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Effect of foliar products on the inflorescence yield of lavender and essential oil

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Abstract. The topic of the effect of foliar fertilization on the productivity and oil content of lavender is relevant, but not sufficiently studied. The present study aims to establish the effect of foliar products on the growth, development and productivity of lavender. The field experiment was carried out at the Agricultural University - Plovdiv with lavender of 'Jubileina' variety during 2019–2020. The following variants were included in the study: 1. Untreated control; 2. Treatment with Fertileader Gold (FG) - 3 L ha^{-1}; 3. Treatment with Fertiactyl Trium + Fertileader Vital (FT + FVital) - 1.5 + 1.5 L ha^{-1}; 4. Treatment with Fertileader Viti (FViti) - 3 L ha^{-1}; 5. Treatment with Fertileader Vital (FV) - 3 L ha^{-1}; 6. Treatment with Fertileader Alpha (FA) - 3 L ha^{-1}. Those preparations are bio stimulants for foliar application. The treatments were made in two consecutive lavender vegetation seasons. The first application was carried out in the second growing season (2019) and the second in the next, third growing season (2020). The foliar application of all tested products increased the photosynthetic activity, but it was better expressed when using the plant nutrition products FV, FViti and FT + FVital. A positive effect was also observed in the height and diameter of the bush, but during the third vegetation period. The number of flowering stems increased by 62.9%; 59.4%; 53.3% and 8.4%, respectively, when applying the fertilizers FG, FT + FVital, FViti and FV. The application of FG and FT + FVital increased the yield of fresh inflorescences by 6.1% and 3.7%. The application of the different products affected the oil yield in different ways; the application of FG, FT + FVital and FViti increased it, while FV and FA decreased it by 27 kg ha^{-1} and 16 kg ha^{-1}, respectively, for the first vegetation and by 43.4 kg $ha^{-1}$and 33.1 kg ha^{-1} for the second vegetation. The boron containing products FG, FT + FVital and FViti led to a significant increase in the essential oil yield, while the application of the foliar fertilizers FV and FA reduced it. Based on those results, the first three products are recommended.

Key words: medicinal crops, *Lavandula angustifolia*, foliar fertilization, flower yield, oil yield, oil content.

INTRODUCTION

The quantitative and qualitative parameters of lavender production (number of flowers and essential oil yield) are influenced by a complex set of factors, such as soil, climate, varietal composition, degree of flowering, duration of the distillation process, fertilizer application, etc. So far little is known about the factors that cause variations in lavender essential oil or control the monoterpene profile and abundance of monoterpenes.

Secondary metabolites, such as monoterpenes, perform various environmental functions and therefore they are regulated by the environmental factors. It was suggested that the released volatile substances can serve or support pollinators (Raguso & Pichersky, 1999). It was also found that monoterpenes acted as a barrier against heat stress (Velikova et al., 2006) and their radiation was regulated by the level of irradiation in some plant species (Staudt & Seufert, 1995).

Flowering is a factor influencing the quantitative and qualitative indicators of lavender essential oil (Konakchiev, 2015). The author established the crucial importance of the flowering stage on the quantitative and qualitative parameters of the extracted lavender oil. The duration of distillation process (DT) had also a significant effect on the quantity and quality of lavender oil.

The application of fertilizers is one of the most important factors determining plant productivity (Bardule et al., 2013; Almeida et al., 2015). Among the agronomic practices, nutrient management in oil-bearing crops affected most significantly the yield and quality of essential oils (Pal et al., 2016). The synthesis of essential oil in aromatic plants can be positively or negatively affected by the form, type and amount of fertilizers (Yadegari, 2015; Lamptey et al., 2017; Lukošiūtė et al., 2020). Nutrients such as nitrogen (N), phosphorus (P) and potassium (K) could affect the growth and synthesis of essential oil in aromatic plants and are used to build many organic compounds, such as amino acids, proteins, enzymes and nucleic acids. Those nutrients affect the function and levels of enzymes involved in terpenoid biosynthesis (Hafsi et al., 2014).

The application of N fertilizer reduced the essential oil content of creeping juniper (*Juniperus horizontalis* L.), (Robert & Francis, 1986), although an increase in the yield of Thyme essential oil (*Thymus vulgaris* L.) was established by Baranauskienne et al. (2003) and in cumin (*Cuminum cyminum* L.) by Azizi & Kahrizi (2008). Phosphorus plays an important role in various metabolic processes, such as a component of the nucleic acids, phospholipids, and coenzymes activating the production of amino acids used in the synthesis of proteins, DNA, RNA and ATP (Rouached et al., 2010). High levels of P lowered the essential oil yield of chamomile (*Matricaria chamomilla* L.), (Emonfor et al., 1990), but increased it in feverfew (*Tanacetum parthenium* L.), (Saharkhiz & Omidbaigi, 2008) and common sage (*Salvia officinalis* L.), (Nell et al., 2009).

