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The Effects of Natural Boron Mineral on the Essential Oil Ratio and Components of the Spearmint (*Mentha spicata* L.)

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ABSTRACT

This study was carried out to determine the effects of boron mineral on the essential oil ratio and quality in spearmint (*Mentha spicata* L.) species. Different boron doses (0, pure and 1/2 dose, 1/8 dose (8 L decare^{-1})) were applied in this study, but no measurement could be take due to plant death in the pure dose and 1/2 dose. The essential oils of spearmint harvested at two different time were obtained by the method of hydro-distillation. In the analyses by GC_MS/FID (Gas Chromatography/Mass Spectrometry - Flame Ionization Detector), the essential oil ratio based on boron doses was measured as 1.25% for the boron-free condition and 2.22% for the 1/8 dose, the main essential oil components were a total of 35 components in the leaves (without boron), and 29 components for the 1/8 dose. The main essential oil components obtained from the leaves (without boron) were Carvone by 55.12%, Limonene by 9.99%, 1,8-cineole by 8.81% while those for the 1/8 dose were Carvone by 56.02%, Limonene by 14.22%, 1.8-cineole by 6.79% in the first harvest. The essential oil components were found to be rich in terms of terpenes. In this study, which is the first study in which boron mineral was applied to spearmint with the application of boron mineral in solution form, the recommended dose for spearmint was found to be 1/8 boron dose.

Keywords: Spearmint, Liquid boron application, GC/MS-FID, Essential Components

1. Introduction

The mint plant is a member of the Lamiaceae (Labiatae) family. It is a perennial medicinal and aromatic plant which has a prevalent distribution around the world and a very high economic significance due to its valuable essential oil. Mint, which is used prevalently in important industrial fields such as food, perfumery, cosmetics and especially medicine because of its tannin, pulegone, isomenthon, methyl acetate, menthone and especially menthol compounds that it contains, is also a significant spice plant with its leaves (Herro & Jacob 2010; Baydar 2013). As Mentha species have a highly polymorphic structure and a tendency for hybridization, they show high diversity. Highly variable numbers of mint species have been reported between 20 and 90 around the world. 42 species are registered in the Plant List, and there are 2.524 Latin names including synonyms and subspecies for these species. 15 taxa belonging to 10 species are distributed in Turkey. Among mint species, especially species such as *M. piperita* (peppermint), *M. spicata* (spearmint), *M. arvensis* (wild mint) and *M. pulegium* (pennyroyal) are significant species (Neset 2018). *M. spicata* is also named as *M. viridis*. Carvone and D-limonene, 1,8-Cineole and Myrcene are significant components of the essential oil obtained from the plant *M. spicata*. Carvone is prominently used as a scent and flavor addition for food items such as liqueur and chewing gum and to improve the flavor of soaps, perfumes and toothpaste due to its pleasant scent, as potato germination inhibitor, building block and biochemical environment indicator. Carvone has also found an area of usage in the drug industry as it has different biological effects such as antibacterial and antifungal activities (De Carvalho & Da Fonseca 2006). D-limonene is used due to its pleasant citrusy scent, clinically to dissolve cholesterol-containing gallbladder stones and to alleviate heartburn as it has an effect that neutralizes stomach acid and repairs peristalsis. It is also known that D-limonene has a chemo-preventive effect against several types of cancer (Sun 2007). It was reported that mint contains terpenes such as N-menthol, neomenthol, isomenthol, d-menthone, isomenthon, menthofuran, methyl acetate, carvomenthone, cineol, limonene, piperidone, O-pinene, carvacrol, N-pinene, and dipentene, but these compounds vary based on the season, climate and the structure of the plant. In addition to this, it was also stated that mint contains flavonoids such as quercetin, mentosit, isoroifolin, vitamin K, thymol and eugenol. It was reported that all these components have antioxidative and free radical preventive effects and these flavonoids increase the antioxidant enzyme potential (Jagetia et al. 2002). While pure boron minerals have been utilized from the past to the present, with the industrialization and advanced technology in recent years, the demand and need for boron minerals have been increasing day by day. In the agriculture sector, boron minerals are used in areas such as biological improvement and control chemicals, fertilizers, insecticides-herbicides, weed control. As boron is highly compatible with having bonds with oxygen, it forms several different oxygen compounds. Due to this characteristic of boron, it has 230 different minerals that have been determined so far. The commercial value of seven of these minerals is high. High-value minerals are water-soluble boron salts such as tincal and kernite, and non-water-soluble minerals such as colemanite, ulexite, pandermite, boracite, and sassolite. Boron minerals that have high-grade contents are more valuable and demanded more (Yenmez 2009). The deficiency and toxicity range of boron is remarkably narrow. Fertilization may be the solution of the deficiency problem, while a set of procedures can be utilized to ameliorate soil boron toxicity. However, these approaches are costly and time-consuming, and they do not have permanent effects most of the time. Plant species and also the genotypes within the species are highly different in terms of their boron requirements. So, a sort of soil boron which is accepted deficient for one crop may exhibit toxic effects on another (Brdar-Jokanović 2020).

