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Research Article

Determination of agricultural and technological characteristics of different lavender (*Lavandula angustofolia* Mill.) genotypes in ecological conditions of Çorum province *

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ABSTRACT

This study aims to determine the agricultural and technological properties of *Lavandula angustofolia* Mill. varieties under the ecological conditions of Çorum province from 2019 to 2020. Raya, Munstead, Silver, Sevtapolis and Vera lavender varieties collected from the Sungurlu district of Çorum province were used in the study. The highest plant length (60.27-68.43 cm) was obtained from Silver cv. in both years. The best fresh stem flower yield was obtained from Mustead cv. (479.2 kgda^{-1}) in 2019 and Sevtopolis cv. (545.6 kgda^{-1}) in 2020. Raya and Mustead cv. Because of these varieties are registered; after the variety name, the cv. shortening is not required gave the highest essential oil ratio in both years. In addition, it was observed that the Sevtapolis variety had the highest linalool ratio (49.07%). Also, Mustead and Sevtapolis varieties stood out in their fresh flower yield and essential oil quality.

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1. Introduction

Lamiaceae or *Labiatae* family is an extensive family containing perennial, herbaceous plants, shrubs and trees, with about 236 genera and around 7173 taxa. Species belonging to the *Lamiaceae* family spread over many continents globally and can grow in different ecological regions and distinct areas, at different altitudes and in different habitats. The *Lavandula* genus is an essential member of the *Lamiaceae* family and includes 39 known species (Paton et al., 2004). The *Lavandula* genus geographically spreads from Europe, Southwest Asia, Arabian Peninsula, North and South America and North Atlantic Islands to India via the Mediterranean Basin (Upson and Andrews 2004; Aprotosoaie et al., 2017). The genus *Lavandula* includes annual or short-lived herbaceous perennials, shrub-like perennials, short bushes or shrubs (Upson and Andrews 2004). Many members of the genus are grown extensively for their essential oils commercially and ornamentals for garden and landscape use in temperate climates. *Lavandula* species are generally known for their multiple pharmacological effects sedative, antispasmodic, anticonvulsant, analgesic, antioxidant and local anesthetic activity. They are also used for medicinal purposes (Kovatcheva et al., 2001; Kageyama et al., 2012).

The essential oils found in most of the *Lavandula* species contain 50-60 compounds consisting of monoterpenes and sesquiterpenes. These terpenes are compounds commonly found in these plants that perform important ecological functions such as repelling insects and suppressing the growth and development of other competitive plants (Gershenzone and Croteau 1991; Southwell et al., 2003; Franks et al., 2012). *Lavandula angustofolia* (lavender) *Lavandula* x intermedia (lavandin), *Lavandula latifolia* (*Lavandula spica*; spike lavender) and *Lavandula stoechas* (Spanish lavender) are widely used in medicine, food, cosmetics, perfumery and aromatherapy (Vairinhos and Miguel, 2020). Both lavender and lavandin essential oils have wide applications in a various industrial products including perfumes, pharmaceuticals, cosmetics, and personal care and home care products (Cavanagh and Wilkinson, 2002; Lesage-Meessen et al., 2015). Lavender oil content and species characteristics depend on many factors such as genotype, differences between varieties and their hybrids, climatic data, agronomic factors, and processing and storage of raw plant materials (Morgan et al., 2006; Mantovani et al., 2013; Golubkina et al., 2020). Many agronomic studies have been carried out with lavender species, and there are production and agronomic studies under organic agriculture or good agricultural practices. Many scientific studies have been conducted on yield, yield components and essential oil content in fertilization and plant density under different organic production conditions (Renaud et al., 2001). In this regard, it is of great value to analyze lavender species with economic importance in different environmental conditions and to determine especially *Lavandula angustofolia* varieties with high yield and quality that can adapt to the ecological conditions of Çorum province. Therefore, this study aims to identify the agricultural and technological characteristics of some lavender varieties of the high commercial value used for the first time within the regional conditions and determine the genotypes with high flower and essential oil yields of high adaptability.

2. Materials and methods

2.1 Plant materials and supply

The plant material of the study comprised the open rooted cuttings of Raya, Munstead, Silver, Sevtapolis and Vera varieties belonging to *Lavandula angustofolia* Mill.

