*Turk J
Field Crops
2023, 28(2), 323-332
DOI: 10.17557/tjfc.1371206*

ASSESSING THE IMPACT OF CUTTING SEASON ON THE YIELD, ESSENTIAL OIL, AND COMPOSITION OF SPEARMINT CULTIVARS

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Received: 04.10.2023

ABSTRACT

The objective of this study was to assess the productivity, oil content, and composition of two spearmint species, *Mentha spicata* and *M. suaveolens*, during different harvesting periods in the continental climate of the Lake Region of Turkey. The study was conducted during at a two-year period, including both summer and autumn cutting seasons in 2016 and 2017. The investigation revealed a significant increase in yields during the summer harvest season. Carvone emerged as the predominant compound, with the exception of the Pinedo cultivar. Carvone contents of the genotypic variations were from 28.0% to 51.0%, exhibiting heightened concentrations during the initial harvest, followed by a subsequent reduction during the autumn harvest season. The major components of the Pinedo was piperitenone oxide, accounting for 67.0% of the oil, and underwent a decline during the autumn harvest.

Keywords: Cultivar, main component, *M. spicata* L., *M. suaveolens*, seasonal variation

INTRODUCTION

The genus *Mentha*, which belongs to the Lamiaceae family, consists of 31 species worldwide (Tucker and Naczi, 2007). Some of these species, such as *Mentha arvensis*, *M. x piperita*, and *M. spicata*, are of economic significance due to the presence of valuable essential oils including menthol, menthone, carvone, pulegone, and piperitenone oxide (Telci et al., 2010).

The essential oils of carvone-rich spearmint species (*Mentha spicata*, *M. gracilis*, *M. longifolia*, *M. villoso-nervata*, and *M. suaveolens*) have a range of industrial uses, including in food, cosmetics, and cleaning products (Kokkini, 1992; Kokkini et al.,1995; Telci and Sahbaz, 2005). Additionally, the fresh and dried leaves of these species, which are rich in carvone, are used as spices and in the preparation of hot and cold beverages such as herbal tea. In recent years, the inclusion of compounds like piperitone, piperitenone, and piperitone oxide, which are predominantly found in some natural mint species, on commercial lists of essential oils has also increased the commercial value of mint oils with different chemotypes, such as piperitone, piperitonone, and piperitone oxide, due to their potential uses in fields like aromatherapy, cosmetics, pharmaceuticals, and chemicals (Aksit at al., 2013; Božović et al., 2015; Llorens-Molina et al., 2017).

In *Mentha* species, yield and quality are directly proportional to appropriate growing conditions and repeated cutting times during the vegetation period. Studies have shown that the yields and oil compositions of these plants are influenced by a complex interplay of genetic and environmental factors. Specifically, the climate and soil properties, humidity levels, temperature regime, photoperiod, diurnal temperature fluctuations, water availability, and plant age all significantly impact herb yields and oil compositions of the plants (Clark and Menary, 1979; Clark and Menary, 1980; Charles and Simon, 1990; Farooqi et al., 1999; Telci and Sahbaz, 2005). The results of these studies highlight the need for a comprehensive understanding of the underlying mechanisms that govern these interactions in order to optimize the growth and development of *Mentha* species.

The yield and oil compositions variations observed in mint species during the growing season are contingent upon the provision of optimal growing conditions. Studies have shown that the accumulation of essential oils, which are particularly concentrated in trichomes, can be influenced by seasonal variation (Gershenzon et al., 2000; Tiwari, 2016). For instance, in a study on peppermint (*Mentha piperita*), there were significant differences in essential oil and menthol content depending on the cutting season, but no differences in essential oil composition were observed in spearmint (*Mentha viridis*) (Alvarenga et al., 2021).

Similarly, in a study involving four different mint species (*Mentha arvensis*, *M. piperita*, *M. longifolia*, and *M. spicata*), significant changes in essential oil yield and composition were observed depending on the seasonal growth stage (Hussain et al., 2010). However, it should be noted that the effects of seasonal variation on essential oil accumulation in mint species are complex and unclear, with evidence from limited studies indicating scarce results. As such, further research is needed to gain a comprehensive understanding of the effects of climatic and seasonal factors on essential oil production in mint species and its other chemotypes such as carvone, piperitenone oxide.

The Turkish province of Isparta boasts a highly developed essential oil and cosmetics industry, a result of its extensive cultivation of both roses and lavender. In fact, Isparta provides about 50% of Turkey's rose oil production (Ministry of Agriculture and Forestry, 2022). Along with the economic and trade benefits of rose and lavender cultivation, it also has positive effects on the sociocultural structure of the region. As investors and growers seek to expand beyond just rose and lavender, they are interested in increasing production of valuable medicinal plants such as mint, immortelle, and sage. However, farmers often lack important information on which cultivars of these plants will thrive in the region and produce high-quality essential oils. In this study, we aimed to address this knowledge gap by examining the adaptation of Spearmint varieties to the climate of Isparta, including seasonal variations in summer and autumn harvests.