The region (Kutahya) where this study was carried out is a region that is rich in boron minerals in Turkey. Boron can be very useful and cheap fertilizer for crops in the region. With this study aimed to determine to suitable dose of boron for essential oil yield and quality of spearmint.

2. Material and Methods

2.1. Plant material

Spearmint (*Mentha spicata* L.) was used as plant material in the trial. The plant materials (spearmint seedlings) were obtained from the Kutahya Municipality Hekim Sinan Botanical Garden. *Mentha spicata* L. kind is a perennial and herbaceous species with shorter, bright green color, pale blue flowers, flowers at the ends of the branches and spike-shaped and similar to *M. piperita*. Soil analysis of the trial area in Kutahya is given in Table 1. The Gediz district of the province of Kutahya has a microclimate that is hot and dry in summers, has precipitation in winters. The warmest months in Gediz are July and August, while the coldest ones are January and February. The lowest measured temperature is 5.5 °C. The amount of annual precipitation is 483.08 mm. The months with the most precipitation are May and June, while the one with the least precipitation is September (Anonymous 2017). These temperatures are appropriate for the plant to grow. Boron is found in nature not as a single element but as compounds in combination with multiple elements. Its more frequently encountered compounds include Na, Ca and Mg. Those with Na origins are known as tincal (borax), calcium-rich ones are known as colemanite, sodium and calcium-rich ones are known as ulexite (Yenmez 2009). The type of boron that was used in this study was colemanite. Chemical analysis of the natural boron mineral to be used in the field trials was carried out (Table 2

Table 1- Pre-sowing chemical analysis of experimental soil

Soil variables	*Values*	*Status*
Potassium (K_2O; kg ha^{-1})	20.01	Medium
Phosphorus (P_2O_5; kg ha^{-1})	6.23	Medium
Lime (%)	4.03	Limy
Organic matter (%)	0.78	Very little
Total salts (%)	0.003	Salt-free
pH	7.14	Neutral
Saturation (%)	53.3	Clay and loam

Table 2- Chemical analysis of pure boron mineral

Nutrient/ element	*Calcium*	*Potassium*	*Magnesium*	*Sodium*	*Iron*	*Manganese*	*Zinc*	*Copper*	*Nickel*	*Cadmium*	*Chromium*	*Cobalt*
Units	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	µg kg^{-1}	µg kg^{-1}	µg kg^{-1}	µg kg^{-1}	µg kg^{-1}
Values	108.9	19.66	33.22	58.68	0.680	0.042	0.10	<10	<10	<10	0.034	<10

2.2. Field trial

The field trial was carried out in 2016–2017 in the medicinal and aromatic plants trial field of the Gediz Vocational School at Dumlupınar University. It located in the Gediz district of Kutahya, Turkey - 39°0'27.65" N, 29°24'14.66" E; 802 m above sea level. The seedlings started to be planted into the field beginning with April 2016. In both years, experiment was conducted with a randomized complete block design in triplicates.

The dimensions of each planting area were 40 cm × 30 cm. A total of 72 plants were planted by 24 plants per plot. There were 3 rows of plants in each plot, and each plot had an area of 1.6 m × 3 m. Observations and measurements were made on leaf samples obtained from 9 plants labeled in 72 healthy plants in each plot. Since the first year was the plantation year and the plant growth was too low, no and measurement could be taken and no doses were applied. In the trial, 4 different boron mineral doses (0, pure and 1/2 dose, 1/8 dose [8 L decare^{-1}]) were applied on the spearmint planted plots. Boron mineral started to be given when the plant reached 10 cm of height in all plots in the second year. The mineral was given as 100 ml of fluid per plant and re-applied as 50 ml of fluid one month later. Boron minerals that were given without processing led the plants to dry.