2.2. Location and terrain characteristics of the trial

This study was carried out for three years (2018 was the year of establishment) between 2018 and 2020, in Çorum Province Sungurlu District Çavuş Village Toytepesi Location 0 Island 1031 parcel. The experimental area was located in the semi-arid climate zone and in terms of climate and soil conditions, it was established by planting open root seedlings in October 2018. 2018, the year of the first establishment, was not evaluated and the research was evaluated in the light of the findings that included the second year (2019) and third year (2020).

2.3. Soil characteristics of the trial field

Samples were taken from different parts of the field where the study was carried out. The slope of the trial area was very low, and there was no drainage problem. The experimental area had a clay-loam structure, and the soil pH 8.05. The findings showed that the area was slightly alkaline, the level of lime was moderate, the potassium level was good, the amount of phosphorus was sufficient and the amount of organic matter in potassium was low.

2.4. Climatic characteristics of the trial area

Table 1 shows the averages of the climate data belonging to a long-term period in the region, the monthly temperature (°C), relative humidity (%) and precipitation (mm) values during the vegetation period of the trial years.

The monthly total precipitation, average temperature and relative humidity data 2019-2020 are presented in Table 1. The total precipitation of 438 mm in the first year (2019) vegetation period was similar to the long-term average, In the 2nd year (2020), it was well below the average of 267.6 mm for long years and 2019. Especially in August 2020, precipitation of 0.0 mm was seen as an extreme situation. The average monthly temperature in the first year (2019) and the second year (2020) is similar to the long-term average, and it has been observed that the average relative humidity is higher than the long-term average in the first year and lower than the long-term average in the second year.

Table 1. Some climates data in 2019, 2020 and long-term period

Climate data	Year	Months												Total / Average
		Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Average temperature (°C)	2019	0.5	4.6	6.4	10.4	17.7	21.9	21.9	22.7	19.2	16.1	8.5	3.3	153.2 / 12.76
	2020	1.2	3.2	8.7	10.2	16.3	20.4	24.9	23.7	22.7	18.0	5.6	4.3	159.2 / 13.26
	Long -term (2013-19)	0.9	5.0	8.1	12.2	17.0	20.7	23.8	24.4	20.2	13.9	7.4	1.7	155.3 / 12.9
Total Precipitation (mm)	2019	51.3	30.6	17.6	56.8	24.0	125.2	30.2	35.7	2.1	0.3	35.0	29.7	438.5 / 36.6
	2020	21.6	67.5	13.9	21.3	37.9	90.4	7.9	0.0	5.5	5.2	14.5	9.7	295.4 / 24.6
	Long -term (2013-19)	42.07	21.54	53.43	30.2	63.89	88.31	1.8	14.81	14.53	24.16	28.91	32.81	416.5 / 34.7
Average Relative Humudity (%)	2019	88.6	78.7	63.4	69.4	61.2	69.3	58.1	61.0	56.7	60.4	70.1	91.7	828.6 / 69.03
	2020	84.5	79.5	69.3	64.6	63.7	66.3	54.0	37.0	42.5	40.1	61.7	68.4	731.6 / 61
	Long -term (2013-19)	83.5	71.3	64.2	57.66	61.6	60.9	48.6	49.3	49.1	60.4	67.6	83.7	757.8 / 63.1

Source: Meteorological Service

2.5. Planting

The research field trial was established in October 2018, and the unsprouted seedlings were replanted in April 2019. Open-rooted varieties of 15-20 cm tall were planted in the holes with 10 cm depth each, and the length between rows was 0.5 m and the length between furrows was 1.4 m. Totally 1330 plants were planted in 1 decare. A total of 450 seedlings were planted, 90 from each of the 5 varieties.

2.6. Fertilization

The research field trial was established in October 2018, and Fertilization is one of the critical parameters affecting the yield and quality of lavender. After planting in the trial field, seedlings were fertilized with 6 $kgda^{-1}$ of pure nitrogen (N) and 6 $kgda^{-1}$ of P_2O_5.

2.7. Essential oil obtaining, and essential oil components analysis

Fresh stemmed and dried lavender flowers were brought to the laboratory after harvest, 100 g of lavender flowers were added together with 1 liter of distilled water and placed in a Clevenger flask. The essential oil of the plant materials was obtained by hydro-distillation using Clevenger apparatus. The distillation process was terminated when it was observed that the amount of oil collected in the metered section did not change, and then the amount of essential oil was determined.