MATERIALS AND METHODS

Climate and soil characteristics

This study was conducted in Isparta, a city located in the Lakes Region of Turkey. Isparta has a climate that is transitional climate between hot-summer Mediterranean (Koppen climate classification: Csa) and temperate continental (Trewartha climate classification: Dc) (Peel et al., 2007). Most of the precipitation in the region falls during the winter months, while the summers are hot and dry. The lakes in the region have a moderating effect on the climate. The dry period in the region begins in the late spring and irrigation is often needed, especially for irrigated crops. This dry period lasts until the end of September. During the years 2016 and 2017, when the field studies were conducted, the temperature in the region was higher than average and there was more precipitation than the long-term average for the region (Figure 1) (Yilmaz and Telci, 2022).

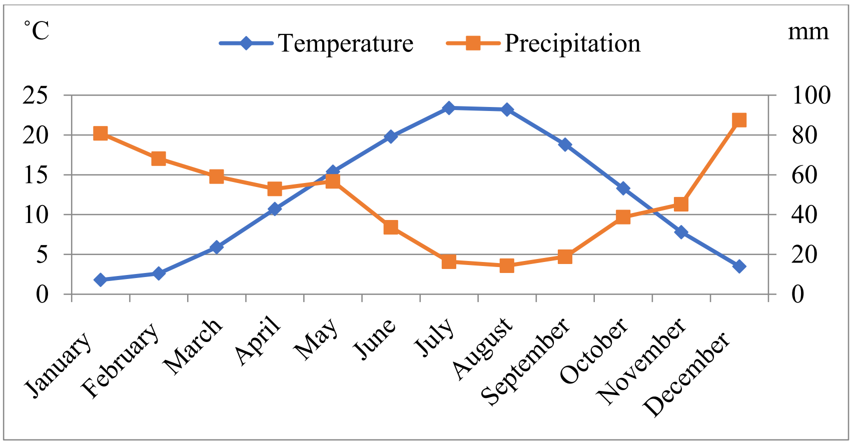

Figure 1. Long-term diagram of climate (Yilmaz and Telci, 2022)

The precipitation regime in the experimental area was irregular during the study years. Rainfall in February 2017 was lower than in 2016; however, the plants were not affected by the drought because they were in their dormant period. Irrigation was needed at the end of May and June to meet the plants' water needs. The temperatures in July and August of the study years were higher than in previous years (Figure 1 and 2) (Yilmaz and Telci, 2022). The first cuttings were made in mid-July in both years, while the second cuttings were taken at the beginning of October when the temperatures decreased and the differences between daytime and nighttime temperatures increased.

The soils of the region have a calcareous structure, which is typical of the Mediterranean region. According to soil analysis, the soil texture was clayey loam, and the salinity was low. The potassium oxide (K_2O) content was sufficient, while the phosphorus (P_2O_5) content was low. The tested soil had a high amount of lime and medium alkalinity (pH 8.07), and the organic matter content was sufficient (Table 1).

Table 1. Physical and chemical properties of the soil in the study area

Soil Texture	pH	Salinity (%)	$CaCO_3$ (%)	Organic Matter (%)	Available P_2O_5 (kg da^{-1})	Available K_2O (kg da^{-1})
Clayey-Loamy	8.07	0.02	22.2	2.7	4.8	72.0

Plant material

Mint is a common name for the genus *Mentha*, which includes valuable spice and essential oil plants. In this study, four commercial cultivars of *M. spicata* and *M. suaveolens* (Applemint, Pinedo, Crispa, and Maracco) and a clone (Clone-T.) selected from local genotypes (landraces) were used as the plant material (Table 2).

Table 2. Cultivars and clones used in the present study

No	Genotypes	Type	Status	Origin	Plant properties
1	Applemint	*M. suaveolens*	cv	Europe	Habitus erect and leaves rugros
2	Pinedo	*M. suaveolens*	cv	Europe	Rugros and white margins leaves
3	Crispa	*M. spicata*	cv	Europe	Delicate curly leaves
4	Maracco	*M. spicata*	cv	Maracco	Slightly wavy rigid leaves
5	Clone-T.	*M. spicata*	sc	Turkiye	Delicate leaves

cv: cultivated variety; sc: selected clone from Turkey

Field experiments

The field study was conducted at the Agriculture Faculty of the Isparta University of Applied Sciences (37°45'N, 30°33'E). Running cuttings of the cultivars were planted in experimental plots in the fall of 2015 using a Randomized Complete Block Design (RCBD) with three replications (Duzgunes et al., 1987). The plants were spaced 30 cm apart in rows and 20 cm apart within rows in parcels. The plots were fertilized with 50 kg ha^{-1} P_2O_5 and 50 kg ha^{-1} nitrogen. The plants were irrigated with a drip irrigation system and protected from weeds by hand hoeing. Although the field studies were established in the fall of 2015, the first cuttings were done in 2016. The plants were harvested twice each vegetation periods of 2016 and 2017, with the first cutting in July and the second cutting in October, at the beginning of the flowering period in both years.

