DETERMINING LEAF YIELD, SOME PLANT CHARACTERS AND LEAF ESSENTIAL OIL COMPONENTS OF DIFFERENT CULTIVARS OF LAVENDER AND LAVANDIN (*LAVANDULA* SPP.) ON THE HARRAN PLAIN ECOLOGICAL CONDITIONS

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Abstract. This study was conducted to determine the yield and some plant characters of different types of lavender (*Lavandula* spp.) at Harran University, Faculty of Agriculture, in Şanlıurfa, Turkey, during 2015, with Randomized Complete Block Design with three replications. In the study, 5 different types of lavender [*L. angustifolia* (Grosso Tina, English cv.) and *L. x intermedia* (Abriel, Dutch, Grosso cv.)] were used as plant material. This research was determined the plant height (29.30-31.15 and 25.47-30.10 cm), canopy diameter (47.72-56.86 and 44.33-47.60 cm), dry herb yield (91.32-111.80 and 66.17-103.31 g plant^{-1}), dry leaf yield (68.52-83.11 and 53.36-78.99 g plant^{-1}) and essential oil ratio (0.92-0.99% and 0.87-0.99%) of *L. angustifolia* and *L. x intermedia*, respectively. In addition, the major constituents of the essential oils of *L. angustifolia* and *L. intermedia* leaves were determined to be 1.8 cineol (33.11-36.19%), camphor (21.04-22.15%) and borneol (7.33-9.63%).
Keywords: *leaf yields, volatile oil constituents, herb yields, L. angustifolia, L. x intermedia*

Introduction

In recent years, the use and trade of medicinal and aromatic plants has increased significantly. This has made these crops sought after in domestic and foreign markets (Baydar and Erbas, 2007). The *Lavandula* genus belongs to the family of *Lamiaceae* (*Labiatae*) and has perennial species containing aromatic flowers and leaves. There are about 39 lavender species (*Lavandula* spp.), most of which originate from the Mediterranean region. There are three important species of lavender in the world with high commercial value. These are lavender (*Lavandula angustifolia* Mill), lavandin (*Lavandula x intermedia* Emeric ex Loisel) and spike lavender (*Lavandula spica* Medik.). More in the world, lavender and lavandin species are being cultivated (Baydar, 2009). Lavender essential oil quality is the best, while lavandin varieties have higher essential oil yield (Baydar and Erbas, 2007). Lavender and lavandin essential oils have a wide range of uses due to its many properties. It is used in perfumery and cosmetics industry because of its beautiful smell and is used in the pharmaceutical industry due to its sedative and pain-relieving properties (Baydar, 2009). Also, the herb essential oils of lavender and lavandin possible used be in fermentative or enzymatic processes involving various microorganisms, especially filamentous fungi, for the production of antimicrobials, antioxidants and other bio products with pharmaceutical and cosmetic activities, opening up new challenging perspectives in white biotechnology applications (Meessen et al., 2015).

It has been reported that the essential oil components of *Lavandula* species vary according to plant parts (Touati et al., 2011), genotype (Kara and Baydar, 2013), ecological conditions (Khalajee et al., 2017) and cultivation technique (Chrysargyris et al., 2017). The essential oils of *Lavandula* species show different chemotypes. The main

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components of lavender essential oil are linalyl acetate (25.0-47.0%), linalool (25.0-45.0%) and camphor (0.5-1.5%) (ISO 3515), whereas the main components of lavandin essential oil are linalool (28.0-38.0%), linalyl acetate (19.0-29.0%) and camphor (7.0-11.0%) (ISO 3054). Lavender essential oil is included the lower camphor content than the essential oil of lavandin. Therefore, lavender essential oil is better than lavandin essential oil (Kara and Baydar, 2013). For these reasons, we can say that the most important indicator of lavender essential oil quality is the camphor ratio.

The leaves and stems of *Lavandula* plants are contain essential oil like flowers. In commercial lavender essential oil production, flowers are generally used, but contain a significant amount of essential oil of leaves and stems. For this reason, it is important to know the essential oil components of lavender and lavandin leaves.

