles in the quantity of the components (Coteau et al., 2005). It is known that the genetic characteristics of the plant, climatic conditions, and agronomic applications play roles in these changes.

The oil composition of peppermint depends on climatic factors, such as photoperiods and temperature, which affect the coenzyme $NADPH_2$. Day length, temperature, light density, day-night temperature difference, and $NADPH_2$ levels increase the conversion rate of pulegone, menthone, and menthol (Clark and Menary., 1980). Optimal environmental conditions, on the other hand, increase the amount of the main components.

In the study, menthol content was higher in the second harvest (midautumn), which shows that the temperature in fall is ideal for peppermint growth in the Isparta province. Peppermint, which is originally from England, has adapted to the temperate climate of Europe

Table 2. Variation of essential oil composition in the peppermint cultivars.

		RI[b]	Citaro		Swiss		Multimentha		Tokat CL-8		Chocolate	
No	Components[a]		Mean	*sd*	Mean	sd	Mean	*sd*	Mean	*sd*	Mean	*sd*
1	*α*-Pinene	933	0.5	*0.1*	0.5	*0.1*	0.5	*0.1*	0.6	*0.1*	0.5	*0.1*
2	Sabinene	972	0.6	*0.0*	0.5	*0.1*	0.5	*0.1*	0.5	*0.0*	0.5	*0.1*
3	*β*-Pinene	978	1.0	*0.0*	0.8	*0.1*	0.8	*0.1*	1.0	*0.1*	0.9	*0.1*
4	*β*-Myrcene	991	0.4	*0.3*	0.3	*0.0*	0.5	*0.1*	0.0	*0.0*	0.2	*0.0*
5	Limonene	1030	1.8	*0.5*	5.5	*0.5*	0.7	*0.4*	1.9	*0.4*	1.9	*0.6*
6	1,8-Cineole	1031	6.6	*1.0*	5.5	*0.9*	5.0	*0.9*	6.4	*0.9*	6.1	*1.2*
7	*cis*-Ocimene	1035	0.2	*0.0*	0.4	*0.1*	0.2	*0.0*	0.0	*0.0*	0.2	*0.1*
8	*γ* –Terpinene	1058	0.1	*0.0*	0.0	*0.0*	0.0	*0.0*	0.3	*0.0*	0.3	*0.0*
9	*trans*-Sabinene hydrate	1070	2.4	*0.5*	0.7	*0.4*	1.0	*0.4*	2.3	*0.8*	2.5	*1.0*
10	Linalool L	1084	0.0	*0.0*	0.2	*0.0*	0.3	*0.1*	0.4	*0.1*	0.4	*0.1*
11	**Menthone**	**1158**	**17.8**	***11.6***	**20.8**	***10.8***	**47.3**	***7.9***	**17.8**	***11.4***	**19.2**	***9.8***
12	Menthofuran	1164	2.1	*0.7*	0.0	*0.0*	2.5	*0.8*	1.4	*0.7*	3.1	*1.8*
13	**Menthol**	**1184**	**50.3**	***5.8***	**43.3**	***4.2***	**34.2**	***6.9***	**48.3**	***5.8***	**47.4**	***0.8***
14	*α*- Terpineol	1198	0.2	*0.1*	0.0	*0.0*	0.2	*0.0*	0.0	*0.0*	0.0	*0.0*
15	Pulegone	1241	1.2	*0.0*	1.9	*0.0*	1.1	*0.9*	1.4	*0.0*	0.8	*0.0*
16	Carvone	1246	0.2	*0.0*	0.0	*0.0*	0.0	*0.0*	1.3	*0.6*	0.5	*0.0*
17	Piperitone	1267	0.5	*0.1*	1.6	*0.1*	1.4	*0.3*	0.5	*0.1*	0.5	*0.1*
18	**Menthyl acetate**	**1290**	**11.5**	***8.4***	**13.1**	***12.1***	**3.4**	***1.7***	**13.6**	***9.5***	**14.0**	***9.4***
19	*β*-Bourbonene	1382	0.3	*0.0*	0.3	*0.1*	0.2	*0.0*	0.4	*0.1*	0.5	*0.2*
20	*β*-Elemene	1390	0.0	*0.0*	0.0	*0.0*	0.3	*0.1*	0.0	*0.0*	0.3	*0.0*
21	*trans*-Caryophyllene	1421	1.7	*0.5*	0.3	*0.1*	0.8	*0.2*	1.7	*0.7*	1.8	*0.9*
22	(+)-Aromadendrene	1438	0.6	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*
23	*β*-Farnesene, (E)-	1456	0.2	*0.0*	0.3	*0.1*	0.0	*0.0*	0.4	*0.0*	0.5	*0.0*
24	Germacrene-D	1480	1.5	*0.6*	0.7	*0.4*	0.6	*0.2*	1.5	*0.8*	1.6	*1.0*
25	Bicyclogermacrene	1488	0.3	*0.0*	0.5	*0.0*	0.0	*0.0*	0.5	*0.0*	0.4	*0.0*
26	Ledene	1495	0.0	*0.0*	0.3	*0.0*	0.0	*0.0*	0.6	*0.1*	0.6	*0.0*
27	Spathulenol	1576	0.0	*0.0*	0.3	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*
28	Virdiflorol	1594	0,8	*0.4*	0.0	*0.0*	0.0	*0.0*	0.7	*0.2*	1.2	*0.0*
	Monoterpene hydrocarbons		4.6		8.0		3.2		4.3		4.5	
	Oxygenated monoterpenes		92.8		87.1		96.4		93.4		94.5	
	Sesquiterpene hydrocarbons		4.6		2.4		1.9		5.1		5.7	
	Oxygenated sesquiterpenes		0.8		0.3		0.0		0.7		1.2	

[a]: Components are listed in order of elution on CP-Wax 52 CB Columns, [b]: Retention index, *sd*: Standard deviation

and northern latitudes. It is known to have lower menthol content in summer harvests compared to autumn harvests due to the temperature, which is an effective factor for the proper growth of peppermint. In the study conducted in Adana and Pozantı, both of which are located in the same geographical region with Isparta, the menthol ratios were higher from Pozantı with high altitude and low temperature than Adana with a semitropical climate (Özgüven and Kırıcı, 1999).