Experiment was irrigated considering rainfall, air temperature, and humidity in the soil to save plants from moisture stress. No other additives or fertilizer were applied to the plant neither before nor during the planting session except for boron mineral. The weeds were observed and they were cleared manually. In the second year, two harvests (24.05.2017 and 10.09.2017) were made, and the beginning of flowering was preferred as the harvest time.

2.3. Extract preparation

The extract that was used in our study was prepared from natural boron minerals. The boron mineral obtained from the Emet region was powdered, and afterward, the powdered boron mineral was weighed as 20 g and shaken in 100 ml of distilled water and homogenized for 5 minutes. The boron in the homogenate form was centrifuged at 3500 rpm for five minutes. Its supernatant part was taken and kept in a fridge. This extract to be used was applied as pure or by dilution with distilled water in ratios of 1/2 and 1/8 (Karayel 2006).

2.4. Essential oil isolation and determination of essential oil composition by GC-MS

Samples were diluted 1: 100 with hexane for analysis. At the beginning of the trial essential oil analysis, 20 g of dry material was weighed and taken in a 500 ml flask. Samples were diluted with 1% hexane and injected into gas Chromatography in 1 µl with 40:1 split ratios. Agilent 7890A Capillary columns (HP InnowaxCapillary; 60.0 m x 0.25 mm x 0.25 µm) were used to separate the components. The column was split into two fractions at a rate of 1:1 using a splitter in the FID and mass spectrometry detector (Agilent 5975C). Helium was used as carrier gas at a flow rate of 0.8 mL/min. The injector temperature was maintained at 250 °C, the column temperature program was 10 minutes at 60 °C, raised at 4 °C/minute (40 minutes) at 60 °C and 220 °C and 10 minutes at 220 °C. The detector was set for 60 minutes. The scan range (m/z) for the mass detector was 35-450 atomic mass units and the electron bombardment ionization energy was 70 eV. The data of Wiley and Oil Adams libraries were taken as basis in the diagnosis of the components of the essential oil. The data from the FID detector were used for the volatile oil component ratios (Tabanca et al. 2006).

3. Results and Discussion

3.1. Essential oil ratio (%)

The first year (2016) measurement was not taken to determine the essential oil ratio and components. The reason for this may be explained as that the spearmint plant's adaptation to the soil and the ecological environment could not be completely achieved, and the development of the plant was low. It arrived at the harvest period by completing 50% flowering till the end of the 2017 May. Two harvests for aerial parts of plants at flowering periods were made on 24.05.2017 and 10.09.2017 in the second year. Considering the flowering dates of the plant based on the doses, it was determined that the 1/8 boron dose reached the first and complete flowering dates earlier than the other doses. The plants under the treatment of the 1/8 boron dose started flowering earlier, while those under the boron-free started later. In this context, in our study, the 1/8 boron dose provided more than 1.5% essential oil contents. The lowest essential oil ratio was 1.25% in the boron-free, while the highest one was 2.22% in the 1/8 boron dose. Figure 1 shows the comparison of the amounts of essential oil ratio for the boron-free dose and the 1/8 boron dose (%).

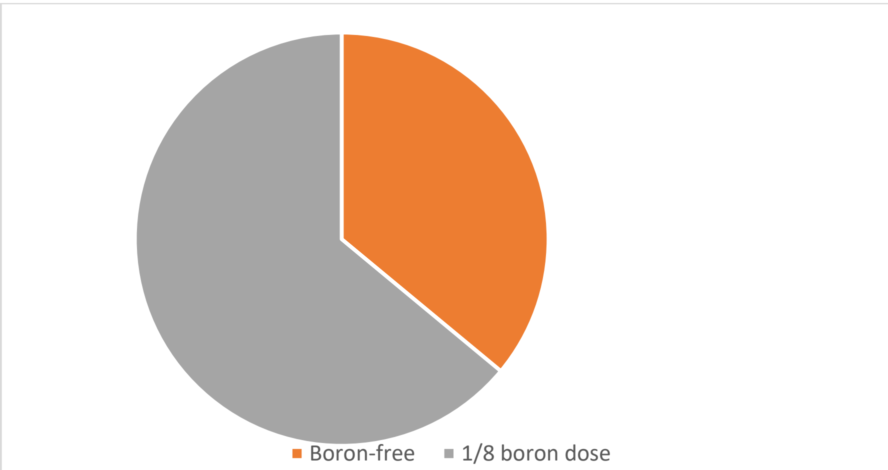

Figure 1- Comparison of the essential oil ratios of the spearmint based on the boron-free dose and the 1/8 dose of boron

