

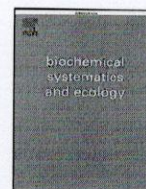
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Effects of variety and growth year on the essential oil properties of lavender (*Lavandula angustifolia* Mill.) and lavandin (*Lavandula x intermedia* Emeric ex Loisel.)

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ABSTRACT

Essential oil (EO) properties of six *L. angustifolia* (LA) and two *L. x intermedia* (LI) cultivars were evaluated during summer harvest periods of 2017 and 2018. The cultivars were grown in Dörgicse, Hungary. According to our results, the essential oil (EO) content was highly dependent on the varieties in both experimental years (2017: $p < 0.0001$ and 2018: $p < 0.0001$). In 2017, the EO content values of LI accessions were all higher than those of the LA cultivars. However, in 2018, the mean EO content value of 'Budakalászi' (LA) (8.2 mL/100g) exceeded that of 'Grosso' (LI) (7.7 mL/100g). The EO of 'Maillette' (LA) and 'Budakalászi' (LA) contained the highest linalool proportions (52.9% and 47.0%) while 'Beate' (LA) showed the lowest (18.1%); and this latter variety was richest in linalyl-acetate (58.9%). LI varieties produced lower linalyl acetate and total ester ratios in comparison to the LA cultivars. Concerning EO composition, only the UK varieties 'Hidcote Blue' (LA) and 'Munstead' (LA) met the requirements of the Ph. Eur.

This study provided evidence that the effect of growth year on the EO content was significant only in two varieties out of the eight. However, in the more rainy year 2018, the accumulation of linalool and linalyl acetate was significantly affected in several cases, where linalool proportions decreased and linalyl acetate ratios increased.

1. Introduction

Lavender is a valuable medicinal and aromatic plant of northwest Mediterranean origin; it has drought tolerance, and requires sunny, warm growing locations (Weiss, 1997). The genus *Lavandula* includes several species; however, the most important are *Lavandula angustifolia* and *Lavandula x intermedia*. Both species are grown mainly for essential oil (EO), which is primarily used in the perfume and cosmetic industry as well as in aromatherapy (Piccaglia, 1998; Lis-Balchin, 2002; Grant et al., 2011). The biological activity of the lavender EO is also well known, several authors demonstrated antibacterial and anti-inflammatory effects (Jinau et al., 2013; Giovannini et al., 2016).

The main essential oil components of *L. angustifolia* are linalool (25–38%) and linalyl acetate (25–45%) (Lis-Balchin, 2002), while *L. x intermedia* also accumulates some other monoterpenes (1.8-cineole, camphor, isoborneol) in higher concentrations. In general, *L. angustifolia* produces essential oil of higher quality, while the accumulation level is higher at *L. x intermedia*. Nevertheless, the latter is considered to

have lower quality volatile oil due to the higher camphor and lower linalyl acetate percentages, respectively (Lawrence, 1994).

The required quantity and quality of the EO of *Lavandula* species are included in pharmacopoeias. In Ph. Eur. VII., min. 1.3 mL/100g EO content is required for *Lavandulae flos*, while the following limits are included for EO composition: max 1% limonene, max. 2.5% 1.8-cineole, max. 1.2% camphor, 20–45% linalool, 25–47% linalyl acetate, 0.1–8% terpinene-4-ol, 0.1–8% lavandulyl acetate, and max. 2% α -terpineol is indicated European Pharmacopoeia. The required ranges for the quality parameters of *L. angustifolia* essential oil are included in the ISO standard (ISO 3515:2002/Cor 1:2004) as well concerning different origins (French, Bulgarian, Russian, etc.). ISO 8902:2009 specify the required EO composition of 'Grosso' (LI) as follows: 4–8% 1.8-cineole, 24–37% linalool, 6–8.5% camphor, 1.5–3.5% isoborneol, and 25–38% linalyl acetate, respectively.

