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DETERMINATION OF LAVENDER AND LAVANDIN CULTIVARS (*Lavandula sp.*) CONTAINING HIGH QUALITY ESSENTIAL OIL IN ISPARTA, TURKEY

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ABSTRACT

The research was carried out during the 2009 and 2010 growing period with the aim of determining agricultural and technological characteristics of lavender cultivars.When the agricultural characteristics of the lavender and lavandin cultivars were examined, in both years the highest fresh stem flower yield was obtained from Dutch (5467 and 8204 kg ha^{-1}, respectively) and the highest dry stemless flower yield from Super A (1083 and 1463 kg ha^{-1}, respectively) cultivars. The highest essential oil content in both fresh stem flowers (the first year 2.00 %, the second year 1.90 %) and dry stemless flowers (the first year 9.62 %, the second year 8.87 %) was determined from Silver. Linalool, linalyl acetate and camphor were determined as the main components of essential oil in the lavender cultivar. The highest linalool content in fresh stem flowers was determined to be from Dutch (43.3 %) in the first year and from Vera (43.9 %) in the second year. The highest linalyl acetate content from Super A (42.5 and 19.8 %, respectively) and camphor content from Super A (19.8 %) in the first year and Dutch (10.0 %) in the second year were determined. The highest linalool content in dry stemless flowers from Dutch (46.5 and 47.0 %, respectively), linalyl acetate content from Super A (32.8 and 29.5 %, respectively) in both years and camphor content from Silver (12.6 %) in the first year and Dutch (10.9 %) in the second year were obtained.

Keywords: Lavender, lavandin, essential oil, essential oil components

INTRODUCTION

Lavandula, belonging to the *Lamiaceae* family, is a precious essential oil plant. *Lavandula,* which is cultivated around the world, is a significant perfume, cosmetic and pharmaceutical plant because of the high content and quality essential oil (Guenther, 1952). *Lavandula* oil is especially useful for use in nervous system stimulants, hypnotics, sedatives, tranquilizers and stress repellents. In addition, it has useful dermatological uses in the treatment sunburn and skin rashes (Cavanagh and Wilkinson, 2002), as well as strong antiseptic (disinfectant), and antibiotic (bacteria killing) effects (Lis-Balchin and Hart, 1999).

Lavandula is a plant which is fairly resistant to drought and temperature (Weiss, 1997). There are 39 *Lavandula* species (*Lavandula sp.*) which are mostly of Mediterranean origin. However, there are three important species within the genus producing lavender (*Lavandula angustifolia* Mill. = *L. officinalis* L. = *L. vera* DC), lavandin (*Lavandula intermedia* Emeric ex Loisel. = *L. hybrida* L.) and Spike lavender (*Lavandula spica* = *L. latifolia* Medik.) (Tucker, 1985). Lavender essential oil is higher quality than that produced by lavandins because lavender essential oil has lower camphor content than lavandin cultivars. Therefore, lavender essential oils are used in perfumes and aromatherapy, and lavandin essential oils are used in soap, detergents and cosmetics products (Lis-Balchin, 2002). However, lavandin essential oil yield is higher than that from lavenders (Beetham and Entwistle, 1982). *Lavandula sp.* is one of important medicinal and aromatic plants that are cultivated in Turkey. Isparta is the most significant lavandin (*L.x intermedia* Super A) production area of Turkey. In Isparta, lavandin is cultivated on an area of 250 hectares, with an annual production of 2.5 tons (Kara and Baydar, 2011).

In Isparta, average fresh stem flower and dry stemless flower yields per hectare of *L.x intermedia* Super A are 5-7.5 and 1-2.5 tons, respectively (Baydar and Erbas, 2007). Essential oil content of lavandin varies between 1.0-1.5 % in fresh stem flowers and between 5.0-6.0% in dry stemless flowers (Baydar, 2009). Quality and marketable value of lavender essential oil is measured according to essential oil composition. Generally, high quality lavender essential oil contains high levels of linalool and linalyl acetate, but the scent of essential oil deteriorates as the camphor content increases (Adam, 2006). Lavender essential oil has more than 100 components with linalool, linalyl acetate, 1,8-cineol and camphor as the major constituents. Linalyl acetate in lavender essential oil and linalool in lavandin essential oil are higher (Beetham and Entwistle, 1982). Generally, lavender essential oil is better quality because lavender essential oil has a lower camphor content than lavandin cultivars (Lis-Balchin, 2002; Baydar, 2009). The study was conducted with the aim to determine the lavender and lavandin cultivars that have high dry stemless flowers containing high quality essential oil (high linalyl acetate and low camphor) and high adaptation ability.