Considering previous studies on the essential oil ratio, the ratios of essential oils obtained by hydro-distillation of the spearmint plant dried with different methods were found between 0.95 and 3.16% (Kripanand et al. 2015). In Pozantı location of Adana, the essential oil yields of spearmint varied in the ranges of 0.25 – 3.11 L da^{-1} in the 1st year and 0.37 – 3.66 L da^{-1} in the second year (Ozguven & Kırıcı 1999). There were significant differences among the essential oil ratios of spearmint dried in different drying conditions (Shade, stove 35 °C and 50 °C). The highest essential oil ratio (1.7%) was obtained from the samples dried in shade. In the spearmint dried in a stove, the essential oil ratio was 1.3% in those dried at 35 °C and by 0.6% in those dried at 50 °C (Karakapan 2017). In parts of the mint plant (*Mentha piperita* L.), the highest amount of oil was obtained as 3.18% by drying the tip in shade, while the lowest was obtained as 2.40% by drying the same part in sunlight. In the middle part, the highest amount of oil was obtained as 2.07% by drying in a stove, the lowest was obtained as 1.58% by drying in sunlight, while in the bottom part, the highest was obtained as 1.11% by drying in the stove, and the lowest was obtained as 0.92% by drying in sunlight (Ozer 2012). Essential oil is obtained from the flowering fresh plant by steam distillation with an average yield of 0.6%. Its major components are; 1-carvone (40-70%), limonene (20%), carveols, carvone isomers, carvyl acetate, as well as menthol, borneol, linalool, menthol, jasmone, perilalcol, monoterpenes and sesquiterpenes (Akgul 1993). The essential oil amounts of the *Mentha spicata* L. (spearmint) species determined based on different fertilizer doses (0 da^{-1} N, 5 da^{-1} N and 10 kg da^{-1} N) and drying methods varied between 1.4% and 2%. It was reported that fertilizing with nitrogen increased the essential oil content (Buyukbayraktar 2014). In Mentha arvensis, boron supply between 0.5 and 1.0 g (B) m^3 was optimal for the maximum shoot and root growth and essential oil yield per plant. There was no significant effect of B supply on the relative percentage of menthol, menthone and methyl acetate in the oil. The incorporation of (U-14C) saccharose into the essential oil increased significantly with increasing B supply. The impacts of foliar boron fertilization on the yield of flower heads as well as the chemical composition, content, and yield of essential oils (EO) of *Arnica montana* L. and *A. chamissonis* were studied. The content of EO was from 0.174% to 0.200% and from 0.158% to 0.188%, respectively. The highest EO content in the inflorescences of the two plants was noted at the B rate of 200 g ha^{-1}. Similarly, this dose caused a ca. 35% and 43% increase in the EO yield in *A. montana* and *A. chamissonis*, respectively (Sugier et al. 2017). Our results regarding spearmint's essential oil ratio and the effect of boron application on essential oil ratio are in agreement with previous studies.