The essential oil composition is primarily determined by plant genotype Landmann et al., 2007, but it may also be influenced by environmental and ontogenetic factors, as well as by morphogenetic

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features (Boeckelmann, 2008; Guitton et al., 2010; Zámboi-Németh, 2015). Intraspecific differences among lavender accessions have been described previously (Tajuddin et al., 1983; Lalande, 1984; Lis-Balchin, 2002). According to Hassiotis et al. (2010, 2014) and Zheljaskov et al. (2012), the climate of the cultivation area and harvest time affected the quantity and the quality of EO. Furthermore, soil salinity can also be an influencing factor on essential oil content (Cordovilla et al., 2014). Nutrient supply, especially the nitrogen doses, changed the linalool and linalyl-acetate ratios, where the highest concentrations could be ascertained at 100 kg/ha N dosage. The oil composition has also been changed by weather conditions (Zeliha et al., 2013). However, it was demonstrated by Zheljaskov and Nielsen (1996) that air or soil heavy metal pollution did not affect negatively the essential oil content and composition. During actual production, postharvest methods may also play an important role in EO properties: according to Baydar and Erbas (2009), higher drying temperatures decreased the EO content and changed the oil composition. Moreover, the method of extraction and the distillation time may also affect the oil quality (Zagorcheva et al., 2013; Zheljaskov et al., 2013).

In Hungary, the cultivation of *Lavandula* species has expanded considerably in recent years. According to the literature reviewed, there is a lack of scientific information on available varieties of *L. angustifolia* and *L. x intermedia*, especially from Central European regions. Beside the well-known cultivars of both species, there are others lacking reliable scientific data (e.g. 'Budakalászi', 'Beate', 'Aromatico Silver', etc.). Consequently, the main aim of our research was to evaluate the quantity and quality of the volatile oil in regard to intraspecific accession of the two *Lavandula* species and growth year.

2. Materials and methods

2.1. Plant material

The *L. angustifolia* and *L. x intermedia* cultivars which we examined and data concerning their origins are presented in Table 1. (Lis-Balchin, 2002).

2.2. Growth area

The experimental area is located in Dörgicse (D), Transdanubia, Hungary (46° 55' 01" N, 17° 43' 19" E), where the lavender fields were established in 2003. General environmental conditions and soil characteristics of the growing area are included in Tables 2 and 3, while monthly precipitation values in the vegetation period under study are shown in Table 4.

2.3. Sampling

Samplings from *L. angustifolia* (LA) were carried out during the full blooming period in June, in the case of *L. x intermedia* (LI) varieties in July of 2017 and 2018, in 3 replications for each variety. Inflorescences

Table 1
Origins of the cultivars.

Species	Cultivar	Abbreviation	Origin of varieties ^a
<i>L. angustifolia</i>	'Aromatico Silver'	A	Unk., unk.
	'Beate'	Be	Unk., unk.
	'Budakalászi'	Bu	Hungary, 1974
	'Hidcote Blue'	HiB	UK, 1950
	'Maillette'	Mai	France, unk.
	'Munstead'	Mu	UK, 1916
<i>L. x intermedia</i>	'Grappenhall'	Gra	UK, 1902
	'Grosso'	Gro	France, 1972

Legends: unk = unknown, UK = United Kingdom.

^a According to Lis-Balchin (2002).

Table 2

Details of the Dörgicse, Hungary habitat.

Study conditions	Characteristics of the growth area
Region	Balaton Uplands, Veszprém County
Location	46° 55' 01" N, 17° 43' 19" E
Exposure of growing area	plain
Base rock	limestone
Soil type	rocky brown forest soil
Average annual temperature	9–10 °C.
Average annual rainfall, mm	600–650

of approximately 20-cm stalks were cut in full bloom stage from randomly selected individuals of the plantations. All the samples were dried and stored at room temperature until the time of essential oil isolation.

2.4. Essential oil isolation

Dried plant material (5–10 g) was hydro-distilled for 1 h, using a Clevenger type apparatus, according to the Pharmacopoea Hungarica 7th edition (1986). The essential oil (EO) contents of samples were expressed in mL/100g, calculated on the basis of dry weight (DW). The oils were collected and stored in airtight vials in a refrigerator at 4 °C prior to analysis.