In both crop seasons, the plant biomass was quantified by weighing the harvested samples in parcels, and the herb yields per hectare were calculated from the fresh herb biomass. The harvested herbs were dried in room conditions for essential oil distillation. The essential oil was subsequently isolated from the dried leaves, and the chemical composition of the oils was analyzed using gas chromatography-mass spectrometry (GC-MS) analysis.

Essential oil distillation

Essential oils were extracted from dried leaves by hydro distillation using a Clevenger distillation apparatus. Twenty grams of dried leaves were distilled with 500 mL of water for 2 hours. The accumulated oil in the graduated burette was measured in mL100 g^{-1} (%) (Yilmaz and Telci, 2022). The essential oil samples were stored at 4°C until they were analyzed for their components.

Essential oil composition

Gas chromatography with flame ionization detection (GC-FID) and gas chromatography with mass spectrometry (GC-MS) analyses of the essential oil compositions were performed using a QP Shimadzu 5050 gas chromatography and mass spectrometer at the Suleyman Demirel University Experimental and Observational Student Research and Application Center. The samples were diluted in hexane and then injected into the clone CP-Wax 52 CB (50 m × 0.32 mm; film thickness = 0.25 µm) column to separate the components. The initial temperature of the column was 60°C, and it was increased by 10°C per minute up to 250°C. The temperature was then held at 220°C for five minutes. The injection block temperature was 240°C, and the detector temperature was 250°C. The detector energy flow was set at 70 eV, and the ionization method was EI. Helium was used at a flow rate of 20 mL min^{-1} The flow rate was set at 10 psi. The components of the essential oils were identified by comparing their retention times to those of authentic standards and by comparing their mass spectral fragmentation patterns to those in the WILLEY and NIST database/Chem Station data system.

Data evaluation

1. The randomized complete block design (RCBD) with three replications was used in the field study. The variance of fresh herb yield and essential oil content was analyzed with the year, cultivars, and harvest period as factors. F values were calculated, and the significance levels ($p \leq 0.05$ and $p \leq 0.01$) were determined using SPSS statistical software (version 18, Inc., Chicago, IL, USA). Significant differences were grouped using the Duncan multiple comparison test (Steel and Torrie, 1980).

2. The cultivars were grouped according to their essential oil chemical composition using cluster analysis with the Euclidean distance measure, along with agglomerative and hierarchical methods. The data were analyzed using SPSS version 18 (SPSS Inc.).

3. The means and standard deviations of the main components in the cultivars according to year and cutting period are shown in the figures

RESULTS AND DISCUSSION

Fresh herb yield

Applemint and Pinedo cultivars of *M. suaveolens* yielded between 10.2 and 10.7 t ha^{-1} of fresh herb, while *M. spicata* cultivars yielded between 9.1 and 10.1 t ha^{-1}. There was little difference in fresh herb yields between cultivars of both species, and the differences were statistically insignificant. Yields during the summer cutting period were higher than those in the autumn cutting period. Additionally, the number of plants per unit area increased due to the development of lower buds and running stems after cutting, leading to higher yields in the second year compared to the first year (Table 3).

The long development period, spring precipitation, and high relative humidity in the first cutting season contributed to better plant growth and higher yields. The development of new buds after the cutting in first year caused high herb yield in first cutting of second year with suitable growing conditions. The plants were cut in October in second cutting. The decrease in sunlight and temperature and the difference in day and night temperature during the autumn negatively impacted plant development and resulted in lower yields from the second cutting crops (Clark and Menary, 1979; Clark and Menary, 1982; Farooqi et al., 1999).

Table 3. Fresh herb yield values of mint clones and varieties (t ha^{-1})

	2016		2017		
Cultivar	**1. cutting**	**2. cutting**	**1. cutting**	**2. cutting**	**Mean** $_{\text{Cultivar}}$
M. suaveolens					
Applemint	9.3	9.2	13.8	8.4	10.2 ^{ns}
Pinedo	9.0	9.1	13.4	11.5	10.7
Mean $_{\text{years×cutting}}$	**9.2**^{b**}	**9.1**^{b}	**13.6**^{a}	**9.9**^{b}	
M. spicata					
Crispa	8.8	8.0	13.2	9.6	9.9 ^{ns}
Maracco	9.6	8.8	11.1	6.8	9.1
Clone T	11.2	8.0	12.3	9.1	10.1
Mean $_{\text{years×cutting}}$	**9.9**^{a**}	**8.3**^{b}	**12.2**^{a}	**8.5**^{b}	