3.2. Essential oil composition (%)

In the analysis of the essential oil at different boron doses (boron-free and 1/8 dose 8 L $decare^{-1}$) in spearmint (*Mentha spicata* L.), in the second year, 35 - 29 components were identified from the dried leaves. These components constituted respectively 96.71% and 99.31% of the average total essential oil in the dried leaves (average of the first and second harvests). The values of the components of the essential oil obtained from the leaves of the *Mentha spicata* L. species were determined in the specimens obtained in two harvests in the 2nd year. The values of the essential oil components of the *Mentha spicata* L. species are separately shown in (Table 3) (boron-free dose) and Table 4 (1/8 boron dose). The main components obtained from the dry leaves according to the average measures of the first and second harvest for boron-free dose are as follows: Carvone 54.57%, Limonene 9.68%, 1,8-cineole 8.88%, β-caryophyllene 3.88%, Myrcene 3.49%, Trans-Sabinenehydrate 2.41%, Carvacrol 1.21%. On the other hand, the main components obtained from the dry leaves according to the average measures of the first and second harvest are as follows for 1/8 boron dose, Carvone 56.07%, Limoneneby 14.2%, 1,8-cineole 6.80%, Myrcene 3.54%, β-caryophyllene 2.50%, Trans-Sabinenehydrate 2.32%, Carvacrol 1.60%. Other components are also shown in Tables 3 and 4. Figure 2 shows the comparison of the amounts of essential oil components for the boron-free dose and the 1/8 boron dose (%). As the boron dose was diluted the essential oil ratio increased, the essential oil components decreased, and some components were not obtained (Tables 3-4). Limonene, which was one of the main components obtained in the 1/8 boron dose, was found as 14.2% and higher than the values obtained in boron-free application (Table 4). According to the doses applied to the *Mentha spicata* L. species, the essential oil components varied to some extent. The top component in the *Mentha spicata* L. species was carvone by 55.12% without boron application, while it was the same but by 56.02% in boron application at the 1/8 dose in the first harvest. Boron with 1/8 dose had an increaser affect to carvone compound in the essential oil of spearmint. In the *Mentha species*, the composition of the essential oil determines its quality and flavor. This composition changes depending on ecological conditions, variety and harvest times. When the main components of essential oils are compared according to their harvest averages it was found out that the average values of 1,8-Cineole, trans-Sabinenehydrate, β-Caryophyllene components of the boron-free dose application were higher than of 1/8 boron dose application. Akgul (1993) stated that the most important components of *M. spicata* L. species are Carvone (40-70%) and Limonene (20%). Considering this statement of Akgul, it was seen that 1/8 boron dose had a significant effect on Limonene and Carvone components. The positive result on *M. spicata* L. strain increased as the dose of boron was diluted. The results obtained from the dose effect trials between boron-free dose and 1/8 boron dose are given in Table 5. According to pharmacopeia, in *M. piperita* oil, the rates should be as menthol by 50–78%, menthone by 10–30%, menthofuran by 2.5–5% and methyl acetate by 5–10%, while for *M. spicata* oil, the carvone ratio should be 42–67% (Wagner et al. 1984). Considering previous studies on essential oil component ratios, the menthol ratios of *M. piperita* species were found to be low (6.23–40.47%) in comparison to *M. arvensis* (66.20–72.29%). In *M. spicata* ssp. spicata, the carvone ratio varied in the range of 39.38–69.41%. The menthol ratios obtained in Adana were usually closer to or smaller than the lower limit of the range stated by researchers as 50–78%. The carvone ratio in *M. spicata* ssp. spicata varied in the range of 39.38–69.41%, which was within the range stated by researchers (Ozguven & Kırıcı 1999). The carvone ratio of spearmint leaves was found as 51.9–52.4 (Zheljazkov et al. 2014). The carvone ratio of spearmint leaves varied in the range of 39.38–69.41%, which was within the range specified by researchers (Singh et al. 1995; Wagner et al.

1984). The most important component for the oil of mint (*Mentha piperita* L.) was L-menthol, and it was found to be the highest occurring component in oils obtained from the tips and bottom parts (not the middle parts) by sun-drying (at least 30.50% – at most 42.58%). The ratio of this component increased from the tip to the bottom part, while the highest increase was in the bottom part material (Ozer 2012). The main components of essential oils included high rates of menthone and menthol in *M. piperita*, while these two compounds were found to be very low or non-existent in *M. spicata* and *M. villoso-nervata*. On the other hand, these two species contained higher ratios of carvone. The significant components of them were carvone, limonene and 1,8 cineol (Cam et al. 2012). Menthone was found to be 0.42% in the boron-free application and 0.48% in the 1/8 boron dose application. No L-menthol was obtained in the boron-free application and for the 1/8 boron dose application. Ratios of essential oil components in spearmint determined for different doses of N (0 da^{-1} N, 5 da^{-1} N and 10 kg da^{-1} N), the carvone ratio varied in the range of 49.70–61.50% (Buyukbayraktar 2014). The carvone and limonene ratios in the essential oil of spearmint were found as 4.52–60.54% and 9.44–51.90% respectively (Antal et al. 2011). The carvone and limonene ratio of the essential oils of spearmint leaves were found as 9.09–67.62% and 13.08–55.36% respectively (Kripanand et al. 2015). Our results regarding spearmint's essential oil composition and the effect of boron application on essential oil composition are in agreement with previous studies.