The aim of this study is to determine the leaf yields, some plant characteristics and leaf essential oil components of lavender and lavandin varieties.

Materials and methods

In the study, *L. angustifolia* (Grosso Tina and English cv.) and *L. x intermedia* Emeric ex Loisel, (Abriel, Dutch and Grosso cv.) obtained from the Atatürk Horticultural Central Research Institute, Yalova, seedlings were used as plant materials.

The trial was carried out in the summer of 2015 in Harran University, Faculty of Agriculture, Eyyübiye Campus, Agricultural Research and Application Field, in Şanlıurfa, Turkey. The experimental field was located in South-eastern Anatolia region (in the Harran Plain) where semi-arid climate conditions are prevail, and some climatic data for the area are given in *Table 1*.

Table 1. *Monthly average some climate data in Şanlıurfa (Anonymous, 2016)*

Mounts	Temperature (°C)			Total Precipitation (mm)	Relative Humidity (%)	Sunshine Duration (h)
	Minimum	Maksimum	Mean			
January	-3.1	17.2	6.2	82.5	68.8	3.7
February	-0.6	18.2	7.6	100.8	74.3	3.5
March	2.5	24.8	11.7	79.0	58.9	5.8
April	4.7	29.9	15.7	24.3	49.7	7.9
May	11.8	36.9	22.8	10.3	38.0	10.4
June	16.7	38.4	27.7	0.7	35.3	12.1
July	21.4	42.8	33.2	0.2	26.5	12.4
August	22.1	43.1	31.5	0.0	37.4	11.1
September	18.7	40.4	29.8	0.0	30.5	9.0
October	12.7	33.0	21.6	58.8	50.5	6.0
November	6.8	24.3	14.0	7.9	48.1	6.1
December	0.5	20.0	8.6	25.3	50.8	4.6
Average/ Total	-3.1	43.1	19.2	389.8	47.4	7.7

In the Sanliurfa province, where the typical continental climate prevails, the summers are hot and dry and the winters are cold and rainy. Throughout vegetation period, totally 389.8 mm precipitation were recorded.

The soils where the experiment was established are deep and flat soils with flat all sides. Typical red profiles have a clayy texture. The whole profile is very calcareous, low organic matter content, high cation exchange capacity (Dinç et al., 1988).

The trial area was plowed deeply before planting, then mixed by a cultivator and made ready for planting. In trail area, before the surface tillage, 150 cc da^{-1} herbicide

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(*trifluralin*), 10 kg da^{-1} N, 10 kg da^{-1} P_20_5 and 10 kg da^{-1} K_2O composite fertilizer (15.15.15) was applied. The experiment was set up as four rows each was 5 m in length, for each cultivars. The seedlings were planted by hand, in the each plot with 70 x 50 cm distance on May 16, 2014. The trial was planned to the Randomised Block Design with three replicated. Immediately after planting, seedlings were given water. During the growing period, according to the needs of the plant irrigation and weed operation was performed according to the weed condition. The 10 plants were harvested, after the side effects were removed from the middle parts (3 repetitions), with 15 cm high from the ground on November 20, 2015 and the related observations were taken. After harvest *Lavandula* plant samples were separated in leaves and stems. Each samples were naturally dried in shadow and kept at 4°C until analysis. In the trial, plant height (cm), canopy diameter (cm), dry herba yield (g $plant^{-1}$), dry leaf yield (g $plant^{-1}$), volatile oil ratio in dry leaf (%) and volatile oil components (%) were determined to the method proposed by Balyemez (2014). Since the varieties did not bloom in the experimental year, there were no observations about the flowers.

Essential Oil isolation

Each dry *Lavandula* leaf sample (50 g) was hydrodistilled with 500 ml water in a Clevenger type apparatus during 3 h. The essential oil was stored in a dark glass bottle and kept at 4°C until GC-MS analysis.