**$p \leq 0.01$; ns: non-significant

Although there are morphological differences within the *Mentha* species, the fresh herb yield of Pinedo cultivar in *M. suaveolens* species was the highest, yet the variation in fresh herb yields among cultivars was statistically insignificant. Studies on the yield potential of these mint cultivars are limited, so it is difficult to compare the results of previous studies in terms of yield. The values of the yields obtained in this study under Isparta conditions were lower than those obtained in the Central Black Sea climate, ranging from 18-36 t ha^{-1} (Telci et al., 2010). There were significant changes in the genotypes × years interactions in the studies (Figure 3). Although the yields in the second year were higher than those in the first year due to cutting, some mint species experienced a decrease in yield after the second year due to physiological aging (Telci and Sahbaz, 2005).

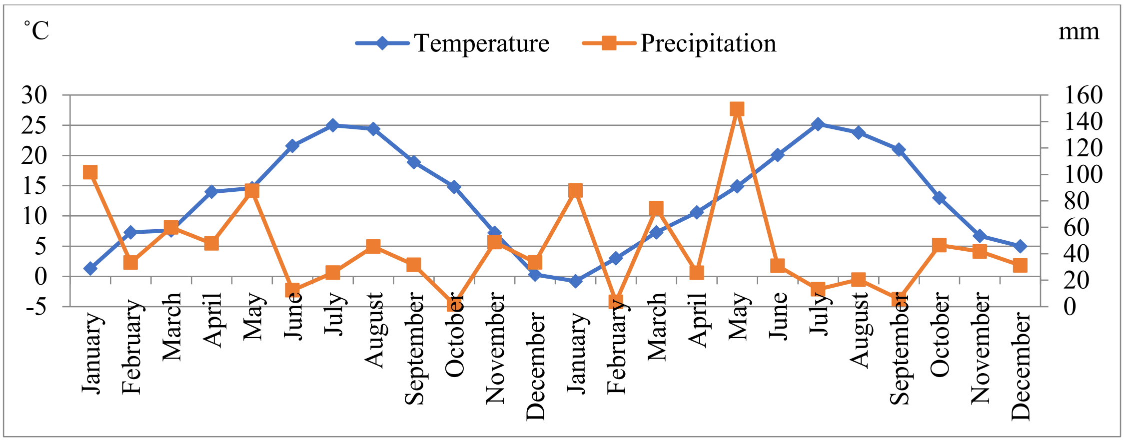

Figure 2. Temperature and precipitation data of the experimental area at Isparta in 2016-2017

Essential oil content

The differences in essential oil contents between the main factors year, cutting, and genotypes and interactions were significant in this study (Table 4). The results showed that higher values of oil content were obtained in the first cuttings compared to the second cuttings in both years. The essential oil content of the cultivars varied between 1.4% (Pinedo; *M. suaveolens*) and 2.9% (Maracco; *M. spicata*). The highest essential oil content of 2.9% was obtained from Maracco in both years and cutting seasons. As previously mentioned, interactions of factors were statistically significant (Table 4 and Figure 4).

So, Pinedo cultivar showed the greatest difference in essential oil content between the two cutting periods and was more affected by climatic conditions (e.g., temperature, precipitation) during these seasonal periods. For instance, the average temperature in July 2017 was higher than that in July 2016, and we observed that the Pinedo cultivar is more sensitive to temperature changes. The essential oil ratios of the first cutting period were higher in the cultivars except for Maracco in the second year.

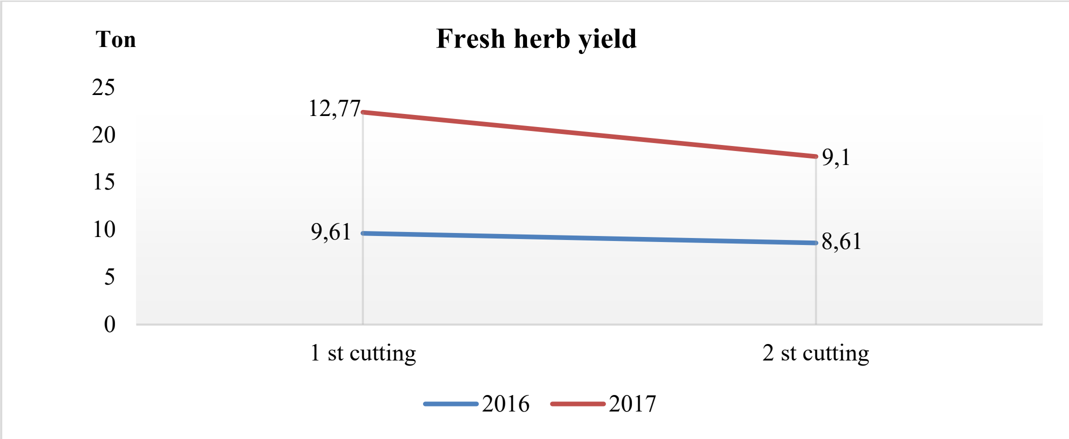

Figure 3. Variation in year × cutting season (Y x C) interaction of fresh herb yield (t ha^{-1})