2.8. Essential oil components analysis

GC analysis of the essential oils from lavender flowers was performed using Agilent 6890N Network GC and 5973 Network mass selective detector GC-MS system. The analysis was performed using HP -Innowax column (60.0 m × 0.25 mm × 0.25 mm) (Agilent Technologies, USA) and helium as the carrier gas (1.2 mL min^{-1}). The operating conditions were: The oven temperature was set at 60°C for 10 min after injection, then increased to 220°C with a heating ramp of 4°C for 10 min, and then increased to 240°C with a heating ramp of 1°C min^{-1} without holding; the injector and detector (FID) temperatures were 250°C; the split ratio was set at 50:1; the injection volume was 2.0 µL. MS conditions were as follows: Ionization energy 70 eV; ion source temperature 280°C; interface temperature 250°C; mass range 34-450 atomic mass units. The compounds were identified by comparing their relative retention indices and mass spectra to those found in the literature, as well as their mass spectra to those found in the Wiley and Nist libraries. The percentages of the components were calculated from the GC peak areas using the normalization method

2.9. The statistical evaluation of trial design and trial results

The experiment was planned and established in a randomized block design with three replications. The variance analysis (VA) of the data obtained as a result of measurements and analyzes from the research was performed using the MSTAT-C (Michigan State University, version 2.10) computer package program. Differences and importance levels between lavender species and varieties were determined with MSD (Minimum Significant Difference) Test.

3. Results and discussion

Variance analysis was carried out using the plant height, the number of flower heads number of flowers per spike, fresh stem flower yield ($kgda^{-1}$), and fresh stem flower essential oil ratio (%) of lavender varieties in 2019 and 2020. The differences in the number of flower heads (pieces), number of flowers per spike (pieces), fresh stem flower yield ($kgda^{-1}$), and fresh stem flower essential oil ratio (%) of the varieties were found to be significant in both 2019 and 2020 at the level of $p \leq 0.01$. The following table (Table 2) presents the significance levels of the differences between the averages of these characteristics and the results of the MSD test. The average plant height of lavender genotypes showed a significant change in 2019, and it was found to be between 44.83-60.27 cm. The longest plant height (60.27 cm) was determined in the Silver variety. Also, the plant height of other varieties is between 43.93-46.93 cm. In 2020, the highest plant height (68.43 cm) was determined in the Silver variety and the lowest plant height (46.10 cm) was determined in Raya variety. Silver variety gave the highest value in terms of plant height in both 2019 and 2020. In different studies, it has been reported that the plant height of lavender varies between 60.4-69.5 cm (Arabaci and Bayram, 2005) and 46.1-59.8 cm (Atalay, 2008). In a similar study, the height of lavender varieties varied between 62.2-81.1 cm and the highest plant height (86.2 cm) among lavender varieties was determined in the Vera variety. Moreover, the lowest plant height (63.2 cm) was found in the Munstead variety. It was observed that the plant height of the early Raya and Munstead varieties was significantly shorter than the late maturing genotypes tested in each year of the two-year study and for an average of two years. In another study, no significant difference was found between lavender varieties in plant height, but plant height varied between 29.30-31.15 cm. It was observed that the Grosso Tina variety had the highest plant height (Balyemez, 2014). In a spiking study, plant height was found between 33.63-42.66 cm in L. angustifolia variety (Balcı, 2019). In this study, it was seen that the varieties were among the values reported in the literature in terms of plant height. In the study conducted by Özyazıcı and Kevseroğlu (2019), the plant height *in Lavandula angustofolia* varied between 30.00-40.60 cm, and the highest plant height was determined in the complete flowering phases.

The number of flower heads belonging to lavender genotypes showed a significant change in 2019, the number of flower heads per plant varied between 152.2-528.2. The highest number of flower heads per plant (528.2 pieces) was reached in the Sevtopolis variety, and the lowest number of flower heads per plant (152.2 pieces) was reached in the Silver variety. In 2020, the number of flower heads varied between 164.1 and 545.3 pieces. The highest number of flower heads (545.3 pieces) was determined this time in the Munstead variety, and the lowest number of flower heads (164.1 pieces) was determined in the Silver variety. Munstead varieties in both years and Sevtapolis varieties in 2019 stood out regarding number of flower heads. In a study, the highest flower spike (1217.8 pieces $plant^{-1}$) was found in the Raya variety compared to an average of two years, and the lowest flower spike (632.1 pieces $plant^{-1}$) in the Silver variety. The number of flower spikes of Sevtapolis and Munstead varieties was significantly higher, while the number of flower heads of the Silver variety was significantly low. When the varieties were compared in the study, Silver and Munstead varieties showed parallelism with our findings regarding their performance. However, it is seen that the varieties give lower values in terms of flower head numbers. The average number of flowers per spike of lavender genotypes showed significant changes in 2019 and 2020. In 2019, the number of flowers per spike varied between 36.10-54.40 per plant.