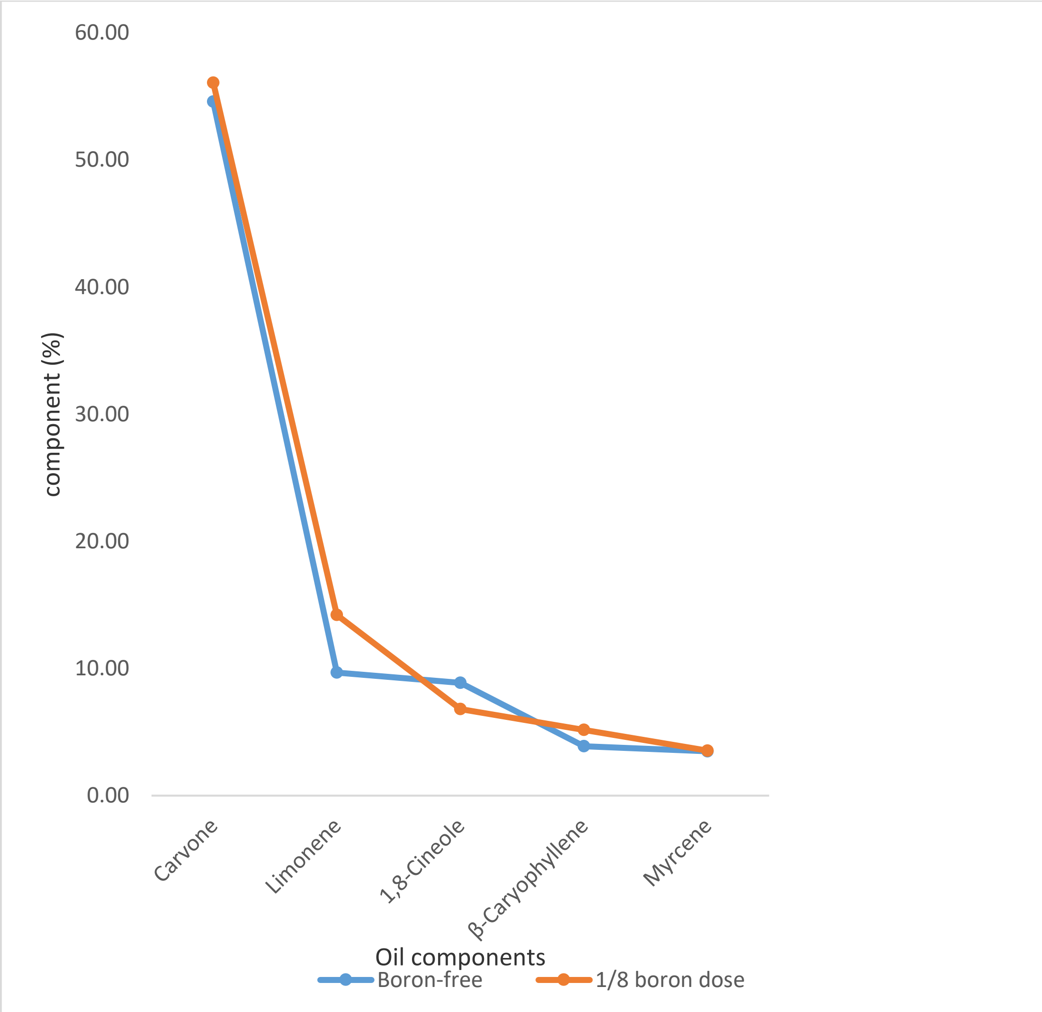

Figure 2- Comparison of the essential oil components of the spearmint for the 1/8 boron dose and the boron-free dose

Table 3- Effect of different doses of boron mineral on essential oil components (%) obtained from the leaves of Mentha spicata L. (Boron-free dose)

