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COMPARATIVE RESEARCH OF PRODUCTIVE AND QUALITATIVE INDICATORS IN LAVENDER VARIETIES CULTIVATED IN EASTERN BULGARIA

Vanya DELIBALTOVA, Svetlana MANHART, Istiliyan STOYCHEV, Martin NEDYALKOV

Agricultural University of Plovdiv, 12 Mendeleev Blvd, Plovdiv, Bulgaria

Corresponding author email: vdelibaltova@abv.bg

Abstract

Lavender (Lavandula angustifolia Mill.) is one of the most significant essential oil crops in Bulgaria. It is a perennial bush belonging to the Lamiaceae family and is mainly cultivated for its fresh inflorescences. The experimental work was conducted in the Eastern Bulgaria region, specifically in the city of Aytos, during the period of 2020 to 2022. The experiment was carried out on cinnamon forest soil type using a randomized block design with four replications and a plot size of 10 m^2. Three lavender varieties were tested: Hemus, Yubileyna, and Sevtopolis. The aim of the investigation was to establish the productivity and quality of lavender varieties cultivated in the eastern part of Bulgaria. The analysis of the results showed that over the three-year experimental period, the highest yield of fresh inflorescences was obtained from the Sevtopolis variety, while the highest percentage of essential oil content, as well as the highest essential oil yield, was realized from the Yubileyna variety. The content of linalyl acetate and linalool is 1:0.7 only in the Hemus variety, which defines the essential oil as high quality.

***Key words**: lavender, variety, yield, quality, essential oil.*

INTRODUCTION

Lavender is one of the most common essential oil crops grown in the world. The genus *Lavandula*, native to the Mediterranean region, includes 39 species (*Lavandula* sp.) and about 400 recorded cultivars (Benabdelkader et al., 2011; Ghavami et al., 2022; Mardani et al., 2022). They are perennial bushes that form tufts and differ in morphological and chemical composition (Lesage-Meessen et al., 2015; Marovska et al., 2022).

The yield of fresh inflorescences, as well as the chemical composition and quality of lavender essential oils, depends on many factors, such as: variety, geographical location, altitude, soil and climatic conditions, harvest time, drying methods or extraction techniques and cultivation technique (Crișan et al., 2023; Détár et al., 2020; Duskova et al., 2016; Hristova et al., 2020; Minev et al., 2022; Mihalascu et al., 2020; Özel, 2019; Saunier et al., 2022; Sonmez et al., 2018; Soskic et al., 2016; Stanev & Angelova 2023).

The variety has a significant effect on quantitative and qualitative indicators of lavender (Adaszyńska et al., 2013; Akdoğan et al., 2022; Bayındır et al., 2023; Stanev et al., 2016).

Establishing the proper variety structure depending on the concrete agroecological conditions of the region can significantly increase the yield of fresh inflorescences and the quality of essential oil. That requires a very good understanding of the characteristics of the different varieties, to be able to make the right choice. The field experiment in the region of Isparta, Turkey found that the highest fresh stem flower yield as well as linalool content was obtained from Dutch variety while the highest essential oil content was determined from Silver variety. The highest linalyl acetate content was obtained from Super A variety (Nimet and Baydar, 2013). According to Yanchev (2017) in the region of Plovdiv, the essential oil contents of Sevtopolis variety were higher than Yubileyna and Druzhba. Georgieva et al., (2021) reported that in the region of Dobrich, Bulgaria, the highest yield of fresh flowers was obtained by variety Druzhba, while the highest percentage of essential oil was realized from the variety Sevtopolis, and the lowest from the variety Hemus. However, the highest essential oil qualitative was obtained by the Hemus variety, hence the ratio between linalyl acetate and linalool is 1:0.7, which defined the essential oil as high qualitative (Georgieva et al., 2022; Stanev & Angelova, 2022; Stanev & Dzhurmanski, 2011). The Bulgarian varieties of lavender - Druzhba, Sevtopolis, Yubileina and Hebar are characterized by high adaptability, but they retain their yield stability only when the soil and climate conditions of cultivation are good. The Hemus, and Raya varieties give highly stable yields even in less favourable conditions of cultivation (Stanev, 2010).