The highest number of flowers per spike (54.40 pieces) was determined in the Silver variety, and the lowest number of flowers per spike (36.10 pieces) was determined in the Munstead variety. In 2020, the number of flowers per spike varied between 38.00-68.07. The highest number of flowers per spike (68.07 pieces) was again in the Silver variety, and the lowest number of flowers per spike (38.0 pieces) was determined in Munstead variety. The Silver variety stood out in both years regarding the number of flowers per spike, followed by Vera. In another similar study, it was determined that the Silver variety had the highest number of flowers per spike (64.1 pieces) among lavender varieties at an average of two years. The least number of flowers per spike (29.9 pieces) was determined in the Munstead variety. The number of flowers per spike of the short and early Raya and Munstead lavender varieties was lower than the late varieties. Average fresh stem flower yield values ($kgda^{-1}$) of lavender genotypes also showed significant changes in 2019 and 2020. In 2019, the flower yield with fresh stems was 377.7-479.2 (kgda^{-1}). The highest fresh stem flower yield (479.2 kgda^{-1}) and flower yield per plant (g plant^{-1}) were determined in the Mustead variety, and the lowest fresh stem flower yield (377.7 kgda^{-1}) was found in the Silver variety.

Table 2. MSD Test results of some essential agricultural characteristics of lavender varieties

Lavender varieties	Plant height (cm)		Number of flower ears (piece)		Number of flowers per spike (piece)		Fresh stem flower yield (kgda^{-1})		Fresh stem flower essential oil ratio (%)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Raya	45.57 b	46.10 c	191.6 c	199.4 d	43.93 c	44.60 d	425.9 d	477.5 c	1.370 a	1.393 a
Vera	43.93 b	49.17 b	356.9 b	366.9 c	50.57 b	54.33 b	440.1 c	450.8 d	1.190 bc	1.190 c
Munstead	46.93 b	49.47 b	523.3 a	545.3 a	36.10 d	38.00 e	479.2 a	498.8 b	1.367 a	1.403 a
Silver	60.27 a	68.43 a	152.2 d	164.1 e	54.40 a	68.07 a	377.7 e	388.8 e	1.247 b	1.307 b
Sevtopolis	44.83 b	46.20 c	528.2 a	536.5 b	46.73 c	49.40 c	454.4 b	545.6 a	1.157 c	1.197 c
MSD (0.05)	5.665	0.822	6.762	6.782	3.195	3.346	5.669	10.81	0.084	0.059

The letters in the same column represent the statistically ($p \leq 0.05$) different groups

In 2020, the fresh stem flower yield was determined as 388.8-545.6 kgda^{-1}, while the best fresh stem flower yield (545.6 kgda^{-1}) was again in the flower yield per plant (g plant^{-1}), the lowest fresh stem flower yield (388.8 kgda^{-1}) was similarly determined in Silver variety. Silver variety gave the lowest fresh stem flower yield values in 2019 and 2020. In both years, it was observed that Mustead and Sevtopolis varieties stood out in terms of fresh stem flower yield (kgda^{-1}), and the results in flower yield per plant (g plant^{-1}). In a similar study, the lavander's highest fresh flower yield was 556.7 kgda^{-1} in the first year and 1499.0 kgda^{-1} in the third year (Arabaci and Bayram 2005). According to the combined results of two years in another fertilization experiment, the highest fresh flower yield (378.22 kgda^{-1}) in lavender was obtained when 2.5 kgda^{-1} nitrogen was applied (Atalay, 2008). In another study conducted in Isparta province, Raya, Munstead, Silver and Vera lavender varieties were used as materials. A high fresh stem flower yield was obtained from the 597.2 kgda^{-1} Raya variety compared to the two-year average, followed by Vera (569.5 kgda^{-1}), Mustead (499.2 kgda^{-1}), and Silver (476.2 kgda^{-1}) varieties. Karık et al. (2017) found the highest fresh flower yield in Munstead (232.87 kgda^{-1}) and Hidcote (186.87 kgda^{-1}) genotypes in their study. In another study conducted in Adana ecological conditions, the fresh flower yield of *Lavandula angustofolia* Mill. was determined as 14.27-18.66 kgda^{-1} according to the data obtained in the first year, and this low yield was attributed to the first planting year (Balcı 2019). Compared with all these previous studies, it is clear that Sevtopolis and Mustead varieties used in this study gave satisfactory results in flower yields. The fresh stem flower essential oil ratio (%) of lavender genotypes in the mean years showed a significant change in 2019 and 2020. The essential oil rate of fresh stem flowers in 2019 was determined as 1.157-1.370%. Raya variety gave the highest fresh stem flower essential oil ratio (1.370), followed by the Mustead variety with 1.367%. On the other hand, the Sevtopolis variety with 1.157 % was the lowest amount.