		Leaf					
S.no	*Component Name*	*RI*	*RT*	*1st Harvest*%*	*RT*	*2nd Harvest*%*	*Harvest Average*%*
1.	*α*-Pinene	1011	11.42	1.15±0.025	11.28	1.35±0.085	1.25±0.055
2.	*β*-Pinene	1096	14.84	1.52±0.030	14.41	1.65±0.050	1.58±0.040
3.	Sabinene	1082	15.43	0.99±0.130	13.12	0.78±0.088	0.88±0.109
4.	Myrcene	1123	17.24	3.43±0.102	14.85	3.56±0.097	3.49±0.099
5.	*α*-Terpinene	1141	18.02	0.26±0.060	18.54	0.22±0.160	0.24±0.110
6.	Limonene	1160	18.92	9.99±0.162	19.39	9.38±0.242	9.68±0.202
7.	1,8-Cineole	1171	19.43	8.81±0.126	18.10	8.95±0.020	8.88±0.073
8.	*cis*-*β*-Ocimene	1192	20.47	0.49±0.068	21.80	0.45±0.151	0.47±0.109
9.	ϒ-Terpinene	1204	20.92	0.44±0.040	21.42	0.38±0.090	0.41±0.065
10.	*trans*-*β*-Ocimene	1227	21.10	0.15±0.065	21.38	0.12±0.171	0.13±0.118
11.	Terpinolene	1241	22.52	0.17±0.105	23.24	0.15±0.155	0.16±0.130
12.	3-Octanol	1344	26.71	0.77±0.098	26.53	0.78±0.070	0.77±0.084
13.	Hexyl isovalerate	1397	28.74	0.18±0.087	30.12	0.12±0.183	0.15±0.135
14.	*trans*-Sabinene hydrate	1417	29.48	2.44±0.061	30.40	2.38±0.162	2.41±0.111
15.	Menthone	1425	29.76	0.41±0.075	28.90	0.44±0.128	0.42±0.101
16.	*cis-3*-hexenyl isovalerate	1439	30.20	0.23±0.095	31.11	0.18±0.075	0.20±0.085
17.	*β*-Bourbonene	1475	31.44	1.04±0.140	30.86	1.00±0.140	1.02±0.140
18.	Linalool	1490	32.05	0.11±0.085	18.89	0.08±0.075	0.09±0.080
19.	*β*-Elemene	1543	33.73	0.13±0.116	33.68	0.10±0.111	0.11±0.113
20.	*β*-Caryophyllene	1552	34.01	3.91±0.036	34.18	3.85±0.065	3.88±0.050
21.	*trans*-Dihydrocarvone	1567	34.52	0.32±0.050	34.27	0.34±0.096	0.33±0.073
22.	Dihydrocarvyl acetate	1618	36.10	0.48±0.086	36.78	0.38±0.104	0.43±0.095
23.	*α*-Humulene	1623	36.25	0.12±0.100	35.78	0.08±0.070	0.14±0.085
24.	Bicyclosesquiphellandrene	1625	36.34	0.23±0.079	36.98	0.18±0.07	0.20±0.074
25.	*α*-Terpineol	1642	36.84	0.25±0.088	36.08	0.24±0.090	0.24±0.089
26.	Borneol	1646	36.92	0.36±0.083	35.86	0.34±0.072	0.35±0.077
27.	Germacrene - D	1663	37.40	1.78±0.070	38.01	1.72±0.100	1.75±0.085
28.	Bicyclogermacrene	1686	38.15	0.38±0.090	37.85	0.33±0.110	0.35±0.100
29.	Carvone	1691	38.34	55.12±0.100	38.12	54.02±0.155	54.57±0.127
30.	*cis*-Carvyl acetate	1713	38.90	0.27±0.090	38.14	0.23±0.098	0.25±0.094
31.	*trans*-Carveol	1773	40.64	0.09±0.065	39.24	0.07±0.056	0.08±0.060
32.	*cis*-Carveol	1801	41.45	1.53±0.045	41.56	1.50±0.090	1.51±0.067
33.	*cis*-Jasmone	1892	43.8	0.46±0.095	43.65	0.43±0.095	0.44±0.095
34.	Caryophyllene oxide	1939	45.05	0.23±0.066	45.21	0.21±0.086	0.22±0.076
35.	Carvacrol	2129	49.71	1.23±0.065	49.76	1.20±0.075	1.21±0.070
	Total (%)			99.47		97.19	96.71

*Each value represents the mean ± standard deviation of triple analyses, RI: Retention indices; RT: Retention time (min)

Table 4- Effect of different doses of boron mineral on essential oil components (%) obtained from the leaves of Mentha spicata L. (1/8 boron dose)