MATERIALS AND METHODS

Experimental Conditions

In the research, Raya, Munstead, Vera and Silver lavender cultivars belonging to *Lavandula angustifolia* species Mill. and Dutch, Giant Hidcote and Super A lavandin cultivars belonging to *Lavandula x intermedia* Emeric ex Lois. were used as plant materials. These lavender cultivars are among the important varieties that have high commercial value in world. The samples belonging to these cultivars were taken in the years 2009 and 2010 from the experiment founded in 2007 as four replications in a Randomized Complete Block Design at the Experimental Farm of the Agriculture Faculty of Suleyman Demirel University. The distance between rows was 1 m and intra row spaces were 50 cm (McGimbsey and Porter, 1999). Each plot area was 6 m in length and had 6 rows.

Lavender and lavandin cultivars were used in the experiment and their locations are shown in Table 1.

Table 1. Lavender and lavandin cultivars used in experiment

Species	Cultivar name	Commercial name	Origin (locations)
L. angustifolia	Raya	Lavender	Bulgaria –Kazanlık
	Munstead	“	France- Grasse
	Vera	“	Bulgaria-Kazanlık
	Silver	“	France- Grasse
L.x intermedia	Dutch	Lavandin	Germany- Ahrensburg
	Giant Hidcote	“	France-Grasse
	Super A	“	Turkey-Isparta

Some morphological characteristics and harvest dates belonging to the means of the experiment year of lavender and lavandin cultivars cultivated in Isparta ecological conditions are shown in Table 2 (Kara, 2011).

Table 2. Some morphological characteristics and harvest dates belong to lavender cultivars

Morphological characteristics		*L. angustifolia*				*L.x intermedia*		
		Raya	Munstead	Vera	Silver	Dutch	G. Hidcote	Super A
Flower colors (h^0)	L	44.6	44.3	44.1	44.2	37.0	38.0	44.0
	+a	22.8	19.7	18.4	19.6	19.9	24.4	20.3
	-b	20.3	17.8	16.0	16.7	16.7	21.9	17.7
Plant height (cm)		69.7	63.2	85.0	83.2	86.2	86.0	81.5
Growing form		Upright	Upright	S. Aslope	S. Aslope	S. Aslope	S. Aslope	S. Aslope
Ear number per plant		1217.8	955.7	860.3	632.1	941.7	821.7	600.5
Stem length with ear (cm)		30.3	24.1	33.6	36.8	35.7	33.2	35.8
Ear length (cm)		6.9	6.3	9.6	9.5	12.4	9.8	9.2
Flower number per ear (flower/ear)		34.9	29.9	63.0	64.1	65.7	61.2	73.5
Cluster number per ear (cluster/ear)		6.3	5.4	10.2	8.4	11.0	10.0	9.0
Harvest dates	2009	June 22	June 22	July 13	July 12	July 13	July 16	July 10
	2010	June 22	June 22	July 12	July 10	July 12	July 14	July 08

L: shine +a: red, -b: blue, S: Semi

Climatic Data and Soil Structure of the Experimental Area

Meteorological data for the growing seasons are shown in Table 3. Isparta Province is located at a 37° 45' N latitude, 30° 33' E longitude and 1050 m altitude. The long-term annual mean temperature, relative humidity, total annual precipitation, wind speed and sunshine duration per day in the area are 12.2 °C, 55 %, 493.4 mm, 2.4 m s^{-1} and 7.6 h, respectively (Anonymous, 2009-2010). With these climate characteristics, Isparta has features of the semi-arid climatic characteristics found in the Southwestern Anatolia region. The average temperatures and total precipitation in 2009 and 2010 were 12.9 and 13.7 °C and 666.7 and 710.4 mm respectively (Table 3). Meteorological data for 2009 and 2010 were higher compared to long-term meteorological data.