2.5. Gas chromatography and mass spectrometry

GC-FID analysis was carried out using an Agilent Technologies 6890N GC System instrument equipped with an HP-5 (5% phenyl methyl siloxane) capillary column (30 m x d = 350 µm, film thickness: 0.25 µm), programmed as follows: initial temperature 50 °C (10 min), from 50 to 150 °C at a rate of 4 °C min⁻¹; from 150 to 220 °C at a rate of 12 °C min⁻¹ and 220 °C (10 min). Carrier gas: helium (constant flow rate 0.5 ml min⁻¹), injector and detector temperatures: 250 °C, split ratio: 22.6:1. Injected quantity: 0.2 µl. The percentage composition of the essential oil was computed from the GC peak areas. Total ester percentage was also calculated, as a high percentage contributes to the appropriate quality of EO.

The gas chromatography-mass spectrometry (GC-MS) analyses were carried out using the instrument above equipped with an Agilent Technologies MS 5975 inert mass selective detector. The temperature program was the following: initial temperature 60 °C., then by a rate of 3 °C./min up to 240 °C.; the final temperature was maintained for 5 min. Carrier gas was helium (1 mL min⁻¹), injector and detector temperatures were 250 °C. Split ratio: 30:1. Injected quantity: 0.2 µl (solvent: *n*-hexane). Ionization energy was 70 eV. The MS (mass spectra) were recorded in full scan mode, which revealed the total ion current (TIC) chromatograms (mass range *m/z* 50–550 *uma*). The compounds were identified by linear retention indices which were calculated using the generalized equation of Van Den Dool and Kratz (1963), with literature data, and by matching their recorded mass spectra with those in mass spectral library references (NIST MS Search 2.0 library, Wiley 275) and a mass spectra library (Adams, 2007).

2.6. Statistical analysis

The EO content (mL/100g DW) and relative peak area percentage composition (%) values were presented as means ± standard deviations. The results were analysed by the IBM SPSS Statistics 23, using one-way ANOVA to compare the EO content and linalool and linalyl acetate proportions of each cultivar, where the significance level was set at *p* < 0.05. For evaluating the effect of the growth year on the EO content and linalool and linalyl acetate ratios of the varieties, one-way ANOVA was also used. Homogeneity of variances was checked by Levene's test. Tukey and Games-Howell post hoc methods were applied

Table 3Soil characteristics of the growing area of *Lavandula* in Dörgicse.

Soil parameters												
pH	K _A	CaCO ₃ m/m %	Humus m/m %	NO ₃ ⁻ + NO ₂ ⁻ -N mg/kg	P ₂ O ₅ mg/kg	K ₂ O mg/kg	Mg mg/kg	Na mg/kg	Zn mg/kg	Cu mg/kg	Mn mg/kg	SO ₄ ²⁻ mg/kg
7	43	5	2	11	261	117	317	116	14	2	214	22

Table 4

Quantity of precipitation (mm) prior to harvest period in 2017 and 2018 (mm/month) (According to the data provided by OMSZ-National Meteorology Service).

Amount of precipitation (mm/month)	Dörgicse	
Harvest year	2017	2018
January	20.3	27.7
February	46.5	43.8
March	20.9	121.5
April	53.8	17.2
May	15.2	56.6
June	81.6	84.8
From January to May	156.7	266.8

to check normality and homogeneity of SD, and to determine the groups of variants.

3. Results and discussion

3.1. Essential oil content

3.1.1. Effect of variety on the essential oil content

For the year 2017, significant differences in the EO content could be established among all the varieties studied ($p < 0.0001$) (Fig. 1). The highest accumulation level was determined in 'Grosso' (LI) (9.5 mL/100g), while the lowest was in 'Beate' (LA) (1.9 mL/100g). Interestingly, the LA variety 'Budakalászi' showed almost the same level of EO content as 'Grappenhall' (LI). The volatile contents of 'Maillette', 'Munstead' and 'Aromatico Silver' LA cultivars were not statistically different from each other; they produced concentrations ranging from 3.1 mL/100g to 3.4 mL/100g.