		Leaf					
S.no	*Component Name*	*RI*	*RT*	*1st Harvest*%*	*RT*	*2nd Harvest*%*	*Harvest Average*%*
1.	*α*-Pinene	1011	11.40	1.17±0.055	11.41	1.22±0.070	1.19±0.062
2.	*β*-Pinene	1096	14.80	1.45±0.035	14.85	1.34±0.070	1.39±0.052
3.	Sabinene	1082	14.26	0.95±0.015	15.43	0.82±0.050	0.88±0.032
4.	Myrcene	1123	17.40	3.67±0.026	17.24	3.42±0.102	3.54±0.064
5.	*α*-Terpinene	1141	-	-	-	-	-
6.	Limonene	1160	18.29	14.22±0.070	18.91	14.18±0.072	14.2±0.071
7.	1,8-Cineole	1171	20.15	6.79±0.068	19.40	6.82±0.051	6.80±0.059
8.	*cis-β*-Ocimene	1192	21.10	0.28±0.040	20.36	0.22±0.070	0.25±0.055
9.	*Υ*-Terpinene	1204	19.46	0.21±0.070	20.89	0.18±0.085	0.19±0.077
10.	*trans-β*-Ocimene	1227	-	-	-	-	-
11.	Terpinolene	1241	-	-	-	-	-
12.	3-Octanol	1344	26.12	0.41±0.055	26.69	0.46±0.080	0.43±0.067
13.	Hexyl isovalerate	1397	-	-	-	-	-
14.	*trans*-Sabinene hydrate	1417	29.21	2.38±0.090	29.42	2.27±0.055	2.32±0.072
15.	Menthone	1425	30.12	0.50±0.380	29.70	0.46±0.065	0.48±0.222
16.	*cis-3*-hexenyl isovalerate	1439	31.24	0.20±0.358	30.18	0.22±0.070	0.21±0.214
17.	*β*-Bourbonene	1475	30.24	0.67±0.020	31.44	0.72±0.070	0.69±0.045
18.	Linalool	1490	32.00	0.09±0.045	31.97	0.06±0.030	0.07±0.037
19.	*β*-Elemene	1543	-	-	-	-	-
20.	*β*-Caryophyllene	1552	34.21	2.55±0.085	34.00	2.46±0.097	2.50±0.910
21.	*trans*-Dihydrocarvone	1567	33.69	1.42±0.051	34.47	1.44±0.061	1.43±0.056
22.	Dihydrocarvyl acetate	1618	36.25	0.91±0.040	36.08	0.85±0.055	0.88±0.047
23.	*α*-Humulene	1623	36.30	0.11±0.070	36.25	0.14±0.110	0.12±0.090
24.	Bicyclosesquiphellandrene	1625	35.12	0.15±0.065	36.27	0.20±0.052	0.17±0.058
25.	*α*-Terpineol	1642	-	-	-	-	-
26.	Borneol	1646	36.10	0.31±0.050	36.92	0.28±0.090	0.29±0.070
27.	Germacrene - D	1663	37.09	1.14±0.072	37.40	1.22±0.070	1.18±0.071
28.	Bicyclogermacrene	1686	38.56	0.35±0.068	38.10	0.38±0.051	0.36±0.059
29.	Carvone	1691	38.71	56.02±0.080	38.26	56.12±0.080	56.07±0.080
30.	*cis*-Carvyl acetate	1713	38.24	0.41±0.070	38.89	0.38±0.090	0.29±0.080
31.	*trans*-Carveol	1773	40.21	0.14±0.090	40.57	0.17±0.098	0.15±0.094
32.	*cis*-Carveol	1801	40.75	1.01±0.111	41.36	1.04±0.125	1.02±0.118
33.	*cis*-Jasmone	1892	43.52	0.34±0.040	43.79	0.30±0.080	0.32±0.060
34.	Caryophyllene oxide	1939	45.12	0.30±0.061	45.01	0.28±0.153	0.29±0.107
35.	Carvacrol	2129	48.86	1.59±0.045	49.70	1.62±0.119	1.60±0.082
	Total (%)			99.74		99.27	99.31

Table 5- Comparison of the main components of essential oils of boron-free and 1/8 boron doses

Component name	Boron free harvest average	1/8 boron harvest average
Myrcene	3.49±0.099	3.54±0.064
Limonene	9.68±0.202	14.2±0.071
1,8-Cineole	8.88±0.073	6.80±0.059
trans-Sabinenehydrate	2.41±0.111	2.32±0.072
B-Caryophyllene	3.88±0.050	2.50±0.910
Carvone	54.57±0.127	56.07±0.080
Carvacrol	1.21±0.070	1.60±0.082

4. Conclusions

Considering the results of this study, the *Mentha spicata* L. species grown in the ecological conditions of Kutahya-Gediz is appropriate for this region. We may state that the 1/8 boron dose that was applied affected the essential oil ratio and its components. Limonene, 1,8- Cineole, and Carvone were determined to be the dominant essential oil components. At the 1/8 dose of boron application, the Limonene (14.22%) and Carvone (56.02%) ratios were found higher. The ratio of the essential oil was found to be the highest at 2.22% at the 1/8 boron dose ratio. After providing the spearmint plant with the 1/8 dose of boron, the compounds “trans-β-ocimene, terpinolene, Hexyl isovalerate, β-elemene, and α-terpineol” could not be obtained. It is believed that the results obtained from this study will shed light on obtaining essential oils and volatile compounds of medicinal and aromatic plants in the future. The dose to be recommended is the 1/8 boron dose since it has the minimum toxic effect on the plants and a positive effect on the essential oil yield and quality as general.

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