In 2020, the fresh stem flower essential oil rate changed between 1.190-1.403%, and the highest fresh stem flower essential oil rate was found in the Mustead variety with 1.403%. As of 2019, the lowest essential oil rate (1.197%) was determined in the Sevtopolis variety in 2020. Mustead and Raya varieties stood out in terms of fresh stem flower essential oil content, in both years, Sevtopolis variety contained the least essential oil content in 2019 and 2020. The total number of 39 essential oil components in fresh flowers was determined in lavander genotypes (Table 3). In fresh lavender flowers, 33 essential oil components were determined in Raya, Silver and Vera varieties, 34 number in Mustead and 28 in Sevtapolis variety.

Linalol and linalyl acetate were the most fundamental compounds in lavender genotypes. These compounds were followed by lavandulyl acetate, cis-β-ocimene and geranyl acetate. The highest linalool rate (49.071%) was found in the Sevtopolis variety compared with the other lavender varieties whereas the lowest linalool rate (24.186%) was determined in the Silver variety. In terms of linalyl acetate, the highest linalyl acetate ratio (29.993%) was detected in the Raya variety, while the lowest rate (20.959%) was detected in the Silver variety once again.

The highest lavandulyl acetate ratio (8.817%) was determined in the Raya variety, followed by Munstead with 8.148% and Sevtopolis variety with 5.662%. It was found that Raya and Silver equivalents had deficient (less than 2%) lavandulyl acetate content. Except for the Silver variety, the findings showed that the other varieties contained significant amount of geranyl acetate. The content of these four varieties varied between 2.874 and 3.528%, and the highest geranyl acetate ratio was again found in the Sevtopolis variety. According to European (EU) and American and British (USP and BP) ISO 3515:2002 Lavender Oil Quality Standards, linalool and linalyl acetate cannot be less than 20-25% to be evaluated in the cosmetics industry. Accordingly, it is seen that all varieties approach and exceed this limit. It is perceived that the varieties are mainly in compliance with the standards. It was determined that the Silver variety, remained within the lower limits according to linalool and linalyl acetate ratio standards. According to European (EU) and American and British (USP and BP) ISO 3515:2002 standards, the ratio of 1,8-cineole should be below 2.5%, while it was determined that all varieties were in compliance, except Silver variety. It was determined that four varieties had a content varying between 0.282-0.367% in terms of camphor ratio, and the Silver variety contained 6.899% camphor. Similarly, it should be below 0.5% according to European (EU) and American and British (USP and BP) ISO 3515:2002 standards. Except for the Silver variety, all varieties have camphor content in accordance with this standard, while the Silver variety contains 6.899% camphor. In a study conducted by (Karadogan et al., 2003), in the areas where lavender is grown in the lakes region, in terms of essential oil components, it was determined that lavender contains in 43.1% linalool, 22.3 linalyl acetate, 3.8% citronellol, 6.8% camphor and 0.2% borneol, respectively (Karadogan et al., 2003).

Table 3. Fresh stem flower essential oil components of Lavender varieties (%)