Gas chromatography-mass spectrometry analysis

Lavandula essential oil was analysed by GC-MS using an Agilent 7890A equipped with an electron impact quadruple, Agilent 5975C mass spectrometer detector. The electron ionization energy was 70 eV, scan range 35-450 amu and scan rate 1 scans $second^{-1}$. The GC column was used an HP Innowax Capillary (A fused silica capillary column 5% phenyl-poly-dimethyl-siloxane), film thickness of 0.25 µm, a length of 60 m, and internal diameter 0.25 mm. The carrier gas was helium with a flow rate 0.8 ml $minute^{-1}$. Inlet temperature was 250°C. The GC oven temperature program was used as follows; 60°C initial temperature, hold for 10 min, raised at 4°C min^{-1} to 220°C and finally hold at 220°C for 10 min. A 1% (v/v) solution of the sample in n-Hexane was prepared and 1µl was injected using a 40:1 split ratio.

The identification of compounds was performed by comparing their mass spectra with data from Adams, US National Institute of Standards and Technology (NIST, USA) and WILEY 1996 Ed. mass spectra library. The identification of compounds was also based on the Kovats retention indices.

The data were subjected to analysis of variance (ANOVA) using Randomized Complete Block Design. The significance of differences among the different cultivars was determined using LSD with 5%.

Results and Discussion

Determined average the plant height, canopy diameter, dry herb yield, dry leaf yield and essential oil ratios of the varieties of different *Lavandula* species was given *Table 2*.

As shown in *Table 2*, the highest plant height, canopy diameter, dry herb yield and dry leaf yield were determined in Grosso Tina cultivar of the *L. angustifolia* and Grosso cultivar of the *L. x intermedia* type. In general, all properties were examined,

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L. angustifolia species was higher than *L. x intermedia*. This difference may be caused by genotypic difference.

As seen in *Table 2*, there was no statistically significant difference between the varieties in terms of essential oil ratio. The ratio of essential oils were varied between 0.91% and 1.01% depended on cultivars. The highst essential oil ratio was determined on the Grosso Tina and the Grosso cultivars.

Table 2. *Average the plant height, canopy diameter, dry herb yield, dry leaf yield and essential oil ratios depending on the varieties of different Lavandula species in 2015*

Species	Cultivars	Plant Height (cm)	Canopy Diameter (cm)	Dry Herb Yield (g plant^{-1})	Dry Leaf Yield (g plant^{-1})	Essential Oil Ratio (%)
L. angustifolia	Grosso Tina	25.90 a*	67.17 a	138.43 a	101.80 a	1.01
	English	32.30 b	57.73 b	111.30 b	84.70 b	0.96
L. x intermedia	Abriel	32.17 b	56.27 b	106.60 b	80.59 b	0.91
	Dutch	28.80 c	54.33 b	82.80 c	64.37 c	0.98
	Grosso	35.10 ab	57.60 b	116.67 b	89.37 b	1.01
Avarege		32.85	58.62	111.17	84.16	0.97
LSD (%5)		**2.96**	**4.18**	**13.74**	**9.60**	**NS.**

*****The mean values with the same letter within variable are not significantly different (LSD P < 0.05); **NS**. No significant

According to *Lavandula* varieties, the ratio of the essential oil components detected in the leaves and the ratio of the chemical groups of the essential oil components are given in *Tables 3* and *4*, as percentage.