Table 3. Meteorological data of the experimental field*

Climatic factors	Years	Months												Total or Average
		Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	
Average temperature (^0C)	2009	3.4	4.0	5.5	11.0	15.0	20.9	24.6	24.1	18.0	15.1	7.5	5.7	12.9
	2010	4.3	5.6	8.6	11.5	16.5	21.9	24.4	26.4	20.3	12.6	7.0	4.8	13.7
	Long years	1.7	2.6	5.9	10.5	15.5	20.1	23.4	25.8	18.3	12.8	6.9	3.0	12.2
Precipitation (mm)	2009	124.7	70.3	55.2	40.4	66.6	26.8	18.0	0.2	26.2	18.1	51.6	168.6	666.7
	2010	68.0	136.8	33.2	47.0	32.4	64.5	40.1	0.2	29.7	79.1	66.8	112.6	710.4
	Long years	64.2	54.9	52.8	58.8	46.0	27.8	12.8	0.3	15.4	38.0	51.5	70.9	493.4

* Meteorology Station, Isparta

Soil from a depth of 60 cm was sampled before setting the experiment and was subjected to physicochemical analysis. The soil was medium in nitrogen (19.8 kg NH_4^+ ha^{-1}), alkaline (pH 7.9), limy (1.3 $CaCO_3$ %), medium P (22 kg ha^{-1} P_2O_5) and high K_2O (850 kg ha^{-1}) contents.

Fresh Stem Flower and Dry Stemless Flower Yield

When plants reached blooming stage, 3 rows in the center of each plot were harvested manually in June and July (Table 2), and brought to the laboratory. The fresh stem samples were weighted and dried on the wire rack in shade at room temperature for a two-week period. Dry stem flowers were weighted and then dry stemless flowers were obtained by separating with hand from dried stem flower. Fresh stem, dry stem and dry stemless flower yield was calculated by converting from the parcel yield to hectare (Baydar and Erbas, 2007).

Essential Oils Distillation

200 g fresh stem flower in 1.5 L water and 50 g dry stemless flower samples in 1 L water from each plant cultivar were extracted by hydro-distilllation for 3 hours using Clevenger apparatus according to the standard procedure described in European Pharmacopoeia for determining the oil content (v/w %).

GC-MS Analysis

GC-MS (Gas Chromatography-Mass Spectrometry) analysis of the oil samples was performed on QP5050 GC-MS equipped with a Quadrapole detector. GC/MS analysis was employed under the following conditions: capillary column, CP-Wax 52 CB (50 m x 0.32 mm; film thickness = 0.25 μm); oven temperature program (60 ^0C increased to 220 ^0C at a rate of 2 ^oC/min and then kept at 220 ^0C for 10 min); total run time 60 min; injector temperature, 240 ^0C; detector temperatures, 250 ^0C; carrier gas, helium at a flow rate of 20 ml/min. Identification of constituents was carried out with the help of retention times of standard substances by composition of mass spectra with the data given in the NIST library (Stein, 1990). After lavender products were obtained according to the methods explained above, they were stored at 4 ^0C until GC-MS analyses. 1 μL of essential oil diluted with *n*-hexane was injected into the GC-MS system.

All the data were analyzed with analysis of variance (ANOVA) using the SAS Statistical Package Program. Means were compared using the DUNCAN test.

RESULTS AND DISCUSSION

Fresh Stem, Dry Stem and Dry Stemless Flower Yield

According to the results of variance analysis of data regarding fresh stem, dry stem flower and dry stemless flower yields, cultivar, year and year x cultivar interaction were statistically significant at the 0.01 level in both years (Table 4).

Fresh stem (6138 kg ha^{-1}), dry stem (3120 kg ha^{-1}) and dry stemless flower yields (1102 kg ha^{-1}) of the second year in the lavender were higher than those of first year (4626, 2197 and 807 kg ha^{-1}, respectively). Differences between the years might be due to the fact that 3-year-old plants continue to grow and that there was more rain in the second year as compared to the first. Stem number in plant can be higher than that subsequent year in perennial plants it is also reason higher yield in second years. Rainfall may affect crop yield and its components (Table 4).

Significant differences depending on years and cultivars in the fresh stem, dry stem flower and dry stemless flower yields of lavender and lavandin were found. The highest fresh stem and dry stem flower yields were determined in Dutch cultivar (5647 and 8204, 2885 and 4604 kg ha^{-1}, respectively), the lowest fresh stem and dry stem flower yields were obtained in Giant Hidcote cultivar (2905 and 3999 kg ha^{-1}, 1451 and 1955 kg ha^{-1}, respectively) in both years. Among the lavender and lavandin cultivars, the highest dried stemless flower yield was obtained from Super A (1083 and 1463 kg ha^{-1}, respectively), the lowest dry stemless flower yield was determined from Giant Hidcote (459 and 705 kg ha^{-1}, respectively) for both years (Table 4).