Therefore, studies related to the cultivation of lavender varieties in different country regions have particular scientific and practical significance.

The aim of the investigation was to establish the productivity and quality of lavender varieties cultivated in the eastern part of Bulgaria.

MATERIALS AND METHODS

The experimental work was conducted in the Eastern Bulgaria region, specifically in the city of Aytos, during the period of 2020 to 2022. The experiment was carried out on cinnamon forest soil type using a randomized block design with four replications and a plot size of 10 m^2.

Three lavender Bulgarian varieties were tested: Hemus, Yubileyna, and Sevtopolis. The experimental work was carried out following the adopted cultivation technology. Annually were performed 4-5 mechanized tillage between rows and 2-3 in-rows, manual, weed control and soil loosening. In spring, before the first tillage between rows, 100-120 kg/ha N were applied, and in autumn, with the last tillage between rows, 80-100 kg/ha P_2O_5 и K_2O. During the vegetation, the fungicide Topsin - 0.15% and the insecticide Mospilan - 0.02% were applied to control diseases and pests (Yordanova et al., 2022). To achieve the goal of the study, the following characteristics were reported: yield of fresh inflorescences – kg/ha, essential oil content – %, yield of essential oil – l/ha, harvest index – kg and essential oil composition – %.

The essential oil content of fresh inflorescences was extracted by distillation using a Clevenger collector apparatus. Compositions of the essential oil were determined by Gas Chromatography-Mass Spectrometry (GC/MS) analysis.

The obtained data for the values of all indicators were statistically processed by the method of dispersion and correlation analyses (Kuneva & Sevov, 2020; Sevov et al., 2021).

The main climatic factors determining the growth and productivity of lavender are temperatures and precipitation, their combination and distribution during the growing season (Stanev, 2010).

During the study period 2019-2022, the average daily temperature values exceed the perennial ones, and meet the requirements of the culture for heat during the growing season (Figure 1).

From the beginning of vegetation to the beginning of flowering, the required temperature sum for lavender is 1000-1100^{0}C.

During the years of study, it was 2181^{0}C, 2172^{0}C, and 2223^{0}C, for 2020, 2021 and 2022, respectively, i.e. it is sufficient for the development of plants through the leafing, budding and beginning of flowering phases.

During flowering and harvesting, higher temperatures favor the accumulation of more essential oil in the flowers (Stanev et al., 2016).

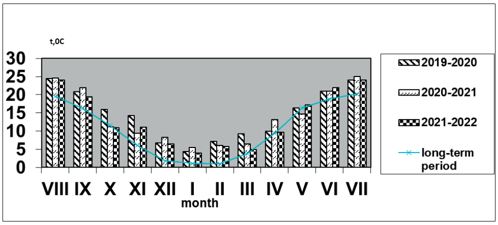

Figure 1. Average monthly air temperature in Aytos, ^{0}C

The amount of precipitation during the experimental period has values lower than those for the multi-year period (Figure 2). The first year of the experiment had the least rainfall – 365.2 mm, compared to the second (435 mm) and the third (515.9 mm). In 2019-2020, the total amount of precipitation was 173.6 mm less than that recorded in the multi-year period. The poor supply of moisture during the winter months, as well as at the beginning of the growing season until the beginning of flowering, adversely affected the growth and development of lavender plants and the production of fresh flowers, while the reported low values of precipitation (2.1 mm) during flowering had a favorable effect on the amount of essential oil. In the economic year (2020-2021), the amount of precipitation fell was 104 mm, less than the recorded for the multi-year period.

The third year of the study (2021-2022) is characterized by the largest amount of precipitation compared to the previous ones.

The supply of moisture during the winter months and the uniform distribution of precipitation from the beginning of the growing season to the beginning of flowering had a favorable effect on the growth of lavender plants and the production of flowers, while rainfall during flowering and harvesting led to a decrease in essential oil content.