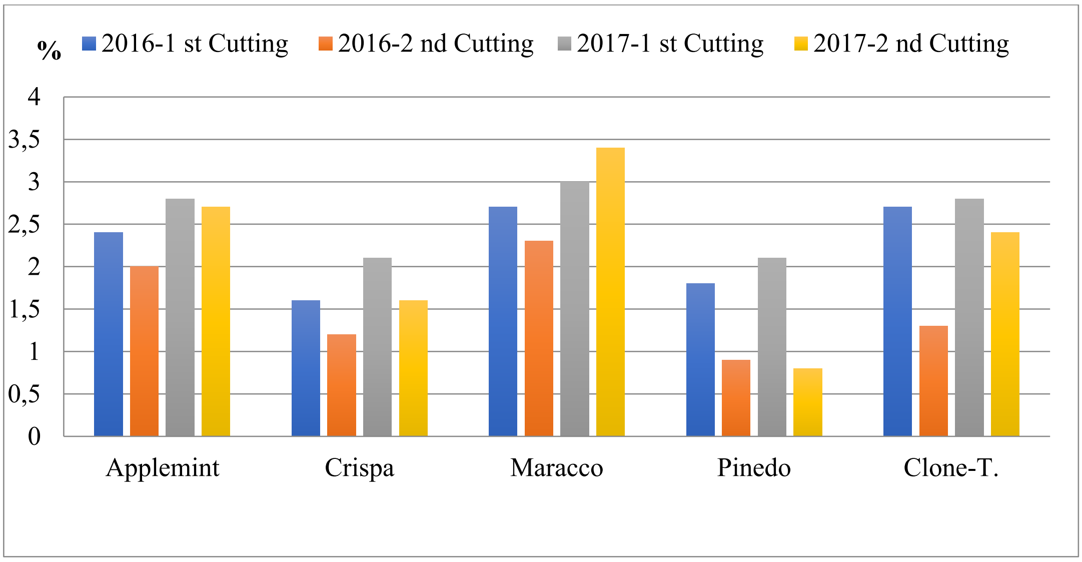

Figure 4. Variation in year × cutting season (Y x C) interaction of essential oil ratio (%)

Climatic factors such as temperature, light intensity, and relative humidity, which are present during the summer season coinciding with the first cutting season, increased the essential oil contents (Clark and Menary, 1982; Sangwan et al., 2001; Telci et al., 2010; Telci et al., 2011). However, the changing climate conditions in October, including decreasing temperature and differences in day-night temperature, decreased the essential oil contents (Figure 2).

In this study, the average essential oil contents were significantly higher in the second year compared to the first year. In addition to climate, the age and morphological and physiological differences of the mint species, which are perennial, may also contribute to the differences in essential oil contents in subsequent years.

Essential oil components

In this study, the essential oil components of the spearmint clones and cultivars were identified using GC-MS and quantified with GC-FID. The changes in composition are shown in Table 5.

Two different chemical groups were identified through cluster analysis. The first group consisted of D-carvone-rich chemotypes including Applemint, Crispa, Maracco, and Clone-T. The other group was the piperitenone oxide rich chemotypes, which contained only one cultivar (Pinedo, *M. suaveolens*) (Figure 5).

Compared to the mean values in the carvone-rich chemotype, the highest carvone content was 51% in Clone-T, followed by the Applemint cultivar of *M. suaveolens* at 40.8%. In Clone-T. and Applemint cultivars, limonene was the second most abundant component at 12.8 and 14.0%, respectively. While there are many chemotypes rich in carvone, chemotypes with piperitone oxide, piperitenone oxide, *trans*-dihydrocarvone, and linalool have also been characterized in spearmint species (Baser et al., 1999; Baser et al., 2012; Aksit et al., 2013). In the mint species group, the main component in the cultivated varieties of *M. spicata* is carvone. In a study conducted with traditionally grown local genotypes of mint in Turkey, the carvone ratio in *M. spicata* ranged from 28-82% (Telci and Sahbaz, 2005; Aksit et al., 2013). The second most abundant compound was 1,8-cineole or limonene. In a previous study, Husain et al. (1988) determined the carvone and limonene ratios in *M. spicata* to be 56.6 and 27.3%, respectively. Baser et al. (2012) found that *M. spicata* has an essential oil content of carvone (59-77%), limonene (2-23%), 1,8-cineole (1-7%), and *trans*-dihydrocarvone (1-4%).