In total, between 51-52 components were quantified and characterized in the leaf essential oils of *L. angustifolia* and *L. x intermedia* cultivars, accounting for 97.31-99.55% (by GC peak area) of total oils. The main constituents in the essential oil of *Lavandula* leaves were 1.8 cineol 35.24% (33.11-36.19%), camphor 21.79% (21.04-22.15%), borneol 8.63% (7.33-9.63%), tau-cadinol 3.01% (2.46-3.35%), limonene 2.53% (2.11-2.86%), caryophyllene oxide 2.39% (2.12-2.63%), cumin aldehyde 1.91% (1.56-2.08%), carvone 1.45% (1.23-1.55%), *delta*-terpineol 1.43% (1.39-1.47%), *gamma*-cadinene 1.28% (1.05-1.44%), *trans*-verbenol 1.17% (1.13-1.24%), *trans*-carveol 1.12% (1.10-1.19%), *p*-cymene 1.11% (1.03-1.18%), *alpha*-terpineol 1.02% (0.90-1.11%) and terpinen-4-ol 1.01% (0.81-1.31%) (*Table 3*). However, the leaf essential oil was characterized by the presence of two dominating constituents (1.8 cineol and camphor with more than 54% composed of components). The other compounds detected in the range 0.05-1.00%. Essential oils of *Lavandula* species have been previously investigated by some researchers. In lavender, it was found the main components of the essential oil that in leaves 1,8-cineole 25.70% and borneol 11.32% (Meftahizade et al., 2011), borneol 15.21%, 1,8-cineole 8.50% and geraniol acetate 5.21% (Skwirzyńska et al., 2013), 1,8-cineole 31.9%, borneol 24% and camphor 16.1% (Hassanpouraghdam et al., 2011); in inflorescence *β*-linalool 18.74-34.43% and linalool acetate 20.68-30.57% (Zagorcheva et al., 2013), 1,8-cineole 64.99-71.08% and limonene 8.58-9.11% (Koleilat et al., 2017), linalool 28.5-43.9%, linalyl acetate 5.38-25.7% and cymene 1.14-11.30% (Kara and Baydar, 2013), linalool 33.7%, 1,8-cineole 17.1% and borneol 14.7% (Hassanpouraghdam et al., 2011).

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Table 3. *The leaves essential oil composition ratio (%) in the cultivars of Lavandula angustifolia and L. intermedia*