Nurzynska-Wierdak (2013) found that the deficit of potassium can disrupt the metabolism of nitrogen, provoke changes in the N:K ratio and/or the proportions of nitrogen fractions, as well as the accumulation of harmful amino substances and ammonium ions in the plant. Chrysargyris et al. (2016) reported that the efficiency of N and P levels may be linked to the appropriate levels of K in plants, underscoring the need for further study. The application of K affected plant growth and essential oil yield of lemongrass (*Cymbopogon flexuosus*), ditania (*Origanum dictamnus*), basil (*Ocimum basilicum*) and rosemary (*Rosmarinus officinalis*), (Economakis, 1993; Puttanna et al., 2010).

Currently, the use of chemical fertilizers in lavender is mainly limited to the application of N and P in soil, while the effect of other macro-and micronutrients has not been studied. There is also a lack of information regarding the influence of organic and organic-mineral fertilizer on lavender and there is no such information about the effect of foliar fertilizer on the quality and productivity of this important for Bulgaria essential oil crop.

The present study aims to establish the effect of foliar products on the growth, development and productivity of lavender.

MATERIALS AND METHODS

In the period 2019–2020, a field trial was carried out at the Agricultural University - Plovdiv to achieve the aim set. The experiment was conducted with lavender of 'Jubileyna' variety. The trial was carried out by the long plot method, in three replications, with the size of the experimental plot 140 m^2 and the harvest plot - 63 m^2. The field trial variants were: 1. Untreated control; 2. Treatment with Fertileader Gold (FG) - 3 L ha^{-1}; 3. Treatment with Fertiactyl Trium + Fertileader Vital (FT + FVital) - 1.5 + 1.5 L ha^{-1}; 4. Treatment with Fertileader Viti (FViti) - 3 L ha^{-1}; 5. Treatment with Fertileader Vital (FV) - 3 L ha^{-1}; 6. Treatment with Fertileader Alpha (FA) - 3 L ha^{-1}. The treatments were made in two consecutive lavender vegetation seasons, the first being carried out in the second growing year (2019) and the second - in the next third growing season (2020).

The following commercial products were used to test the effect of foliar fertilizers on lavender: 1) Fertileader Gold (FG), (5.7% B; 0.35% Mo); 2) Fertiactyl Trium (FT), (5% N; 5% P_2O_5; 7% K_2O; 1.5% Zn); 3) Fertileader Vital (FVital), (9% N; 5% P_2O_5; 4% K_2O; 0.02% Fe; 0.01% Mo; 0.05% Zn; 0.1% Mn; 0,05% B); 4) Fertileader Viti (FViti), (6% P_2O_5; 12% K_2O; 1% B); 5) Fertileader Alpha (FA), (5% N;13% P_2O_5; 2% B).

Soil characteristics

The soil in the experimental field is alluvial-meadow. Geographically the site is located in the Thracian-Strandja region. The alluvial-meadow soils were formed on sandy-loam and sandy-gravel quaternary deposits. According to the International Classification of FAO, they refer to Mollic Fluvisol. They were formed on alluvial deposits, they have a well-formed humus-accumulative horizon, which gradually passes into the C horizon and a gleization process is observed deeply down (below 100 cm) in the soil-forming material - the A-C-G profile. The humus content is usually no more than 1–2%.

The soil sample analysis made before setting the experiment for the c - 8.30 mg kg^{-1}; NO_3^- - 33.20 mg kg^{-1}; Total mineral nitrogen - 41.50 mg kg^{-1}; P_2O_5 - 282, mg kg^{-1}; K_2O - 560 mg kg^{-1}; CaO - 210.3 mg kg^{-1}; MgO - 53.0 mg kg^{-1}; MnO_4 - 210.0 mg kg^{-1}; pH (H_2O) - 7.6.

These data show that the soil has a slightly alkaline reaction, a low content of N and optimal levels of P_2O_5 and K_2O. Exchangeable calcium (CaO) and magnesium (MgO) were in amounts typical for the soil type. The total quantity of MnO_4 was also determined, which defines the soil as well-stocked concerning this element. However, because of the alkaline nature of the soil, mobility and accessibility for the plants are low. The analysis of the specific soil conditions showed that the soil type is particularly suitable for growing lavender (Stoyanova et al., 2009; Minev, 2020).