4. Conclusions

As a result of the research, the following conclusions were obtained: Citaro, Tokat CL-8, and Chocolate contained oil with high menthol resulting in satisfied oil quality. The

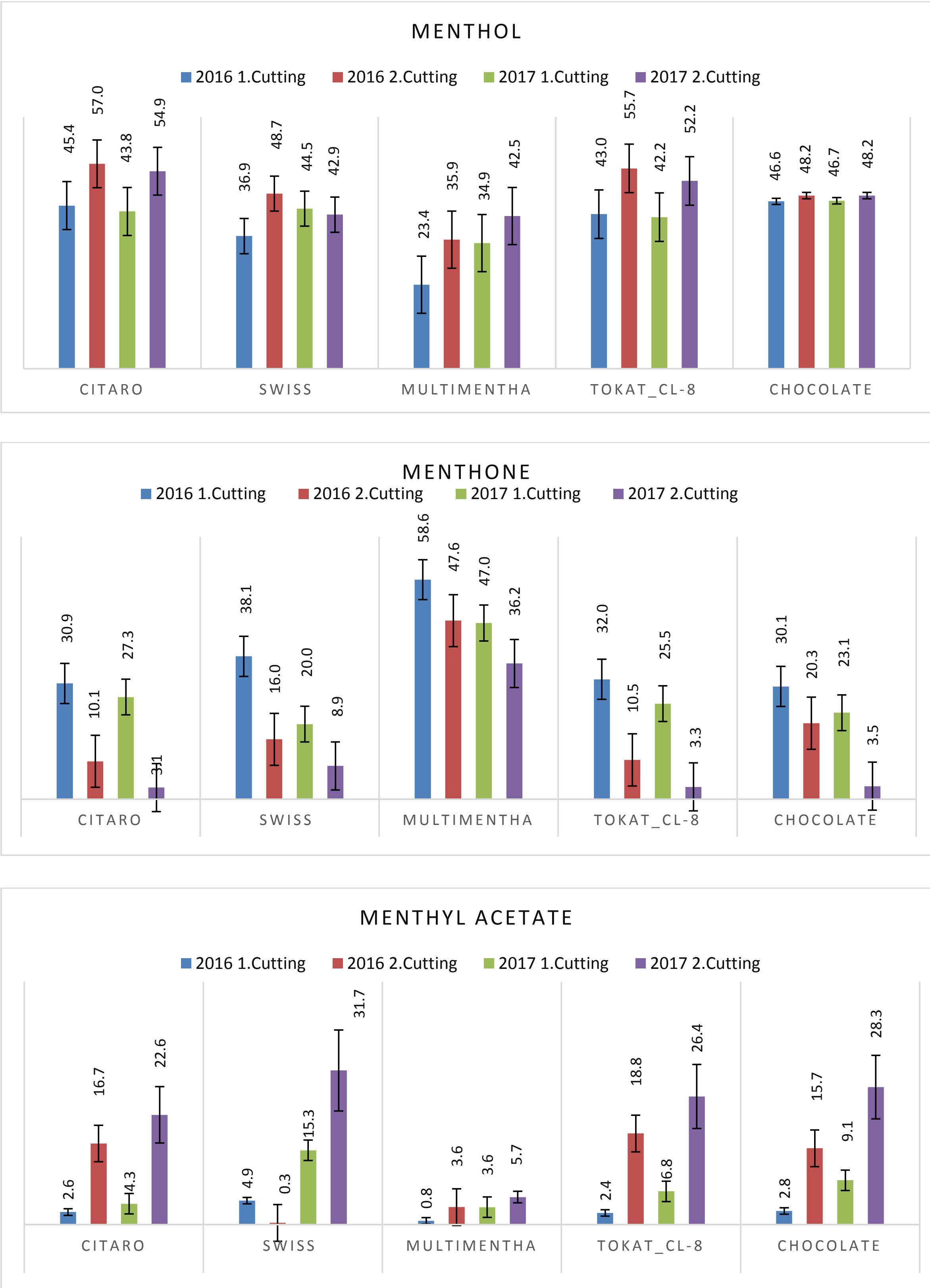

Figure 4. Variation of menthol, menthone, and menthyl acetate contents of the peppermint clone and cultivar according to cutting seasons and years.

essential oil quality of Multimentha was not satisfactory for the sector because of the low menthol contents, although the highest herb yields were obtained from the cultivar during the study. While the Citaro, Tokat CL-8, and Chocolate cultivars contained essential oil with high menthol content, Multimentha, which achieved the highest herb yield during the study, contained essential oil having low menthol content of 34%, which is an insufficient level for the mint-oil industry. Varieties responded differently to the changing climate conditions of the harvesting seasons (summer and autumn) and years. The menthol contents of Citaro and Tokat CL-8 were variable, and in the meanwhile, Chocolate's remained more stable throughout the years and seasons. In conclusion, the essential oils quality of cultivars grown in the Isparta climate, except Multimentha, are suitable for the European Monogram (ESCOP, 2019).

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Conflict of interest
The authors declare no conflict of interest.

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