Ceylan et al. (1988) reported that the dry stemless flower yield of lavender varied between 1017-1948 kg ha^{-1}. Ceylan et al. (1996) determined that the dry stemless flower yield of lavender was 2340 kg ha^{-1}. Arabaci and Bayram (2005) and Atalay (2008) stated that the dry stemless flower yield of *Lavandula angustifolia* Mill. was between 1340-4430 kg ha^{-1} and 641-1134 kg ha^{-1}, respectively. Runham (1998) reported that the fresh stem flower yield of *Lavandula angustifolia* Mill. was 1651 kg ha^{-1}. Baydar (2009) found that 1 kg dry stemless flower was obtained by drying 5 kg fresh stem lavandin flowers (*L.x intermedia* Super A) in Isparta ecological conditions. In terms of dry stemless flower and fresh stem flower yield, our results are similar with the findings of the above-mentioned researchers.

Table 4. Yield and essential oil contents of lavender and lavandin cultivars

Cultivars	**Fresh stem flower yield (kg ha^{-1})**			**Dry stem flower yield (kg ha^{-1})**		
	2009	2010	Combined	2009	2010	Combined
Lavander *(L. angustifolia)*						
Raya	5349 ab	6595 b	5972 b	2069 c	3355 c	2712 d
Munstead	4219 c	5764 c	4992 d	1664 d	2194 e	1929 f
Vera	4968 b	6422 b	5695 c	2384 b	3297 c	2841 c
Silver	4191 c	5333 d	4762 d	2079 c	2762 d	2421 e
Lavandin *(L.x intermedia)*						
Dutch	5647 a	8204 a	6926 a	2885 a	4604 a	3745 a
G.Hidcote	2905 d	3999 e	3452 e	1451 e	1955 f	1703 g
Super A	5106 ab	6649 b	5878 bc	2847 a	3673 b	3260 b
Average	4626 B	6138 A		2197 B	3120 A	
LSD	55.427**	23.387**	21.193**	14.586**	13.146**	6.917**
CV value	5.88	1.23	3.00	3.26	1.75	2.31
Mean Square	34844.92	599872.2	429776.7	12009.67	79975.08	74281.1
	Dry stemless flower yield (kg ha^{-1})			**Fresh stem flower essential oil content (%)**		
Lavander *(L. angustifolia)*						
Raya	850 c	1295 b	1073 c	1.25 cd	1.30 c	1.28d
Munstead	659 d	809 e	734 f	0.32 e	0.38 e	0.35 f
Vera	829 c	1187 c	1008 d	1.30 cd	1.37 c	1.34 d
Silver	804 c	927 d	866 e	2.00 a	1.90 a	1.95 a
Lavandin *(L.x intermedia)*						
Dutch	962 b	1327 b	1145 b	1.67 b	1.55 b	1.61 b
G.Hidcote	459 e	705 f	582 g	1.07 d	1.12 d	1.10 e
Super A	1083 a	1463 a	1273 a	1.50 bc	1.48 bc	1.49 c
Average	807 B	1102 A		1.30	1.31	
LSD	6.053**	6.629**	3.162**	0.266**	0.134**	0.105**
CV value (%)	3.68	2.26	2.77	10.04	6.58	8.98
Mean Square	1637.92	18046.34	14793.58	1.12	0.87	1.90
	Dry stemless flower essential oil content (%)					
Lavander *(L. angustifolia)*						
Raya	4.90 e	4.75 d	4.83 e			
Munstead	2.10 f	2.30 e	2.20 f			
Vera	5.07 de	5.10 d	5.09 e			
Silver	9.62 a	8.87 a	9.25 a			
Lavandin *(L.x intermedia)*						
Dutch	6.10 c	6.97 c	6.54 c			
G. Hidcote	5.87 cd	5.12 d	5.50 d			
Super A	7.12 b	8.37 b	7.75 b			
Average	5.82	5.92				
LSD	0.844**	0.374**	0.325**			
CV value (%)	7.11	3.43	5.73			
Mean Square	21.00	23.33	42.46			

**: Significant at $P<0.01$ probability levels

Means in the same columns followed by the same letter (s) are not significantly different at the 1 % level

Fresh Stem and Dry Stemless Flower Essential Oil Content

According to the results of the variance analysis of data regarding fresh stem and dry stemless flower essential oil content of lavender, cultivar and year x cultivar interaction were statistically significant at the 0.01 level in the both years (Table 4).