R.T.	Components	*L. angustifolia*		*L. intermedia*			Mean
		English	**Grs.Tina**	**Grosso**	**Dutch**	**Abriel**	
12.420	*alpha*-Pinene	0.99	0.87	0.82	1.03	0.96	0.93
13.528	Camphene	1.63	0.56	0.55	0.65	0.62	0.80
14.461	*beta*-Pinene	0.93	0.94	0.87	1.01	0.98	0.95
14.713	Sabinene	0.46	0.38	0.35	0.41	0.38	0.40
15.278	*delta*-3-Carene	0.19	0.21	0.23	0.25	0.19	0.21
15.480	Myrcene	0.11	0.12	0.18	0.15	0.07	0.13
15.859	*alpha*-Terpinene	0.40	0.12	0.20	0.04	0.08	0.17
16.201	Limonene	2.11	2.62	2.53	2.86	2.54	2.53
16.391	1.8 Cineol	36.19	35.16	33.11	35.78	35.94	35.24
16.936	*gamma*-Terpinene	0.36	0.19	0.19	0.21	0.18	0.23
17.275	*o*-Cymene	0.37	0.34	0.38	0.40	0.40	0.38
17.323	*p*-Cymene	1.09	1.03	1.09	1.18	1.16	1.11
18.426	Tyranton	-	0.46	-	0.48	-	0.19
18.845	Hexyl butanoate	0.07	-	0.05	0.03	0.11	0.05
18.947	Perillene	0.16	0.22	0.21	0.22	0.21	0.20
19.078	1-Octen-3-ol	0.21	0.36	0.27	0.23	0.24	0.26
19.183	*p*-Cymenene	0.15	0.16	0.10	0.14	0.04	0.12
19.321	*trans*-Sabinene hydrate	0.65	0.74	0.75	0.94	0.84	0.78
19.408	*trans*-Limonene oxide	0.13	0.16	0.16	0.18	0.16	0.16
19.694	*alpha*-Campholenal	0.28	0.30	0.36	0.29	0.30	0.31
19.862	Linalool	0.12	0.16	0.16	0.16	0.10	0.14
20.050	Camphor	22.05	21.04	21.87	22.15	21.84	21.79
20.149	cis-p-Menth-2-en-1-ol	0.12	0.17	0.17	0.17	0.11	0.15
20.350	Lavandulyl acetate	0.19	0.25	0.24	0.09	0.15	0.18
20.435	Pinocarvone	0.89	0.94	0.95	0.58	0.88	0.85
20.486	Terpinen-4-ol	1.31	1.01	0.96	0.81	0.95	1.01
20.608	*trans*-p-Menth-2.8-dien-1-ol	0.28	0.37	0.38	0.31	0.35	0.34
20.836	Lavandulol	0.22	0.33	0.35	0.24	0.13	0.25
20.879	Myrtenal	0.67	0.70	0.71	0.67	0.68	0.69
20.925	*delta*-Terpineol	1.40	1.47	1.47	1.39	1.42	1.43
21.001	*trans*-Verbenol	1.14	1.18	1.24	1.13	1.17	1.17
21.085	*alpha*-Terpineol	0.90	1.11	1.06	1.03	0.99	1.02
21.201	Borneol	7.33	9.47	9.63	8.37	8.35	8.63
21.331	Lavandulyl isovalerate	0.15	-	0.39	0.04	0.44	0.20
21.366	Geranyl propanoate	-	0.92	0.22	0.80	0.32	0.45
21.386	Eucarvone	0.43	-	0.27	-	0.12	0.16
21.460	Verbenone	0.23	0.20	0.21	0.13	0.23	0.20
21.551	Carvone	1.23	1.53	1.55	1.48	1.48	1.45
21.699	*gamma*-Cadinene	1.05	1.33	1.44	1.25	1.31	1.28
21.758	Myrtenol	0.39	0.40	0.42	0.38	0.41	0.40
21.894	Cumin aldehyde	1.56	2.08	2.02	2.02	1.89	1.91
21.965	*trans*-Carveol	1.02	1.14	1.19	1.10	1.17	1.12
22.044	*p*-Cymen-8-ol	0.69	0.73	0.77	0.70	0.77	0.73
22.163	*cis*-Calamenene	0.17	0.24	0.24	0.19	0.22	0.21
22.947	*alpha*-Terpinen-7-al	0.34	0.35	0.37	0.29	0.34	0.34
23.446	Caryophyllene oxide	2.42	2.35	2.63	2.12	2.41	2.39
23.628	Ledol	0.25	-	0.07	0.13	0.15	0.12
23.757	1.10-di-epi-Cubenol	0.22	0.23	0.28	0.34	0.26	0.27
23.868	*p*-Cymen-7-ol	0.94	1.01	1.07	0.97	0.99	1.00
24.551	*tau*-Cadinol	2.46	3.10	3.35	3.15	3.01	3.01
24.762	*epi-alpha*-Bisabolol	0.20	0.30	0.27	0.29	0.25	0.26
26.393	*cis*-14-nor-Muurol-5-en-4-one	0.23	0.25	0.26	0.24	0.26	0.25
26.534	Cadina-4.10(15)-dien-3-one	0.23	0.25	0.27	0.24	0.28	0.25
Total		**97.31**	**99.55**	**98.88**	**99.44**	**98.83**	**98.80**

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In lavandin, it was found the main component of the inflorescence essential oil that 1,8-cineole 33.54% and camphor 18.89% (Koleilat et al., 2017), linalool 34.8-43.3%, linalyl acetate 3.76-44.46% and camphor 5.28-19.8% (Kara and Baydar, 2013). In *L. dentata*, it was found the main component of the leaf essential oil that 1,8-cineole 33.54% and camphor 18.89% (Touati et al., 2011). In *L. stoechas*, it was found the main component of the essential oil that fenchone 31.6%, camphor 22.4% and *p*-cymene 6.5% (Dob et al., 2006). Some researchers declared that the essential oil composition of lavender and lavandin varied depending on the genotype of the plant (Kara and Baydar, 2013), fertilization (Arabaci and Bayram, 2005; Chrysargyris et al., 2017), growth stage on the harvesting time (Baydar and Erbas, 2007), parts of the plant (Touati et al., 2011), harvest times at different on the day and year (Zheljazkov et al., 2012), drying conditions (Özgüven et al., 2007) and essential oil isolation technique (Skwirzyńska et al., 2013; Khalajee et al., 2017). Some similarities were recorded between our study and the previous reports. Investigation of our results revealed that the main component of leaves essential oils of lavender and lavandin cultivars were found 1.8 Cineol, like other researchers (Hassanpouraghdam et al., 2011; Meftahizade et al., 2011; Touati et al., 2011; Koleilat et al., 2017).