Plant material

Lavender cultivation began in November 2017 with certified seedlings of the Bulgarian 'Jubileyna' variety, following the conventional technology. The planting density was 20,000 per ha, with a row distance of 35 cm and an inter-row distance of 1.4 m. The variety used in the experiment was created by hybridization. It has rounded tufts, erect, up to 56 cm high, with about 460 flowering stems, dark purple in colour. The average yield of fresh flowers is 5,540 kg ha^{-1}, the essential oil content in the flowers averages 2% and the rate of yield is 52.8.

In both experimental years (in November) the granulated product TOP 34 (5% N; 19% P_2O_5; 10% K_2O; 19% SO_3; 0.1% Zn; 0.1% B) was applied to the entire experimental area in a dosage of 200 kg ha^{-1}, by incorporation into the soil. Spring fertilization with nitrogen was carried out with ammonium nitrate (NH_4NO_3) in a dose of 90 kg ha^{-1} N in the second growing season and 120 kg ha^{-1} N in the third. The foliar products were used in the respective doses in the lavender bud formation stage.

Plant samples

Plant samples were taken in the stage of the full flowering (95–100%). The fresh flowers were harvested by hand, weighed and steam distilled, for each experimental treatment separately. For this purpose, a specially adapted device with a capacity of 100 L and a Florentine vessel for separating the essential oil from the water was used. The distillation time (DT) was 1.5 hours for all variants of the experiment. In the phenological stage of full flowering, the following biometric indicators were determined: bush height (cm), bush diameter (cm), number of flowering stems, length of the inflorescence (cm) and number of flowering vertebrae.

Photosynthetic activity and Chlorophyll content

Photosynthetic activity (μmol per m^2 s^{-1}) for all variants of the experiment was determined a week after foliar treatment using a portable measuring system LCA-4, England. The chlorophyll content in lavender leaves (mg m^{-2}) was determined using a portable measuring device Chlorophyll meter MC-100, seven days after the application of the foliar products.

The software product ANOVA was used to process the data statistically.

RESULTS AND DISCUSSION

The quantity of precipitation during the winter months (November - February) of the first experimental year (Fig. 1) was close to the norm for the region, except for December, which was dry. During the months of the active growing season, the situation was different. The period March - May was relatively dry, while in June, when the lavender plants form the essential oil yield, precipitation significantly exceeded the norm determined based on data for a period of 30 years.

The winter months of the second experimental year (2019/2020) were characterized by a small amount of precipitation, which is a prerequisite for the emergence of a deficit of soil moisture. That had a negative effect on the process of fertilizer absorption, even though November was humid and largely neutralized the negative impact of the subsequent drought. The precipitations in the period March - June restored moisture in the one-meter soil layer, which had a positive effect on the growth and development of the crop. Precipitation above the norm was measured in March and April, while in February, March, May and June the quantity of precipitation was about the norm.

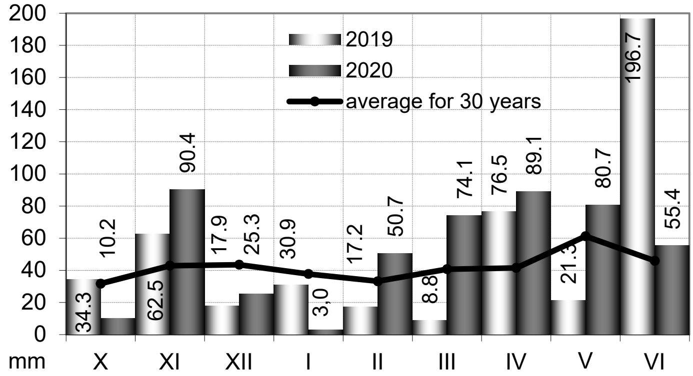

Figure 1. Amount of monthly precipitation (mm) during the study period.

In terms of air temperature, the period November - February in the first experimental year (2018–2019) was characterized by values close to the average for a long period (Fig. 2). February, which is significantly warmer month, was an exception. That was the reason for the earlier resumption of the vegetation of the plantation. The period of active vegetation was characterized by relatively warmer March and June, and, April and May were average in terms of temperature. In general, however, the temperature accumulated during the growing season did not significantly exceed that for the 30 year-period.