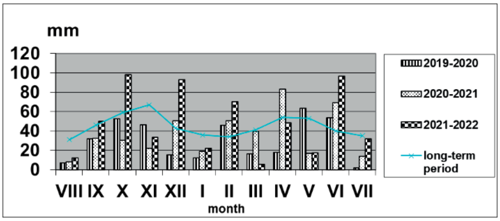

Figure 2. Rainfall in Aytos, mm

RESULTS AND DISCUSSIONS

The results obtained were presented in Table 1 and they showed that both by years and in average for the experimental period Sevtopolis variety surpassed the yield of fresh inflorescences all the other varieties included in the study. The highest yields were obtained in the favorable for lavender year of 2022 when the temperature values and the precipitation sum fully met the plant requirements for warmth and moisture throughout the whole vegetation period.

The yields obtained reached up to 6680 kg/ha in Sevtopolis variety. Referring to yield that variety surpassed the Yubileyna and Hemus varieties by 12.6% and 36.9%, respectively, the differences are statistically significant. In the second experimental year (2021) the yields of fresh flowers obtained varied from 4220 kg/ha in the Hemus variety to 5840 kg/ha in the Sevtopolis variety, i.e. they were by 13.9% lower in average in comparison with 2022. Mathematical processing of data showed that Yubileyna and Hemus varieties significantly fell behind by 540 and 1620 kg/ha than Sevtopolis variety. In the first year of the study (2020) the meteorological conditions during the varieties vegetation were unfavourable and the plants were not able to attain their biological potential.

The yields of fresh inflorescences obtained were within the limits of 3420 to 4210 kg/ha. Statistically proven, the lowest ones were those of Hemus variety and the highest – of Sevtopolis, i.e, they were by 1327 and 2037 kg/ha lower in average in comparison with 2021 and 2022 year. During the period of study (2019-2022) Sevtopolis variety realized the yield of 5577 kg/ha in average and it surpassed the varieties Hemus and Yubileyna by 33.6% and 11.7%, respectively. The results from analyses of variance over three years for the yield of fresh inflorescences found that the effects of Varieties and Year on this indicator were significant. The interaction between the two factors was less expressed.

The analysis of variance (Anova) shows a strong statistically proven influence on both the tested varieties (B) and the years with their specific climatic conditions (A). An interaction between Variety and Year was proven.

The value of inflorescences in the cultivation of lavender is determined by the content of essential oil in them. The values of this indicator were influenced by both the years with different climatic conditions and the varieties (Table 1). The lowest values of the content of essential oil were reported in 2022, precipitation during flowering and harvesting were significant and leads to a decrease in the amount of essential oil. The content of essential oil was from 1.46% in the Hemus variety to 1.90% in the Yubileyna variety. In 2020, when the average air temperature during the period of the lavender flowering was 24.0^{0}C and the rainfall equalled – 2 mm, the varieties had oil content from 1.83% to 2.45%, which was higher from 25.3% to 28.9% than in 2022. Data statistical processing showed that the differences between all the studied varieties were significant. In the second experimental year (2021) the values of this indicator vary from 1.74% to 2.05%, i.e. they were by 14.4% lower in average in comparison with 2020 year. Mathematical processing of data showed that

Yubileyna variety significantly exceed Sevtopolis by 12.0% and Hemus – by 17.8%. On average for the three-year period Yubileyna variety was obtained the content of essential oil of 2.13%, which exceed the varieties Hemus and Sevtopolis by 16.4% and 13.3% respectively. The analysis of variance for the influence of the factors – Variety and Year, as well as their interaction on the indicator "essential oil content" shows a significant influence of the factors on the change of the indicator.