The effect of the years on the essential oil content of lavender and lavandin was unsignificant. Significant differences depending on cultivars in the fresh stem and dry stemless flower essential oil content of lavender and lavandin were observed. The highest fresh stem and dry stemless flower essential oil contents were determined in Silver cultivar (2.00 and 1.90 %, 9.62 and 8.87 %, respectively), the lowest fresh stem and dry stemless flower essential oil contents were obtained from Munstead cultivar (0.32 and 0.38 %, 2.10 and 2.30 %, respectively) in both years. In the research, the dry stemless flower essential oil contents of the shorter Raya and Munstead cultivars were lower than those of the taller cultivars. The dry stemless flower essential oil content of Silver was significantly higher than the others cultivars.

Among the lavender and lavandin cultivars, while Silver, Dutch and Super A had high essential oil contents, Munstead and Giant Hidcote had lower essential oil contents (Table 4).

Some researchers stated that the essential oil of lavender must be at least 1.0-1.5 % (Wagner, 1980; Ceylan, 1996) and 0.5-1.0 % (Baytop, 1999). Ceylan et al. (1988) reported that the essential oil content of *L. officinalis* varied between 1.26-3.14 %. Renaud et al. (2001) found that dry stemless flower essential oil content varied between 7.1-9.9 % in lavandins and 2.8-5.0 % in lavenders. Baydar (2009) and Kara and Baydar (2011) reported that the essential oil content of *L.x intermedia* Super A cultivated in Isparta varied between 1.0-1.5 % and 2.24-2.35 %, respectively, in fresh stem flowers, 5.0-6.0 % and 7.50-8.60 % , respectively, in dry stemless flowers. Atalay (2008) and Arabaci and Bayram (2005) determined that the essential oil content of *Lavandula angustifolia* Mill. varied between 2.1-2.6 % and 1.54–2.34 %, respectively, in dry stemless flowers. In terms of dry stemless flower and fresh stem flower essential oil contents, our results agree with findings of the above-mentioned researchers.

Chemical Composition of the Essential Oil

Essential oil components and their rates obtained with GC-MS in lavender cultivars are shown in Table 5 and 6.

Linalool, linalyl acetate, camphor and terpineol-4-ol were determined as the main constituents in the fresh stem flower essential oil of lavender and lavandin cultivars. In the research, while the highest linalool content was determined in Dutch (43.3 %) during 2009 and in Vera (43.9 %) during 2010, the lowest linalool content was obtained from Raya in both years (28.5 and 37.3 %, respectively). The highest linalyl acetate content in the experimental years was determined from Super A (42.5 and 39.8 %, respectively), the lowest linalyl acetate content was obtained from Giant Hidcote in both years (4.35 and 3.76 %, respectively). Camphor wasn't determined in Raya and Munstead cultivars, the highest camphor content was obtained from Super A (19.8 %) during 2009 and Dutch (10.0%) during 2010. The highest terpinen-4-ol content was determined from Munstead (19.4 and 19.5 %, respectively), the lowest terpinen-4-ol content was obtained from Super A in both years (1.00 and 1.02 %, respectively) (Table 5).

Linalool, linalyl acetate, camphor and α-terpineol and borneol were determined as the main constituents in the dry stemless flower essential oil of lavender and lavandin cultivars. The highest linalool content was determined in Dutch (46.5 and 47.0 %, respectively), the lowest linalool content was obtained from Raya in both years (30.7 and 35.6 %, respectively). The highest linalyl acetate content was determined from Super A (32.8 and 29.5 %, respectively), the lowest linalyl acetate content was obtained from Giant Hidcote in both years (3.52 and 4.13 %, respectively). Camphor wasn't determined in Raya and Munstead cultivars, the highest camphor content was obtained from Silver (12.6 %) during 2009 and Dutch (10.9 %) during 2010. The highest α-terpineol content was determined from Munstead (19.2 and 20.6 %, respectively), the lowest α-terpineol content was obtained from Dutch (1.40 %) during 2009 and Silver (2.41 %) during 2010. The highest borneol content was determined from Giant Hidcote (7.83 and 9.54 %, respectively), the lowest borneol content was obtained from Munstead in both years (0.57 and 0.98 %, respectively) (Table 6).