Table 4. *The leaves essential oil chemical groups ratio (%) in the cultivars of Lavandula officinalis and L. intermedia*

Chemical groups	***L. angustifolia***		***L. intermedia***		
	English	**Grs. Tina**	**Grosso**	**Dutch**	**Abriel**
Monoterpenes	**89.53**	**89.51**	**88.95**	**89.85**	**89.53**
Monoterpene Hydrocarbons	*8.79*	*7.54*	*7.49*	*8.33*	*7.60*
Oxygenated Monoterpenes	*80.74*	*81.97*	*81.46*	*81.52*	*81.93*
Sesquiterpenes	**7.15**	**7.80**	**8.94**	**7.75**	**8.33**
Sesquiterpene Hydrocarbons	*1.22*	*1.57*	*1.68*	*1.44*	*1.53*
Oxygenated Sesquiterpenes	*5.93*	*6.23*	*7.26*	*6.31*	*6.80*
Others	0.63	2.24	0.99	1.84	0.97
Total	**97.31**	**99.55**	**98.88**	**99.44**	**98.83**

Baydar (2009) stated that better quality essential oil was included low camphor content and the camphor content in quality lavender oil must be between 0.5 and 1% in lavenders and between 5.0 and 10.0 in lavandins. Our result show that leaves essential oils of lavender and lavandin were included high camphor content (21.04-22.05% in lavender and 21.79-22.15% in lavandin). In this case, as the percentage of leaves in the plant during harvest increases, the amount of camphor in the volatile oil will also increase. In order to produce quality lavender essential oil, as few leaves as possible should be harvested.

GC/MS examinations of the essential oil indicated that monoterpens (88.95-89.85%) were characterized as the main class of components, followed by a minor rate of sesquiterpens (7.15-8.94%) in leaves of lavender and lavandin cultivars. It consists mainly of oxygenated monoterpenes (80.74-81.97%). Additionally, the leaves essential oil contained 7.49-8.79% monoterpene hydrocarbons, 5.93-7.26% oxygenated sesquiterpenes, 1.22-1.68% sesquiterpene hydrocarbons, and 0.63-2.24% other (*Table 4*). The concentrations of sesquiterpene hydrocarbons were lowest. Higher amounts of oxygen-containing monoterpenes in oils strongly support the dynamic pool of plastidal hydroxylases and dehydrogenases involved in the post-modification of the initial hydrocarbonic compounds (Hassanpouraghdam et al., 2011). Sesquiterpenes had a minor

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share in the component classification, and the oxygenated compounds was higher than that of hydrocarbon sesquiterpenes. The lavender plant was potentiated in the biosynthesis and accumulation of monoterpenes rather than sesquiterpene ones. 1,8-Cineole was characterized as the most important oxidized compound and Camphor was the chief ketonic compounds of leaf essential oil.

Conclusion

Finally, the chemical profile of the leaf essential oil of lavender and lavandin cultivars were similar and showed a high content of 1,8-cineole, borneol and camphor. Camphor ratio was founded to be high in the essential oils of all cultivars leaves. If we are to produce high quality essential oil (low camphor), we must reduce the leaf content in the dry matter. The effect of lavender flower spike axis and stalk essential oil components on commercial lavender oil should be determined.

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