Table1. Quantitative and qualitive indicators

		Yield of fresh inflorescences (kg/ha)	Essential oil content (%)	Yield of essential oil (l/ha)	Harvest index (kg)
Years	2020	3793 [a]	2.14 [c]	81.5 [a]	47.4 [a]
(A)	2021	5120 [b]	1.87 [b]	96.3 [b]	53.6 [b]
	2022	5830 [c]	1.68 [a]	98.5 [b c]	60.3 [c]
Varaety	Hemus	4173	1.68	70.1	60.2
(B)	Yubileyna	4993	2.13	106.3	47.4
	Sevtopolis	5577	1.88	104.8	53.7
2020	Hemus	3420 [a]	1,83 [a]	62.6 [a]	54.6 [c]
	Yubileyna	3750 [b]	2.45 [c]	91.9 [b]	40.8 [a]
	Sevtopolis	4210 [c]	2,14 [b]	90.1 [b]	46.7 [b]
2021	Hemus	4220 [a]	1.74 [a]	73.4 [a]	57.5 [c]
	Yubileyna	5300 [b]	2.05 [c]	108.7 [b]	48.7 [a]
	Sevtopolis	5840 [c]	1.83 [b]	106.9 [b]	54.6 [b]
2022	Hemus	4880 [a]	1.46 [a]	71.2 [a]	68.5 [c]
	Yubileyna	5930 [b]	1.90 [c]	112.7 [b]	52.6 [a]
	Sevtopolis	6680 [c]	1.67 [b]	111.6 [b]	59.9 [b]
Anova	A	**	*	*	**
	B	**	**	*	**
	AB	*	*	n.s	n.s

*Means within columns followed by different lowercase letters are significantly different (P<0.05) according to the LSD test
* F - test significant at P<0.05; ** F - test significant at P<0.01; n.s. - non-significant

The highest values of the indicator - essential oil yield on the investigation varieties were established in 2022 year – 98.5 l/ha, followed by 2021 – 96.3 l/ha and the lowest, in 2020 – 81.5 l/ha. The differences between the years were statistically significant. The results obtained in Table 1 showed that both by years and in average for the experimental period the lowest yield of essential oil were realized by Hemus variety and mathematical processing of data showed that this variety significantly fell behind Sevtopolis by 27.5, 33.5 and 40.4 l/ha and Yubileyna by 29.3, 35.3 and 41.5 l/ha in 2020, 2021 and 2022 year, respectively.

On average for the three years, the highest yield of essential oil was reported by the variety Yubileyna – 106.3 l/ha, followed by Sevtopolis with 104.8 l/ha and the lowest with a value of 70.1 l/ha by Hemus variety. Data statistical processing showed that the differences between the varieties Sevtopolis and Yubileyna are statistically non-significant not only by years but also for the three years of the experiment. The results of the dispersion analysis about the effect of the factors Variety and Year, as well as their interaction, on the indicator yield of essential oil, show a statistically significant effect of the studied factors and an insignificant of their interaction.

The Harvest index is an indicator that shows, the amount of fresh lavender inflorescences necessary to produce one kilogram of essential oil (Minev, 2020). The analysis of the data shows that the yield is influenced by both environmental factors (the amount of precipitation and air temperature) and the varieties. In the conditions of quiet, hot, dry and sunny weather during flowering and flower harvesting in 2020, the Harvest index reached up to 40.8 kg in Yubileyna variety. In unfavorable for flowering and synthesis of essential oil 2022 required raw material for the production of one kilogram of lavender oil varied in varieties from 52.6 to 68.5 kg. The average data for the three - year period show that the variety Yubileyna has lowest Harvest index with values of 47.4 kg, followed by the variety Sevtopolis (53.7 kg). By the variety Hemus the values of the indicator are the highest (60.2 kg).

The analysis of variance (Anova) shows a strong statistically proven influence on both the tested varieties (B) and the years with their specific climatic conditions (A) on the indicator Harvest index. An interaction between Variety and Year was not proven.

The increased requirements in recent years for the quality, safety and authenticity of essential oils can be satisfied with an objective characterization of their chemical composition.

Table 2 presents the results of the gas chromatographic analysis of the lavender oils of the tested cultivars during the three experimental years. The obtained values show that the main components in lavender essential oil are linalool and linalyl acetate. The most important ingredient determining the quality of lavender oil is linalyl acetate. Its high content is an indicator of good quality. This content is highest in the Hemus variety (from 37.59% to 40.94%) and meets the requirements of the standard for Bulgarian lavender oil (from 30% to 42%).

In the Sevtopolis variety, the content of linalyl acetate over the years is slightly below the standard, while in Yubileyna in 2021 and 2022 meets the standard, and in 2020 it is about 14% lower.