Table 5. Essential oil composition (%) in fresh stem flower of lavender and lavandin cultivars

Essential Oil Components	**RT**	***Lavander (L. angustifolia)***								***Lavandin (L.x intermedia)***					
		Raya		Munstead		Vera		Silver		Dutch		Giant Hidcote		Super A	
		2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Myrcene	13.9	1.76	1.39	048	0.43	0.14	0.73	0.16	0.90	0.53	0.81	0.54	0.97	-	1.19
Limonene	16.1	0.47	0.46	0.73	0.62	1.29	1.31	0.77	1.27	0.95	1.43	1.03	1.80	1.01	1.06
Sabinene	16.7	--	1.92	-	1.32	-	13.3	-	12.9	-	16.7	-	16.9	-	6.52
Cymene	18.8	11.3	7.9	8.31	8.2	6.28	5.02	1.14	4.02	1.55	4.10	3.69	4.78	1.47	3.28
Butanoic acid hexyl ester	29.1	-	-	0.54	0.47	0.64	0.46	0.63	0.50	0.67	0.58	0.63	0.52	-	0.54
1-octen-3-ol	31.1	0.25	-	0.80	0.81	0.36	0.41	0.16	-	0.19	59.0	0.65	-	-	-
Linalool	37.4	28.5	37.3	42.5	37.8	38.1	43.9	41.8	43.6	43.3	42.5	34.9	42.8	34.8	41.8
Linalyl acetate	38.1	25.7	19.7	7.45	8.98	11.4	5.38	14.4	11.2	11.7	4.46	4.35	3.76	42.5	39.8
Neryl acetate	41.3	2.97	6.5	1.14	4.36	0.81	2.27	0.67	1.58	0.76	1.33	0.46	1.55	2.15	2.72
Terpineol-4-ol	41.6	3.96	4.94	19.4	19.5	3.27	5.86	1.64	2.56	2.06	3.44	2.41	2.90	1.00	1.02
Farnesene	48.8	1.46	1.72	3.12	2.69	1.56	2.53	0.42	0.78	0.59	1.58	1.83	1.61	0.44	1.30
Nerol	46.6	-	0.58	-	1.74	-	0.67	-	-	-	1.01	-	0.62	-	-
Crypton	46.7	0.31	0.21	1.72	1.64	-	-	-	-	-	0.74	0.75	0.82	0.32	0.55
α -terpineol	47.3	3.61	3.46	0.97	1.09	2.44	1.17	1.83	1.62	1.88	1.59	1.45	1.29	3.48	3.13
Borneol	47.5	0.90	2.6	0.49	0.66	3.52	5.06	3.38	6.57	3.28	5.96	7.61	10.1	1.72	5.13
Geranyl acetate	48.9	8.80	1.85	3.22	1.13	3.11	-	-	0.47	0.30	0.47	0.99	0.64	2.09	2.15
Benzaldehyde 4	53.0	-	0.85	-	0.71	-	-	-	-	-	0.29	-	-	-	0.58
Geraniol	55.7	1.65	2.21	0.63	0.89	0.78	-	0.61	0.84	0.61	0.40	0.23	-	1.54	1.25
Cadinol	73.6	-	0.77	-	1.19	-	0.83	-	-	-	0.44	-	0.46	-	0.30
Nonadecane	58.1	-	2.49	-	2.84	-	2.27	-	0.87	-	1.73	-	0.53	-	-
Heneicosane	68.9	-	1.29	-	1.60	-	1.96	-	0.48	-	1.08	-	-	-	-
α -pinene	8.2	-	-	-	-	-	0.46	-	0.50	-	0.47	-	0.53	-	-
β -pinene	11.6	0.19	-	0.46	-	0.13	0.57	0.11	0.69	0.33	0.59	0.61	0.60	-	-
Camphor	36.6	-	-	-	-	4.11	6.99	14.3	8.35	12.5	10.0	7.27	5.28	19.8	5.87
Eucalyptol	18.4	1.11	-	0.91	-	16.1	-	14.4	-	14.7	-	26.1	-	4.59	-
Sabinene hydrate	34.6	-	-	0.31	-	0.36	-	0.23	-	0.21	-	0.42	-	5.52	-
Caryophyllene	44.0	2.03	-	2.38	-	0.73	-	1.25	-	0.88	-	0.28	-	0.94	-
Lavandulol	49.0	0.54	-	2.28	-	-	-	-	-	-	-	-	-	-	-
Bisabolol	78.2	0.39	-	0.55	-	1.22	-	0.67	-	0.93	-	1.05	-	0.91	-

Table 6. Essential oil composition (%) in dry stemless flower of lavender and lavandin cultivars