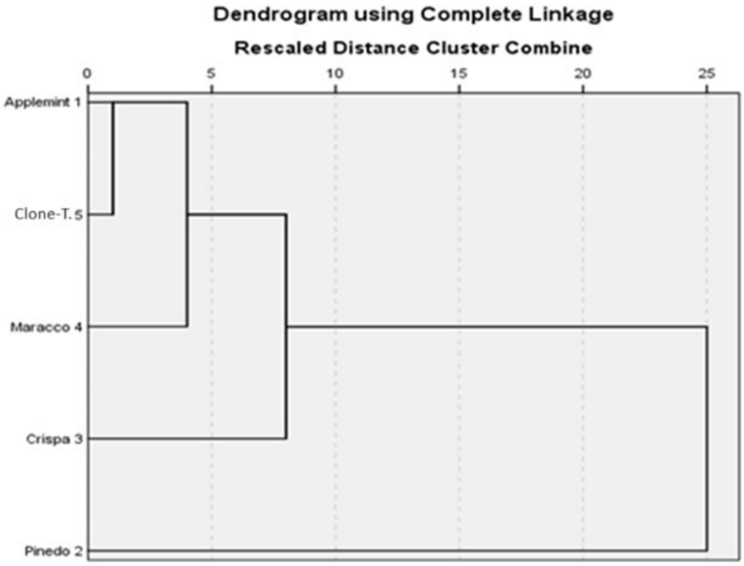

Figure 5. Clustering of genotypes according to oil composition composition in spearmint cultivar

Table 4. Essential oil contents of mint genotypes (Genotype × year × cutting interaction**)

	2016		2017		
Cultivar	**1. cutting**	**2. cutting**	**1. cutting**	**2. cutting**	**Mean** Cultivar
M. suaveolens					
Applemint	2.4	2.0	2.8	2.7	2.4a**
Pinedo	1.8	0.9	2.1	0.8	1.4b
Mean years×cutting	**2.1a****	**1.4a**	**2.4a**	**1.8a**	
M. spicata					
Crispa	1.6	1.2	2.1	1.6	1.6b
Maracco	2.7	2.3	3.0	3.4	2.9a
Clone T	2.7	1.3	2.8	2.4	2.3a
Mean years×cutting	**2.3a****	**1.6a**	**2.6a**	**2.5a**	

**$p \leq 0.01$; ns: non-significant

As mentioned earlier, there are different chemotypes within the same species of *Mentha*. In a study on the *M. suaveolens* species, it was found that the main components were piperitenone oxide (63-77%) and limonene (2-6%). The Applemint cultivar can be classified as a carvone-rich chemotype of *M. suaveolens*, with a carvone content ranging from 20.03 to 61.55% throughout the study (Figure 6) and an average value of 40.8% (Table 5).

The Maracco and Crispa cultivars in the carvone group belong to the *M. spicata* species, and the carvone ratios in these cultivars were found to be 41.8 and 28.0%, respectively, throughout the study. Among these varieties, it was determined that the second most abundant compound after carvone in the Maracco cultivar was *cis*-dihydrocarvone, the isomer of carvone, at 27.8%. In the Crispa cultivar, 1,8-cineol (eucalyptol) and isomentone were the other important compounds. The main component of the essential oil in the Pinedo cultivar, belonging to the *M. suaveolens* species and classified as the second chemical cluster in this study, was piperitenone oxide at 67%. The oil was found to be 4% piperitenone oxide, with limonene as the second most abundant.

Table 5. Essential oil components of spearmint clones and varieties.