Table 2. Essential oil composition (%) in fresh stem flowers of lavender

Essential oil Components	Year	Variety			BDC ISO 3515:2004
		Hemus	Yubileyna	Sevtopolis	
Limonene	2019-2020	0.42	0.15	0.50	max. 0.6
	2020-2021	0.37	0.35	0.38	
	2021-2022	0.26	0.29	0.37	
β- phellandrene	2019-2020	0.18	0.20	0.26	max. 0.6
	2020-2021	0.11	0.22	0.42	
	2021-2022	0.19	0.13	0.21	
1,8-cineole	2019-2020	1.50	1.32	0.40	max. 2.0
	2020-2021	0.28	0.19	0.89	
	2021-2022	0.47	0.54	0.78	
Linalool	2019-2020	34.05	37.59	25.06	22-34
	2020-2021	30.09	27.84	36.04	
	2021-2022	30.80	26.53	33.81	
Camphor	2019-2020	0.10	0.21	0.18	max. 0.6
	2020-2021	0.11	0.12	0.14	
	2021-2022	0.19	0.22	0.19	
Linalyl-acetate	2019-2020	39.04	27.51	34.04	30-42
	2020-2021	37.59	33.47	25.82	
	2021-2022	40.94	33.49	26.17	
Terpinen-4-ol	2019-2020	0.30	3.04	5.20	2-5
	2020-2021	0.52	8.04	3.30	
	2021-2022	0.25	6.14	3.60	
Lavandulol acetate	2019-2020	1.90	3.83	3.40	2-5
	2020-2021	2.35	3.16	3.19	
	2021-2022	1.86	4.00	3.16	
Lavandulol	2019-2020	0.30	0.95	0.70	min. 0.3
	2020-2021	0.34	0.65	0.99	
	2021-2022	0.45	0.97	0.41	
α-Terpineol	2019-2020	0.90	0.95	0.70	0.8-2
	2020-2021	1.21	0.65	0.99	
	2021-2022	0.96	0.97	0.14	
cis-β-Ocimene	2019-2020	2.13	1.14	1.10	3-9
	2020-2021	1.50	0.66	0.69	
	2021-2022	1.16	0.84	0.71	
trans-β-Ocimene	2019-2020	1.60	3.07	6.60	2-5
	2020-2021	1.43	7.52	3.07	
	2021-2022	1.15	6.13	5.24	

Of great importance for the quality of the essential oil is the ratio between linalyl acetate and linalool, which for typical Bulgarian lavender oil should be in a ratio of 1:0.7 (Stanev & Dzhurmanski, 2011; Stanev et al., 2016).

The linalool in the studied varieties was within the limits and slightly above the Bulgarian standard (22-34%, and the ratio between the two components was observed only in the Hemus variety, while in Jubileena and Sevtopolis the amount of linalyl acetate was less than that of linalool.

Other chemical ingredients determining the quality of an essential oil are lavenderol acetate, lavenderol, α-terpineol, 1,8-cineole and limonene. A serious problem in the last few years is the low content of lavender acetate in the Bulgarian lavender oil intended for export. In the region of South-Eastern Bulgaria, all tested lavender varieties meet the Bulgarian standard (2-5%).