Essential Oil Components	RT	***Lavander* (*L. angustifolia* var)**						***Lavandin* (*L.x intermedia* var)**							
		Raya		Munstead		Vera		Silver		Dutch		Giant Hidcote		Super A	
		2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Myrcene	13.9	0.15	0.79	-	0.26	0.12	0.41	-	0.82	-	0.60	0.20	0.59	-	0.99
Limonene	16.1	0.34	0.82	0.49	0.26	1.40	0.83	0.71	0.98	0.82	1.00	1.21	1.05	0.48	0.49
Sabinene	16.7	-	0.84	-	0.40	-	11.0		9.73	-	13.3	-	13.4	-	2.97
Cymene	18.8	10.8	4.82	7.45	4.76	4.52	2.35	1.44	2.98	1.71	3.03	3.93	2.18	1.54	2.12
Butanoic acid hexyl ester	29.1	-	-	0.54	0.67	0.69	0.66	0.53	0.72	0.59	0.59	0.80	0.61	0.57	0.40
1-octen-3-ol	31.1	0.35	0.79	0.93	0.89	0.46	0.96	0.19	0.43	0.32	0.89	0.33	0.65	-	-
Terpineol-4-ol	41.6	2.11	0.58	0.32	0.50	0.21	0.41	-	0.32	0.17	0.35	0.14	0.38	0.16	-
Linalool	37.4	30.7	35.6	46.1	39.5	44.5	46.8	44.9	46.8	46.5	47.0	43.1	45.7	36.5	39.1
Linalyl acetate	38.1	28.2	25.3	6.12	12.2	3.68	4.99	10.5	7.14	9.38	7.12	3.52	4.13	32.8	29.5
Neryl acetate	41.3	1.66	6.27	0.71	4.95	0.35	1.37	0.33	1.14	0.74	1.91	0.46	1.41	2.04	3.19
α -terpineol	47.3	4.72	8.45	19.2	20.6	2.81	3.99	1.87	2.41	1.40	3.13	3.02	3.47	-	-
Farnesene	44.8	1.19	2.48	1.90	3.42	0.86	0.97	0.52	0.53	0.65	0.83	0.92	1.17	0.30	0.09
Nerol	45.6	-	0.86	-	2.17	-	0.85	-	0.59	-	0.28	-	0.86	-	-
Crypton	46.7	0.29	-	1.95	1.69	0.55	0.81	0.33	0.50	0.63	0.53	0.87	0.97	0.28	-
Borneol	47.5	0.94	1.75	0.57	0.98	5.01	8.58	3.79	6.50	3.63	6.04	7.83	9.54	3.26	4.55
Geranyl acetate	48.9	8.56	3.50	3.11	1.20	0.92	-	1.12	1.32	1.24	0.36	1.08	0.75	2.00	3.8
Benzaldehyde 4	53.0	-	0.78	-	0.97	-	0.43	-	0.63	-	0.27	-	0.40	-	0.8
Geraniol	55.7	2.06	1.86	0.79	1.22	0.28	0.47	0.53	1.02	0.70	0.93	0.31	0.39	2.20	2.18
α -pinene	8.2	-	-	-	-	-	0.27	-	0.39	-	0.37	-	0.28	-	-
β -pinene	11.6	0.17	-	-	-	0.11	0.40	-	0.38	-	0.44	0.21	0.36	-	-
Camphor	36.6	-	-	-	-	8.14	9.22	12.6	8.99	11.7	10.9	5.34	8.35	4.30	-
Eucalyptol	18.4	0.48	-	0.58	-	19.8	-	17.4	-	15.6	-	21.7	-	3.92	-
Sabinene hydrate	34.6	-	-	0.48	-	0.51	-	0.48	-	0.41	-	0.39	-	-	-
Caryophyllene	44.0	1.42	-	-	-	-	-	0.47	-	0.27	-	-	-	0.58	-
Lavandulol	49.0	0.40	-	2.56	-	0.85	-	0.33	-	0.59	-	0.94	-	-	-
Germakren D	51.0	0.73	-	0.23	-	-	-	0.47	-	0.34	-	-	-	0.83	-
Bisabolol	78.2	-	-	-	-	1.48	-	0.63	-	0.91	-	1.08	-	0.87	-