Substance name	Raya	Vera	Munstead	Silver	Sevtapolis
α-pinene	0.181	0.200	0.195	0.648	0.088
α- thujene	0.067	0.059	0.045	0.063	0.024
camphene	0.147	0.243	0.196	0.365	0.125
β-pinene	-	0.054	0.029	1.119	tr
sabinene	0.015	0.038	0.025	0.597	tr
Δ-3-carene	0.090	0.188	0.171	0.886	0.081
β-myrcene	1.123	1.128	1.134	1.425	1.115
α-terpinene	0.043	-	0.044	-	tr
limonene	0.408	0.508	0.498	2.905	0.435
1,8-cineole	0.733	1.318	0.701	20.988	0.407
phellandrene	-	-	-	3.544	-
cis-*β*-ocimene	11.502	11.631	13.518	6.030	2.275
γ-terpinene	0.089	0.146	0.170	0.120	-
trans-*β*-ocimene	4.807	4.684	5.168	1.569	2.361
3-octanone	0.312	0.346	0.217	-	-
hexyl acetate	0.196	0.081	0.101	0.035	-
p-cymene	0.343	0.584	0.435	0.400	0.813
α-terpinolene	0.257	0.246	0.245	0.239	0.229
hexyl propionate	0.016	0.010	0.012	0.020	0.019
hexyl isobutyrate	0.039	0.040	0.033	0.081	0.039
1-octen-3-il-acetate	1.188	1.110	1.269	0.029	1.029
rosefuran	0.016	0.030	0.027	0.036	0.012
hexyl butyrate	0.234	0.233	0.225	0.523	0.333
hexyl-2-methyl butyrate	tr	0.017	-	0.170	tr
cis-linalool oxide	0.121	0.137	0.108	0.034	0.211
trans-linalool oxide	0.109	0.109	0.103	0.108	0.177
camphor	0.282	0.367	0.251	6.899	0.290
linalool	30.868	34.473	31.894	24.186	49.071
linalyl acetate	29.993	24.370	25.738	20.959	25.389
bornyl acetate	0.256		0.545	-	0.202
lavandulyl acetate	8.817	0.413	8.148	1.496	5.662
caryophyllene	0.842	1.134	1.213	0.276	1.487
β-farnesene	1.305	1.717	2.328	0.793	1.073
neryl acetate	1.816	1.669	1.232	0.246	2.067
geranyl isovalerate	-	-	-	0.981	-
geranyl acetate	3.077	3.187	2.874	-	3.528
cuminal	0.071	0.050	0.063	0.355	0.152
caryophyllene oxide	0.141	0.204	0.108	0.139	0.441

In another study conducted in different regions in Greece, differences in essential oil composition of *L. angustifolia* genotypes were evaluated; in the Ist Region, the main compounds were determined as linalyl acetate (30.62%), linalool (29.56%), 1,8-cineole (5.18%), and camphor (4.03%). The main compounds for the IInd Region were linalyl acetate (26.92%), linalool (16.78%), 1,8-cineole (15.55%), and camphor (7.41%), (Hassiotis et al., 2010). Kara and Baydar (2013), in their study with lavender and lavandin genotypes in Isparta province, found the highest linalool content (43.3%) in fresh flowers from the Dutch variety in the first year and Vera (43.9%) in the second year. The highest linalyl acetate ratio was found in Super A variety, the highest camphor content in the first year than Super A (19.8%) in the second year and Dutch (10.0%). Dutch variety (46.5% and 47.0%, respectively) gave the highest linalool content, and the Super A variety (32.8% and 29.5%, respectively) gave the highest linalyl acetate content in dry sessile flowers in both years. In 2009 and 2010, the highest camphor content was determined at Silver (12.6%), in the first year and the Dutch (10.9), in the second year. In the study carried out to determine the morphological, yield and quality characteristics of lavender (*Lavandula* species and varieties in the Menemen district of İzmir, it was revealed that the varieties of *Lavandula angustifolia* contained linalyl acetate at 52.84-54.58% (Karık et al., 2017). In another study conducted in our country, 48-59 compounds, constituting approximately 99.5-100.0% of *Lavandula angustifolia*'s essential oils, were characterized. The research, results determined linalool ranging from 31.9

to 50.0%, and linalyl acetate, from 15.4 to 42.0%, as the main components. In another study conducted in Romania, essential oils obtained from *Lavandula angustifolia* variety were analyzed qualitative and quantitative composition. Nine compounds were detected in different amounts, and two chemotypes were formed as Mailette and Vera varieties, linalool and linalyl acetate, respectively. Ecological differences in cultivation area explained differences in essential oil composition of Vera variety in linalyl acetate chemotype. In a similar study by Küçük et al. (2018), it was determined that lavender Mailette and Budakalaszi varieties contained the highest linalool ratios (52.9% and 47.0%), while 'Beate' variety contained the lowest (18.1%). This variety was the widest in terms of linalyl acetate (58.9%).