In 2018, significant differences in the EO content were also observed among cultivars. ($p < 0.0001$) (Fig. 2). 'Budakalászi' (LA) was outstanding also in this year (8.2 mL/100g), exceeding the EO values of all other LA accessions and that of LI cultivar 'Grosso', too.

According to previous references of Renaud et al. (2001, 2002) and

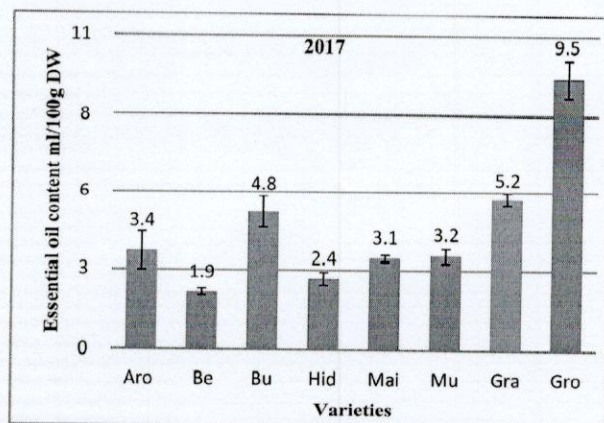


Fig. 1. Essential oil contents (ml/100g DW) of the lavender varieties involved in the study. Legends: A = 'Aromatico Silver', Be = 'Beate', Bu = 'Budakalászi', Hid = 'Hidcote Blue', Mai = 'Maillette', Mu = 'Munstead', Gra = 'Grappenhall', Gro = 'Grosso'.

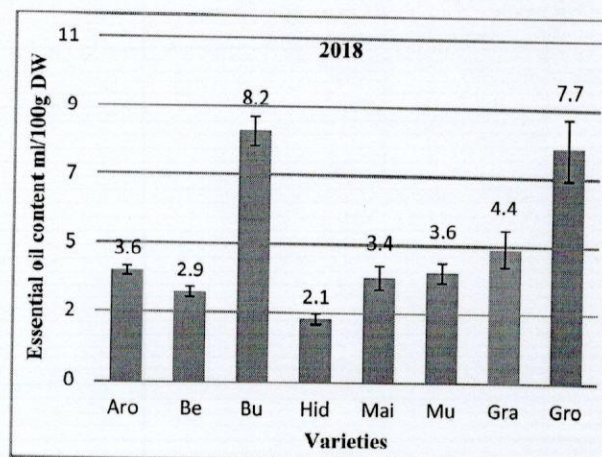


Fig. 2. Essential oil content (ml/100g DW) of the lavender varieties in this study. Legends: A = 'Aromatico Silver', Be = 'Beate', Bu = 'Budakalászi', Hid = 'Hidcote Blue', Mai = 'Maillette', Mu = 'Munstead', Gra = 'Grappenhall', Gro = 'Grosso'.

Nimet and Hasan (2013), the EO content of 'Hidcote' samples ranged between 2.3 and 3.5%, values which are similar to those experienced in our study (2017: 2.4 mL/100g; 2018: 2.1 mL/100g). In the case of 'Munstead' the values varied between 2.3 and 3.6% according to Renaud et al. (2002) from the midwestern United States or between 2.1 and 2.3% as reported by Nimet and Hasan (2013) from Turkey, respectively. The latter values were lower than those detected in our study (2017: 3.2 mL/100g; 2018: 3.6 mL/100g). Renaud et al. (2002) observed a 2.2% difference among the EO content of the six LA varieties they investigated, while we have found a much larger variability in our study, up to 5.3 mL/100g between the lowest and the highest EO content of six LA cultivars.

As for LI varieties, 'Grosso' was already evaluated by Renaud et al. (2002). In their study, 6.3% and 9.9% of EO content was detected during two experimental years, while in our research a more stable behavior could be observed (2017: 9.5 mL/100g; 2018: 7.7 mL/100g) for the same variety. Thus, similarly to the LA varieties, in our study LI accessions showed a larger difference concerning the marginal values (3.3 mL/100g between the two LI varieties).