			Mentha suaveolens				*Mentha spicata*					
		RI*	Applemint		Pinedo		Crispa		Maracco		Clone-T.	
No	Component		mean	*sd*	mean	*sd*	mean	*sd*	mean	*sd*	mean	*sd*
1	*α* -Pinene	933	0.8	0.1	0.8	0.1	1.0	0.1	0.8	0.1	1.0	0.1
2	Camphene	953	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4
3	Sabinene	972	0.7	0.0	0.5	0.2	0.0	0.0	0.5	0.1	0.9	0.1
4	*β* -Pinene	978	1.2	0.1	1.7	0.1	2.0	0.1	1.0	0.1	2.0	0.1
5	*β* -Myrcene	991	0.7	0.1	0.9	0.3	2.8	1.0	0.6	0.1	0.7	0.2
6	3-Carene	1009	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
7	Limonene	1030	14.0	1.4	4.6	1.6	7.1	1.1	7.6	1.3	12.8	2.1
8	1,8-Cineole	1032	6.4	1.0	0.2	0.0	12.5	0.2	3.2	0.2	9.1	0.5
9	*cis*-Ocimene	1035	0.3	0.1	0.9	0.5	1.6	0.3	0.1	0.0	0.3	0.1
10	*γ*-Terpinene	1058	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.1
11	*trans*-Sabinene hydrate	1099	0.1	0.0	0.1	0.0	1.0	0.8	0.3	0.1	1.8	1.1
12	Terpinolene	1086	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0
13	Linalool	1101	0.1	0.0	0.2	0.1	1.3	0.1	0.3	0.1	0.4	0.1
14	Isomenthone	1158	0.1	0.1	0.3	0.2	8.9	2.3	0.2	0.2	0.4	0.1
15	Menthol	1184	0.0	0.0	0.5	0.2	4.7	0.5	0.0	0.0	0.1	0.0
16	*cis*-Dihydrocarvone	1199	15.3	9.6	0.3	0.2	0.7	0.2	27.8	13.6	6.8	2.3
17	Carvone	1246	40.8	16.6	1.0	0.2	28.0	3.1	41.8	13.7	51.0	3.6
18	Piperitone	1267	1.0	0.2	0.3	0.1	1.0	0.3	0.0	0.0	0.0	0.0
19	Menthyl acetate	1290	0.0	0.0	0.2	0.3	5.0	2.8	0.0	0.0	0.0	0.0
20	Dihydrocarvyl acetate	1325	7.4	6.1	0.0	0.0	0.6	0.1	3.6	1.9	2.9	1.8
21	Piperitenone	1339	0.2	0.1	0.3	0.1	0.1	0.1	0.2	0.0	0.3	0.1
22	Piperitenone oxide	1366	0.0	0.0	67.0	11.7	0.0	0.0	0.0	0.0	0.0	0.0
23	*α* -Copaene	1375	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	*β* -Bourbonene	1382	1.8	0.4	0.4	0.2	1.3	0.1	2.2	0.6	1.5	0.3
25	*β* -Elemene	1390	0.1	0.0	0.2	0.1	0.1	0.0	0.1	0.0	0.1	0.0
26	Jasmone	1394	0.3	0.0	1.3	0.3	0.5	0.1	1.4	0.1	0.0	0.0
27	Caryophyllene	1460	1.5	0.4	0.8	0.4	4.7	0.9	1.5	1.0	1.3	0.4
28	Germacrene-D	1480	0.2	0.0	0.1	0.0	0.2	0.0	0.2	0.0	0.2	0.1
29	*β*-Farnesene	1439	0.3	0.1	1.7	0.7	0.7	0.1	0.1	0.0	0.1	0.1
30	Bicyclogermacrene	1497	0.1	0.0	0.0	0.0	0.3	0.1	0.2	0.1	0.0	0.0
31	Spathulenol	1576	0.1	0.0	0.0	0.0	0.5	0.0	0.4	0.1	0.0	0.0
32	Caryophyllene oxide	1587	0.3	0.1	0.1	0.1	0.8	0.2	0.4	0.1	0.4	0.1
33	*α*-Copaene	1375	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1	0.1	0.0