4. Conclusion

In this study, which was carried out to determine the high yield and quality lavender varieties that can adapt to the ecological conditions of Çorum province, lavander genotypes with different agricultural and vegetal characteristics were tested for the first time. It has been observed that there is no general problem in the species' adaptation to the region in general. It was determined that lavender variety gave satisfactory results in fresh stem flower yield, although slightly lower when compared to studies carried out in similar ecologies. On the other hand, it was determined that Vera and Silver varieties had the lowest potential in terms of fresh stem flower yield in both years. In addition, Raya and Munstead varieties stood out in terms of essential oil content. In this context, it is thought that the Sevtopolis variety Munstead and Sevtopolis varieties stand out both in terms of fresh stem flower yield and essential oil quality and recommended for the region.

Compliance with Ethical Standards

Conflict of Interest

The authors declare that they have no conflict of interest.

Authors' Contributions

Mustafa Akdogan: Validation, writing - original draft, methodology, investigation, conceptualization, formal analysis, data curation review and editing. **Serkan Uranbey**: Validation,formal analysis, review and editing. **Sinem Aslan Erdem**: Essential oil analysis, editing manuscript, proofreading.

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Data availability

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Consent for publication

Not applicable.

References

Aprotosoaie, A.C., Gille, E., Trifan, A., Luca V.S., & Miron, A. (2017). Essential oils of Lavandula genus: a systematic review of their chemistry. *Phytochemistry Reviews*, (16), 761-99. https://doi.org/10.1007/s11101-017-9517-1

Arabaci, O., & Bayram, E. (2005). The effect of plant density and nitrogen fertilizer on some agronomic and quality characteristics of lavender (*Lavandula angustofolia* Mill.) in Aydın ecological conditions. *Journal of ADU Faculty of Agriculture*, 2(2), 13-19.

Atalay, A.T. (2008). The effects of organic and inorganic nitrogen fertilizers applied at different doses on the yield and quality characteristics of lavender (*Lavandula angustofolia* Mill.) grown in Konya ecological conditions. Selcuk University Institute of Science and Technology, Department of Field Crops, M.Sc., p. 46.

Balcı, O. (2019). Determination of the appropriate harvest time for the yield and essential oil ratio of lavender (*Lavandula angustofolia* Mill.) in the ecological conditions of Karaisalı in the first year (plant year). Çukurova University Graduate School of Natural and Applied Sciences, Department of Field Crops, Master's Thesis, p. 1-57.

Balyemez, E.O. (2014). Determination of Yield and Some Vegetal Characteristics of Different Lavender (*Lavandula* spp.) Species in Harran Plain Conditions. Harran University Graduate School of Natural and Applied Sciences. 53, Sanliurfa

Cavanagh, H.M.A., & Wilkinson, J.M. (2002). Biological activities of lavender essential oil. *Phytheraphy Research*, 16, 301-308. https://doi.org/10.1002/ptr.1103

Gershenzone, J., & Croteau, R. (1991). Herbivores: their interactions with secondary plant metabolites. In: Rosenthal, G.A., Berenbaum, M. (Eds.), Terpenoids: The Chemical Participants. Academic Press, San Diego, CA, 165-219.

Golubkina, N., Logvinenko, L., Novitsky, M., Zamana, S., Sokolov, S., Molchanova, A., Shevchuk, O., Sekara, A., Tallarita, A., & Caruso, G. (2020). Yield, essential oil and quality performances of *Artemisia dracunculus*, *Hyssopus officinalis* and *Lavandula angustofolia* as affected by arbuscular mycorrhizal fungi under organic management. *Plants*, 9, 375. https://doi.org/10.3390/plants9030375

Franks, S.J., Wheeler,G.S., & Goodnight,C. (2012). Genetic variation and evolution of secondary compounds innative and introduced populations of the invasive plant *Melaleuca qunquenervia*. *Evolution*, 66,1398-1412. https://doi.org/10.1111/j.1558-5646.2011.01524.x

Hassiotis, C, Lazari, D., & Vlachonasios, K. (2010). The effects of habitat type and diurnal harvest on essential oil yield and composition of *Lavandula angustofolia* Mill. *Fresenius Environmental Bulletin*, 19,1491-98.

Kageyama, A., Ueno, T., Oshio, M., Masuda, H., Horiuchi, H., & Yokogoshi, H. (2012). Antidepressant-like effects of anaqueous extract of lavender (*Lavandula angustofolia* Mill) inrats. *Food Science and Technology Research*, 18, 473-479. https://doi.org/10.3136/fstr.18.473

Kara, N., & Baydar, H. (2013). Determination of Lavender and Lavandin cultivars (*Lavandula* sp.) containing high quality essential oil in Isparta, Turkey. *Turkish Journal of Field Crops*, 18(1), 58-65 .