3.1.2. Effect of growth year on EO content

It was established that the effect of the growth year (presumably weather) was significant only in the case of 'Beate' (LA) ($p < 0.001$) and 'Budakalászi' (LA), ($p < 0.001$). The accumulation of volatiles in the other investigated varieties did not change significantly in the two years.

3.2. Essential oil composition

3.2.1. Effect of the variety on the essential oil composition in LA

Concerning LA varieties involved in the study, 12 compounds were determined in the EO samples, representing 87.8–95.7% of total composition (Table 5). The most important major compounds ($\geq 10\%$) were the following: linalool, linalyl acetate, and lavandulyl acetate; while the minor compounds (ranging from 1 to 10% of EO) included β -myrcene,

Table 5

Percentage composition (%) of the essential oil of *L. angustifolia* cultivars in 2017.

			2017					
			A	Be	Bu	HiB	Mai	Mu
Compounds	RT	LRI						
β -myrcene	6.99	995	0.9	0.4	0.8	0.6	0.6	0.6
<i>Cis</i> -beta-ocimene	8.5	1037	9.3	4.6	3.6	4.2	0.9	6.4
<i>Trans</i> -beta-ocimene	8.85	1046	4.5	2.9	2.6	1.2	0.4	1.8
Linalool	10.76	1097	40.9 abc	50.1 bc	31.3 ab	25.7 a	55.4 c	29.5 ab
Isoborneol	13.43	1162	0.4	–	0.8	1.1	3.8	0.6
Lavandulol	13.58	1166	0.6	0.9	0.3	0.2	0.0	0.4
Terpinene-4-ol	13.96	1175	5.2	5.5	0.4	0.9	0.1	7.3
α -Terpineol	14.55	1189	3.4	2.9	6.0	4.2	3.3	4.2
Linalyl acetate	17.11	1250	17.7 _a	18.7 _a	27.2 _{ab}	42.1 _b	25.3 _a	25.2 _a
Lavandulyl acetate	18.59	1285	7.8	4.5	12.6	3.2	0.3	10.4
Geranyl acetate	22.43	1388	1.2	0.8	2.2	1.4	1.3	1.8
β -Caryophyllene	23.68	1420	3.4	4.6	4.1	2.9	2.9	5.8
Total ester %			26.5 _a	23.9 _a	42.0 _{ab}	46.6 _b	26.8 _a	37.34 _{ab}
Total identified %			94.0	95.7	91.9	87.8	94.2	93.9

Legends: RT = retention time, LRI = linear retention index. A = 'Aromatico Silver', Be = 'Beate', Bu = 'Budakalászi', HiB = 'Hidcote Blue', Mai = 'Maillette', Mu = 'Munstead'.

Lower case letters indicate sign. diff. ($p < 0.05$) among varieties.

cis-beta-ocimene, *trans*-beta-ocimene, isoborneol, terpinene-4-ol, α -terpineol, geranyl acetate and β -caryophyllene.

It was established that among the cultivars investigated, the EO of 'Maillette' showed the highest linalool proportion (55.4%) in 2017. Concerning total ester percentages of the EO of the varieties, significant differences were detected in 2017 ($p < 0.008$). 'Hidcote Blue' presented the highest ratio of total ester percentage (46.6%) among the LA varieties (Table 3).

Regarding the main components, the quality of EO matched the levels accepted by Ph. Eur. VII. only in the case of 'Budakalászi' and 'Hidcote Blue'.

In 2018, the identified components of the analysed EO samples represented 90.8–95.9% of total GC composition. The EO of 'Maillette' and 'Budakalászi' presented the highest linalool proportions (52.9% and 47.0%) while 'Beate' showed the lowest one (18.1%) (Table 6). According to our results, the EO of 'Beate' was rich in linalyl-acetate (58.9%). Therefore, it possessed the highest total ester percentage (61.9%), which was an outstanding value among cultivars ($p < 0.0001$) (Table 4). According to the statistical analysis, ratios of linalyl acetate were significantly affected by the LA varieties (2017: $p < 0.004$; 2018: $p < 0.0001$). In 2018, the percentage of the main

components in 'Aromatico Silver', 'Hidcote Blue' and 'Munstead' complied with the limit assigned by Ph. Eur. VII.