Table 3. Values of the coefficient of correlation

	Yield of inflorescences	Essential oil content	Yield of essential oil	Harvest index	Limonene	β- phellandrene	1,8-cineole	Linalool	Camphor	Linalyl-acetate	Terpinen-4-ol	Lavandulol acetate	Lavandulol	α-Terpineol	cis-β-Ocimene	trans-β-Ocimene
Yield of inflorescences	1															
Essential oil content	-0.241	1														
Yield of essential oil	0.795*	0.356	1													
Harvest index	0.341	-0.949	-0.293	1												
Limonene	0.015	-0.195	-0.078	0.086	1											
β- phellandrene	0.263	0.098	0.340	-0.121	0.257	1										
1,8-cineole	-0.359	0.287	-0.253	-0.231	-0.227	0.148	1									
Linalool	-0.092	0.138	-0.109	-0.016	-0.4305	0.325	0.768*	1								
Camphor	0.3285	0.263	0.415	-0.097	-0.506	-0.085	0.002	-0.061	1							
Linalyl-acetate	-0.503	-0.557	-0.758	0.424	0.151	-0.553	-0.238	-0.457	-0.326	1						
Terpinen-4-ol	0.443	0.496	0.813*	-0.530	0.084	0.174	-0.409	-0.482	0.242	-0.408	1					
Lavandulol acetate	0,352	0.726*	0.805*	-0.690	-0.232	0.168	-0.049	-0.109	0.598	-0.707	0.746*	1				
Lavandulol	0.233	0.515	0.629	-0.568	-0,354	0.453	0.060	0.058	0.512	-0.587	0.551	0.818*	1			
α-Terpineol	-0.525	-0.187	-0.484	-0.030	-0.244	-0.135	0.021	0.02	-0.218	0.434	-0.386	-0.205	0.184	1		
cis-β-Ocimene	-0.803	-0.170	-0.894	0.082	0.163	-0.417	0.473	0.145	-0.462	0.638	-0.703	-0.640	-0.577	0.415	1	
trans-β-Ocimene	0.445	0.473	0.763*	-0.469	0.246	0.111	-0.421	-0.563	0.267	-0.368	0.960**	0.694	0.389	-0.553	-0.638	1

*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

Regarding the content of lavenderol, α-terpineol, 1,8-cineole and limonene, all varieties meet the standards.

Unwanted constituents in the essential oil are terpinene 4-ol and camphor. The last selection in Bulgaria was aimed at creating varieties with a very low content of terpinen 4-ol. That is why its content is very low in all Bulgarian varieties.

The requirement of the Bulgarian standard for camphor content is up to 0.6%. In the tested varieties, depending on the year, it varies from 0.10% to 0.22%, i.e. significantly lower than the maximum permissible amount according to BDS ISO 3515:2004.

The results of correlation analysis between the yield of fresh inflorescences, the essential oil content and the oil yield as well as the major components of coriander essential oils, are presented in Table 3. A very strong correlation ($r > 0.9$) was found between the terpinen-4-ol and trans-β-ocimene. High positive values of r ($r > 0.8$ and $r > 0.7$) were reported for yield of essential oil and lavandulol acetate; terpinen-4-ol and yield of essential oil; lavandulol and lavandulol acetate; essential oil

content and lavandulol acetate; yield of essential oil and trans-β-ocimene; linalool and 1,8-cineole; terpinen-4-ol and lavandulol acetate.

Mean correlation was found between the indicators: trans-β-ocimene and lavandulol acetate ($r = 0.694$); cis-β-Ocimene and linalyl-acetate ($r = 0.638$); yield of essential oil and lavandulol ($r = 0.629$); essential oil content and lavandulol ($r = 0.515$). There are positive correlations between lavandulol and β-phellandrene ($r = 0.453$), linalyl-acetate and harvest index ($r = 0.424$) as well as α-Terpineol and cis-β-Ocimene ($r = 0.415$). Weak correlation (r < 0.3) was observed between all the other indicators.

CONCLUSIONS

The productive and qualitative indicators of studied lavender varieties in Eastern Bulgaria are determined by the meteorological conditions of the year and, above all, by the amount and distribution of vegetative rainfall as well as by the genotype.

On average for the three-year experimental period, the highest yield of fresh inflorescences was obtained from the Sevtopolis variety - 5577 kg/ha and it surpassed the varieties Hemus and Yubileyna by 1404 kg/ha and 584 kg/ha, while the highest yield of essential oil was reported by the variety Yubileyna (106.3 l/ha), followed by - Sevtopolis (104.8 l/ha) and the lowest (70.1 l/ha) by Hemus variety.

During the period of study (2020-2022) Yubileyna variety had the content of essential oil of 2.13%, which exceeded the varieties Hemus and Sevtopolis by 16.4% and 13.3%, respectively.

The variety Yubileyna has the lowest harvest index with values of 47.4 kg. By the variety of Hemus, the values of the indicator are the highest (60.2 kg).

The content of the linalyl acetate by the variety Hemus is the highest and meets the requirements of the international standard, as only by this variety the ratio between linalyl acetate and linalool is 1:0.7. and the essential oil could be defined as highly qualitative.

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