Karadogan, T., Baydar, H., & Ozcelik, H. (2003). Detection of plant species belonging to the Lamiaceae family in the Lakes region and determination of their medicinal and aromatic values. TÜBİTAK Project, Project No: TOGTAG-2599, Isparta.

Karık, Ü., Çiçek, F., & Çınar, O. (2017). Determination of morphological and yield quality characteristics of lavender (Lavandula spp.) species and varieties in Menemen ecological conditions. *Journal of Anadolu Aegean Agricultural Research Institute*, 27(1), 17-28.

Küçük, S., Çetintaş, E., & Kurkcuoglu, M. (2018). Volatile compounds of the *Lavandula angustofolia* Mill. (Lamiaceae) species cultured in Turkey. Journal of the Turkish Chemical

Society, Section A: Chemistry. 5, 1303-1308. https://doi.org/10.18596/jotcsa.463689

Kovatcheva, A.G., KolevaI.,L., Ilieva,M., Pavlov, A., Mincheva, M. & Konushlieva, M. (2001). Antioxidant activity of extract from *Lavandula vera* M. incellcultures. *Food Chemistry*, 72, 295-300. https://doi.org/10.1016/S0308-8146(00)00229-6

Lesage-Meessen, L., Bou, M., Sigoillot, J.-C., Faulds C., & Lomascolo, A. (2015). Essential oils and distilled straws of lavender and lavandin: a review of current use and potential application in White biotechnology. *Applied Microbiology and Biotechnology*, 99 (8), 3375-3385. https://doi.org/10.1007/s00253-015-6511-7

Mantovani, A.L.L., Vieira, G.P.G., Cunha,W.R., Groppo, M., Santos, R.A., Rodrigues, V., Magalhães, L.G., & Crotti, A.E.M. (2013). Chemical composition, antischistosomal and cytotoxic effects of the essential oil of Lavandula angustofolia grown in Southeastern Brazil. *Revista Brasileira de Farmacognosia*, 23, 877-884. https://doi.org/10.1590/S0102-695X2013000600004

Morgan, T.J., Morden,W.E., Al-Muhareb, E., Herod, A.A. & Kandiyoti, R. (2006). Essential oils investigated by size exclusion chromatography and gas chromatography–mass spectrometry. *Energy Fuels*, 20, 734-737. https://doi.org/10.1021/ef050364i

Özyazıcı, G., & Kevseroğlu, K. (2019). The effects of ontogenetic variability on the yield of some plants belonging to the Labiatae family (*Mentha spicata* L., Origanum onites L., *Melissa officinalis* L., *Lavandula angustofolia* Mill.). *Turkish Journal of Agricultural Research*, 6 (2), 174-185. https://doi.org/10.19159/tutad.510877

Paton, A.J., Springate, D., Suddee, S., Otieno, D., Grayer, R.J., Harley, M.M., Willis, F., Simmonds, M.S.J., Powell, M.P. & Savolainen, V. (2004). Phylogeny and evolution of basils and allies (*Ocimeae, Labiatae*) based on three plastid DNA regions. *Molecular Phylogenetics and Evolution*, 31, 277-299. https://doi.org/10.1016/j.ympev.2003.08.002

Renaud, E.N.C., Charles, D.J. & Simon, J.E. (2001). Essential oil quantity and composition from 10 cultivars of organically grown Lavender and Lavandin. *Journal of Essential Oil Research*, 13, 269-273. https://doi.org/10.1080/10412905.2001.9699691

Southwell, I.A., Russell, M.F., Maddox, C.D.A. & Wheeler, G.S. (2003). Differential metabolism of 1,8-cineole in insects. *Journal of Chemical Ecology* . 29, 83-94. https://doi.org/10.1023/a:1021976513603

Upson T., & Andrews S. (2004). The Genus Lavandula. Royal Botanic Gardens, Kew 2004, ISBN: 9780881926422.

Vairinhos, J. & Miguel MG. (2020). Essential oils of spontaneous species of the genus Lavandula from Portugal: a brief review. *Biosciences Zeitschrift Für Naturforschung C*, 28,75(7-8):233-245. https://doi.org/10.1515/znc-2020-0044.