Considering the results available from previous studies on EO composition of 'Hidcote Blue' and 'Munstead', significant differences were observed in our study compared with the earlier reports (Table 7). This might be due to the specific pedo-climatic conditions and to the experimental parameters of the different growing areas. In addition, 'Maillette' showed the best stability concerning the main EO components.

3.2.2. Variations in essential oil composition of LI cultivars

Considering *L. x intermedia* cultivars, altogether 15 compounds were identified in the volatile oil samples, with 95.1–99.6% of total GC composition. The most important major compounds ($\geq 10\%$) were the following: linalool, 1,8-cineole, *cis* beta-ocimene, camphor, and isoborneol, while the minor compounds (in the range of 1%–10%) included limonene, *trans*-beta-ocimene, lavandulol, terpinene-4-ol, α -terpineol, linalyl acetate, lavandulyl acetate, β -caryophyllene, *cis*-beta-farnesene and epi-alpha-bisabolol (Table 6).

During the years 2017–2018, high linalool ratios — in terms of the Ph. Eur. VII. and the ISO standard (ISO 8902: 2009) — were found both

Table 6

Percentage composition (%) of the essential oil of *L. angustifolia* cultivars in 2018.

			2018					
			A	Be	Bu	HiB	Mai	Mu
Compounds	RT	LRI						
β -myrcene	6.99	995	1.0	0.7	1.2	0.5	0.7	1.0
<i>Cis</i> -beta-ocimene	8.5	1037	5.9	3.7	2.4	5.9	1.1	7.4
<i>Trans</i> -beta-ocimene	8.85	1046	3.7	1.6	1.4	1.0	1.0	2.1
Linalool	10.76	1097	41.4 _b	18.1 _a	47.0 _b	40.5 _b	52.9 _b	22.4 _a
Isoborneol	13.43	1162	0.0	0.0	0.2	1.4	2.1	0.5
Lavandulol	13.58	1166	0.7	0.0	4.0	0.9	0.1	0.5
Terpinene-4-ol	13.96	1175	8.9	2.2	3.1	1.6	1.9	17.6
α -terpineol	14.55	1189	3.9	2.8	3.6	2.8	3.7	3.1
Linalyl acetate	17.11	1250	22.3 _a	58.9 _c	22.2 _b	28.7 _{ab}	27.1 _{ab}	25.6 _{ab}
Lavandulyl acetate	18.59	1285	5.4	2.2	6.0	2.7	1.4	8.1
Geranyl acetate	22.43	1388	1.0	0.8	1.2	1.4	1.0	1.2
β -Caryophyllene	23.68	1420	1.9	2.3	1.9	3.3	1.7	3.7
Total ester %			28.7 _a	61.9 _b	29.3 _a	32.8 _a	29.5 _a	34.9 _a
Total identified %			95.9	93.2	93.9	90.8	94.8	93.2

Legends: RT = retention time, LRI = linear retention index. A = 'Aromatico Silver', Be = 'Beate', Bu = 'Budakalászi', HiB = 'Hidcote Blue', Mai = 'Maillette', Mu = 'Munstead'.

Lower case letters indicate sign. diff. ($p < 0.05$) among varieties.

Table 7

Percentage composition (%) of essential oil of 'Munstead', 'Hidcote Blue' and 'Maillette' (LA): various authors in comparison with our study (Pistelli et al., 2017).

			Renaud		Nimet			Renaud			Pistelli		Oroian
Growing area	Dörgicse (Hungary)		Norway (USA)	Isparta (Turkey)		Dörgicse (Hungary)		Norway (USA)	Dörgicse (Hungary)		Bibbona (Tuscany)	Bontida (Transylvania)	
Growth year	2017	2018	2002	2009	2010	2017	2018	2002	2017	2018	2014	2015	2019
Cultivars	Munstead			Hidcote Blue				Maillette					
Linalool	29.5	22.4	38.3	46.1	39.5	25.7	40.5	29.1	55.4	52.9	48.4	45.5	39.1
Linalyl acetate	25.2	25.5	15.0	6.1	12.2	42.1	28.7	17.3	25.3	27.1	26.0	26.2	28.6
Lavandulyl acetate	10.4	8.1	5.4	–	–	3.2	2.7	5.3	–	–	–	–	–
α -terpineol	–	–	–	–	–	–	–	–	3.3	3.7	5.7	6.6	–

Table 8

Percentage composition (%) of essential oil of *L. x intermedia* varieties in two experimental years.