Generally, in the study, linalool content was higher than linalyl acetate content in all of the lavender cultivars. According to quality standards of lavender essential oil composition determined by the International Organization for Standardization (ISO 3515:2002), linalool, linalyl acetate, cymene, terpinen-4-ol and camphor should be between 25.0-38.0 %, 25.0-45.0 %, 4.0-10.0%, 2.0-6.0 %, and 0-0.5 %, respectively (Anonymous, 2002). Borneol, eucalyptol, cymene and α-terpineol content in dry stemless flowers of the cultivars were higher than fresh stem flowers. In this study, linalool, eucalyptol, α-terpineol and cymene contents of the cultivars were accordance with ISO 3515:2002 lavender oil standards. Linalyl acetate content in the cultivars, except for Raya and Super A, was lower than ISO 3515:2002 lavender oil standards. Camphor content of the cultivars, except for Raya and Munstead, did not meet ISO 3515:2002 lavender oil standards.

Baydar (2009) stated that lavender essential oil because of the low camphor content was better quality than lavandin essential oil, and that the camphor content in a quality lavender oil must be between 0.5 and 1 % in lavenders and between 5.0 and 10.0 in lavandins. Most researchers stated that the main components of lavender essential oil were linalool and linalyl acetate, and their contents varied between 15.0-35.0 % and 30.0-50.0 % (Wichtl, 1984), 25.1-59.8 % and 25.82-54.76 % (Arabaci and Bayram, 2005), 34.3-54.6 % and 24.0-29.0 % (Kara and Baydar, 2011) respectively. The abundance of linalool correlated with the transcription of the linalool synthase gene, suggesting that linalool production is in part regulated transcriptionally. However, the degree of correlation between linalool abundance and linalool synthase transcription differed between *L. angustifolia* and *L. x intermedia*, suggesting additional, and differing mechanisms that control linalool abundance in these species (Boeckelmann, 2008). Barazandeh (2002) found that essential oil of *L. latifolia* Medik. contained 41 components and its main components were linalool (30.6-31.9 %), 1,8 cineol (18.8-20.9 %) and borneol (8.9-10.1 %). Nogueira and Romano (2002) found that the highest essential oil components of *L. viridis* were 1,8-cineole (18.2-25.1 %), camphor (9.1-15.7 %), α-pinene (8.8-14.1 %), borneol (4.1-4.8 %), β-pinene (1.2-5.6 %), karen (1.0-6.5 %) and α-terpineol (0.8-4.2 %). Fakhari et al. (2005) determined that essential oil of *Lavandula angustifolia* Mill. contained linalool (32.8 %), linalyl acetate (17.6 %), lavandulyl acetate (15.9 %), α-terpineol (6.7 %) and geranyl acetate (5.0 %) as major components. Alatrache et al. (2007) stated that essential oil of *L. latifolia* contained 40 components and linalool 32.3%, camphor 12.4% and 1,8-cineole 11.7 %. In another study it was stated that the highest essential oil components of lavender were linalyl acetate (47.56 %), linalool (28.06%), lavandulyl acetate (4.34%) and *α*-terpineol (3.75 %) (Verma et al., 2010).

Most researchers stated that the essential oil composition of lavender and lavandin varied depending on the genotype of the plant (Lawrence, 1994), growth stage on the date of collection, parts of the plant, harvest times at different times on the day and year (Baydar, 2009; Avcı, 2010), drying conditions and extraction technology (Pinto et al., 2007).

CONCLUSIONS

In term of fresh stem, dry stem and dry stemless flower yields, Super A, Dutch lavandin and Raya, Vera lavender cultivars were determined as high-yielding cultivars. In the research, the highest essential oil content in both fresh stem flowers and dry stemless flowers were determined in Silver lavender and Super A lavandin cultivars. However, these two cultivars were unsuitable for lavender oil standard (ISO 3515:2002) because the linalyl acetate content was lower than linalool content, and had low cimene, terpinen-4-ol and high-camphor content in both fresh stem flowers and dry stemless flowers. Among the lavender and lavandin cultivars, Raya and Munstead were identified as quality cultivars according to ISO 3515:2002 lavender oil standards owing to high contents of linalyl acetate, cimene, terpinen-4-ol and the fact that it is camphor-free in both fresh stem flowers and dry stemless flowers.

Based on the results of the research, Super A and Dutch cultivars had higher fresh stem flower, dry stemless flower yields as compared to the other cultivars. Raya and Munstead cultivars were determined to be higher quality cultivars because of being camphor-free.

As a result, we could recommend Super A and Dutch for dry stemless flower yields, Silver for essential oil content, and Raya and Munstead cultivars for essential oil quality.

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