* RI, retention indices relative to C6—C24 n-alkane

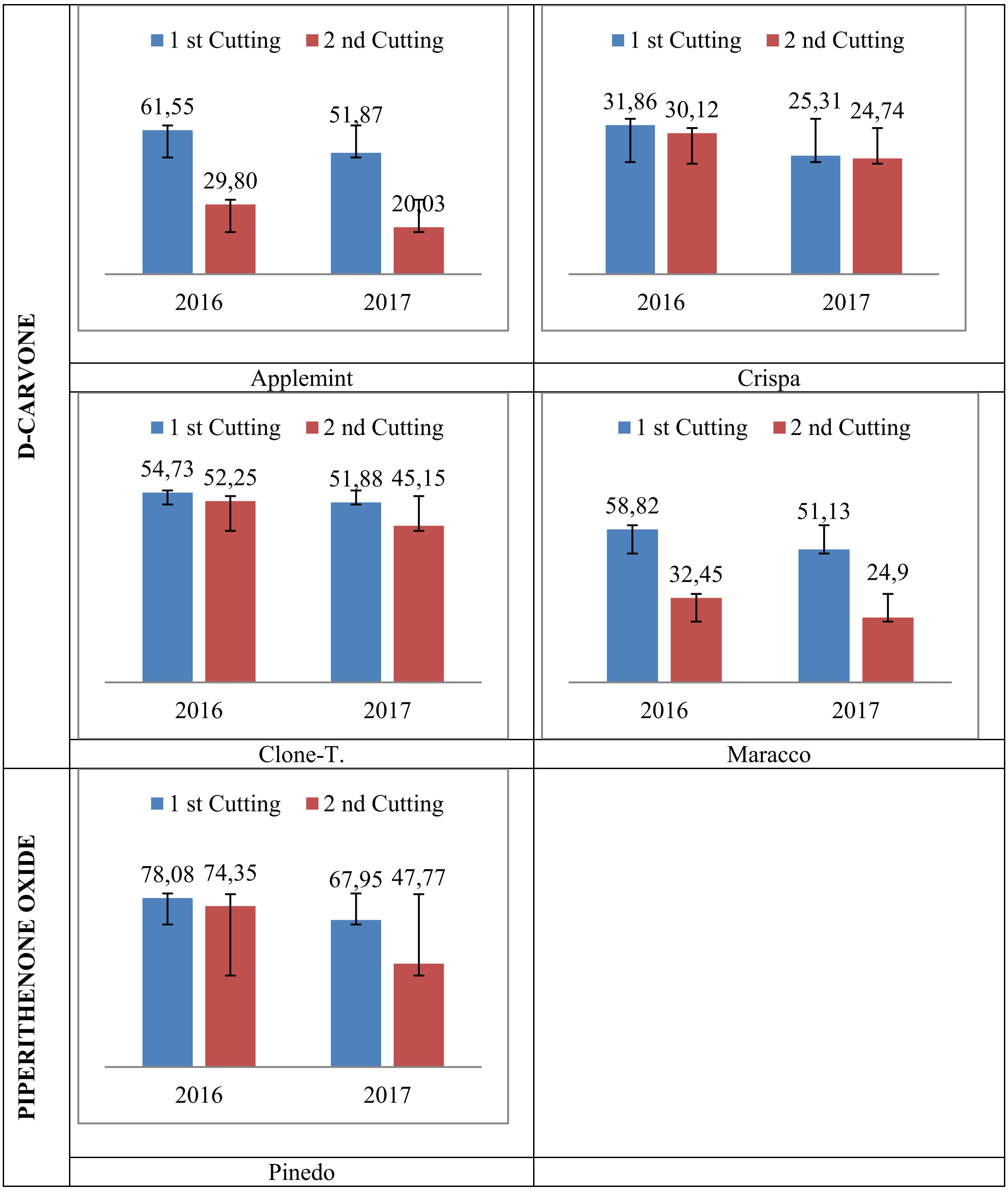

Figure 6. Yield and seasonal variation of main components spearmint cultivar (%)

Year and seasonal variation

In this study, the changes in the main components were examined according to year and cutting periods (Figure 6). The carvone-rich cultivars showed different responses depending on the year and season. The values of the main component, carvone, were higher in the first year compared to the second year and in the summer cutting compared to the autumn cutting of the second year in all carvone-rich cultivars. However, the variations in carvone contents between cuttings were limited in both years in the Crispa and local Clone-T. (landraces) with approximately similar values. The differences between cutting periods were more significant in the Applemint and Maracco cultivars, particularly in the first cutting. While the carvone synthesis of these cultivars (Applemint and Maracco) was more affected by climatic changes during the cutting period, that of the Crispa and Clone-T was more stable. The piperitenone oxide content, the main component in Pinedo, was higher in the first year and in the first cuttings, but the change between cutting periods was greater in the second year. It is known that optimal growth conditions during plant development positively affect the synthesis of main components. The optimal climatic conditions (e.g., temperature, sun exposure) for plant growth in the first cutting season influence the synthesis of organic matter and, consequently, the synthesis of main components. However, the genetic control of plants varies according to cultivars, and thus their responses to changing climatic conditions may be different. The large fluctuations in carvone levels in the Applemint and Maracco cultivars can be attributed to the greater effects of climatic factors on the carvone synthesis mechanism in these cultivars.

Monoterpenes in *Mentha* species are concentrated in glandular trichomes (Gershenzon et al, 1989). A study on *M. spicata* subsp. *spicata* found that plants with a large number of peltate glandular hairs contain a high concentration of essential oils, including carvone (Yetisen, 2011). The amount of carvone in *M. spicata* varies based on the genetic structure of the plant and the climatic conditions in which it grows. It is believed that these factors influence the ratio of essential oils and seasonal changes in the plants, possibly due to heat stress.

CONCLUSION

In this study, which was carried out to determine yield and oil composition according to vegetation periods, significant changes were observed in essential oil components, especially depending on varieties, as well as yields. The yields from the first cutting were higher than those from the second cutting in the study, and the highest fresh herb yields were obtained from the Pinedo (*M. suaveolens*) and Crispa (*M. spicata*) cultivars. The main component in all samples, except for Pinedo, was carvone, while the main component of Pinedo was piperitenone oxide. It was determined that the main components of all cultivars were highest under the climatic conditions of the summer cutting periods, when the highest yields were obtained. In addition, the degree of flexibility of the main components depended on the cultivars. The carvone ratios were high in the first cuttings in both years in the carvone-rich cultivars, but the variations in carvone between cutting seasons were unstable in the Applemint and Maracco cultivars, while they were stable in the Crispa and Clone-T. In other words, the carvone contents in the Maracco and Applemint cultivars were more affected by seasonal variation. Due to the seasonal variation of the cultivars, differences should be considered in their cultivation to account for variations in quality.

ACKNOWLEDGMENT

This manuscript is based on Selma Yasak's MSc Thesis, which was supervised by Dr. Telci. The authors declare that they have no conflicts of interest.

The research and publication ethics guidelines were followed in this study. Ethical committee approval was not required for this study.

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