Growth year		2017		2018	
Cultivars		Grappenhall		Grosso	
Compounds	RT	LRI			
Limonene	8.19	1029	2.3	1.1	0.3
1.8-cineole	8.38	1034	14.5	4.6	1.4
Cis-beta-ocimene	8.5	1037	3.8	1.9	6.2
Trans-beta-ocimene	8.85	1046	0.6	1.1	2.6
Linalool	10.76	1097	51.8	58.9	51.4
Camphor	12.68	1144	2.7	13.9	15.7
Isoborneol	13.43	1162	10.6	4.5	3.9
Lavandulol	13.58	1166	1.2	1.3	1.5
Terpinene-4-ol	13.96	1175	3.5	1.2	0.6
α -Terpineol	14.55	1189	2.0	1.6	1.6
Linalyl acetate	17.11	1250	2.1	3.4	5.3
Lavandulyl acetate	18.59	1285	0.5	0.7	1.7
β -caryophyllene	23.68	1420	0.1	0.6	1.4
Cis-beta-Farnesene	25.27	1459	0.3	0.5	1.2
Epi-alpha-bisabolol	34	1690	1.1	0.1	0.4
Total ester %			2.5	4.1	7.1
Total identified %			99.6	99.7	95.1

Legends: RT = retention time, LRI = linear retention index.

in 'Grosso' (2017: 58.9%; 2018: 51.4%) and 'Grappenhall' (2017: 51.8%; 2018: 41.7%). According to our results, in both experimental years 'Grosso' showed higher ratios of camphor (2017: 13.9%; 2018: 15.6%) than 'Grappenhall' (2017: 2.7%; 2018: 2.9%) Table 8. However, in this latter variety larger proportions of 1.8-cineole (2017: 14.5%; 2018: 3.5%) and isoborneol (2017: 10.6%; 2018: 9.8%) were found (Table 6). In 2018, linalool, limonene, 1.8-cineole, isoborneol and terpinene-4-ol showed decreasing values in LI accessions, when compared with the previous year. In parallel, the proportions of linalyl acetate, lavandulyl acetate and both isomers of ocimene increased in the second year in both cultivars. Because of the lower linalyl acetate percentages, total ester values of the LI varieties were also low in comparison to the LA cultivars.

There are several references about the variety 'Grosso' (Table 9). Compared to the previous studies, our research detected higher linalool and lower linalyl acetate proportions. The most likely reason for this may be the special growth location in Hungary.

Statistical analysis was carried out to compare linalool percentages of all investigated cultivars (both LA and LI), and significant differences were found among them in both years ($p < 0.0001$ in 2017 and 2018, respectively). In the case of linalyl acetate, LI varieties showed significant differences (2017: $p < 0.001$; 2018: $p < 0.005$) from those of the LA varieties.

3.2.3. Effect of growth year on the essential oil composition

To evaluate the effect of the growth year on essential oil properties

Table 9

Percentage composition (%) of essential oil of 'Grosso' (LI) according to different authors in comparison with our study (Se, 2013; Pistelli et al., 2017).

Growing area		Renaud		Se		Pistelli	
Dörögse (Hungary)		Norway (USA)		Olimpic (USA)		Bibbona (Tuscany)	
Growth year	2017	2018	2002	2013	2014	2015	
Cultivar	Grosso						
1.8-cineole	4.6	1.4	10.7	7.5	8.4	7.8	
Linalool	58.9	51.4	27.9	41.9	33.8	42.9	
Camphor	13.9	15.7	8.1	6.5	8.5	7.7	
Linalyl acetate	3.4	5.3	17.8	37.5	16.7	14.7	

of the varieties, one-way ANOVA was performed as well. Regarding linalool ratios, significant differences between the years were only found in the case of 'Beate' (LA) ($p > 0.0001$), 'Grosso' (LI) ($p < 0.004$) and 'Grappenhall' (LI) ($p < 0.001$). Linalyl acetate content was significantly affected by the growth year in 'Beate' (LA) ($p < 0.003$), 'Budakalászi' (LA) ($p < 0.033$), 'Maillette' (LA) ($p < 0.029$), 'Grosso' (LI) ($p < 0.001$) and 'Grappenhall' (LI) ($p < 0.0001$).

Regarding the conditions of growth year, a considerable difference was found in the amount of precipitation: from the start of the vegetation in March till the harvest in June, 110 mm more rainfall was measured in 2018 than in 2017 (Table 4). In the study of Hassiotis et al. (2014), linalool percentage decreased due to rainfall, although it was also affected by temperature and by flowering stage. In 2018, the percentage of linalool was less in the case of 'Beate', 'Maillette', 'Munstead', 'Grosso' and 'Grappenhall', which was in correlation with the above-mentioned findings of Hassiotis et al (2014). By contrast, linalool proportions of 'Budakalászi' and 'Hidcote Blue' were higher than those detected in the previous year (2017).

4. Conclusions

Under the conditions of our experiment, significant differences were found among the LA and LI varieties with regard to the EO content and composition in both experimental years. At the same time, our results confirmed, that based on the intraspecific variability, specific requirements and characteristics of the cultivars should be taken into consideration in order to optimize production and utilization of them. Evaluating the investigated cultivars, we concluded, that 'Budakalászi' (LA) and 'Grosso' (LI) may be candidates for Hungarian production because of their high EO output and acceptable EO quality. Nevertheless, investigations in other regions of the country should confirm this suggestion. Although EO content values were low, only the EO quality of 'Hidcote Blue' (LA) and 'Munstead' (LA) originating from the United Kingdom met the requirements of the Ph. Eur. VII. Further breeding on increased volatile production might rise the cultivation value of these varieties. It is of high importance, that 'Aromatico Silver' (LA), and 'Munstead' (LA) can be seen as the most stable cultivars regarding both EO content and composition which may be their advantage in regions of widely variable weather conditions. On the other hand, the most sensitive cultivars from this point of view were 'Beate' (LA), 'Grosso' (LI) and 'Grappenhall' (LI). In all of these varieties, linalool proportions decreased and linalyl acetate ratios increased in 2018, when more precipitation has fallen prior to the flowering season. If this specific reaction could be ascertained by further trials, agrotechnology may be adjusted accordingly.

It was also found that 'Beate' (LA) represented the largest variability between years in terms of EO content, linalool and linalyl acetate ratios. Beside, EO produced from this cultivar failed to satisfy the requirements of the Ph. Eur. VII. (EO content: 1.3 mL/100g for *Lavandulae flos*), and thus, could not be used for pharmaceutical purposes. Interestingly, EO content increased significantly at 'Beate' (LA) and 'Budakalászi' (LA) in the more rainy year (2018), which ascertains the need for technological optimization according to variety and not only at species level. In our study, 'Grosso' (LI) possessed outstanding linalool ratios comparing with the references, it even exceeded the linalool content of some LA varieties. At the same time, linalyl acetate ratios represented extremely low values which might have been the result of the special growth location and pedoclimatic conditions. This finding calls the attention that adaptation of introduced species and/or cultivars may result in changed quality of the drug therefore detailed investigations are needed to establish a sustainable and prosperous cultivation. The Hungarian 'Grosso' may however, be eligible for enhancing the antimicrobial properties of different lavender products (Carrasco et al., 2016), as unusually high camphor ratios were detected in the EO.

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CRedit authorship contribution statement

Enikő Détár: Investigation, Formal analysis, Writing - original draft. Éva Zámoriné Németh: Validation, Writing - review & editing, Supervision. Beáta Gosztola: Investigation. Ildikó Demján: Resources. Zsuzsanna Pluhár: Conceptualization, Writing - review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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