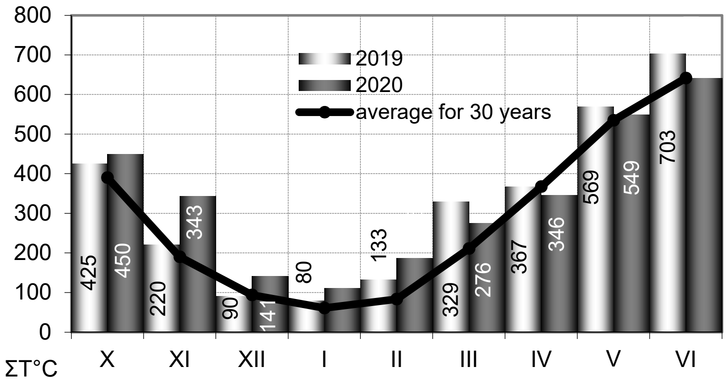

Figure 2. Average monthly temperatures(°C) during the study period.

The temperature values during most of the vegetation of 2019/2020 exceeded that of the long-term period. Exceptions were April and June, which were cooler. As a result, the beginning and the course of the budding and flowering stages were delayed.

Photosynthetic activity and Chlorophyll content

Foliar fertilization is an important agricultural practice worldwide due to the rapid and efficient absorption of the applied plant products (Lasa et al., 2012). It reduced costs and contributed to the sustainable development of organic farming (Fernández & Brown, 2013; Garde-Cerdán et al., 2015). The foliar application of the tested products led to an increase in the photosynthetic activity in all the variants of the experiment (Fig. 3). In the first experimental year (2019), the highest values compared to the control (values above 8 μmol per m^2 s^{-1}) were those treated with FV, FViti, FA and FT + FVital. During the second growing season (2020) the most stimulating activity in terms of this indicator was established in the variants treated with FT + FVital, FV and FViti. That could be due to the neutralizing effect of K_2O on abiotic stress caused by significant amounts of precipitation during flowering (Fig. 1). The application of foliar preparations in the budding stage had some effect on the chlorophyll content of lavender (Fig. 4). For the same reason, the increase in the FT + FVital and FViti variants was more significant in the second experimental year (1,603 and 1,316 mg m^{-2}, respectively) compared to the first.

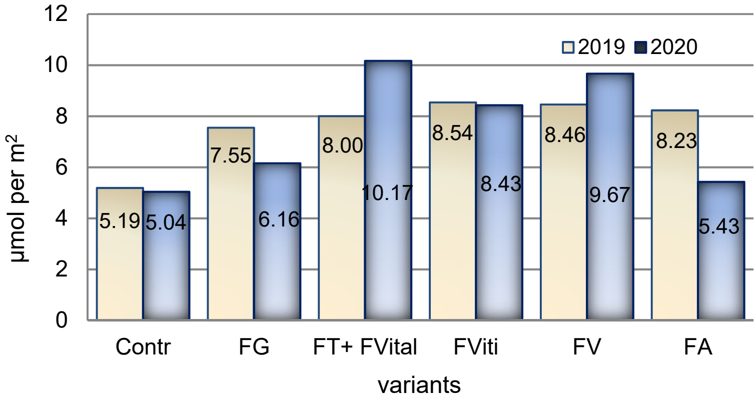

Figure 3. Photosynthetic activity (μmol/m^2s) of lavender 'Jubileyna' variety.

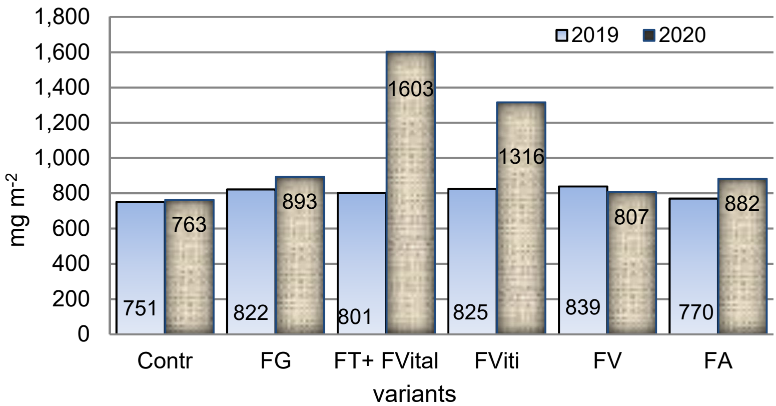

Figure 4. Chlorophyll content (mg m^{-2}) of lavender 'Jubileyna' variety.

Yield and yield components

Fig. 5 shows the data on the yield components of lavender. The bush height in the first year of the experiment ranged from 39.1 cm when applying FViti to 47.0 cm when applying FG. During the second experimental year, the values of the indicator increased significantly compared to the first, ranging from 69.2 cm in the 5th variant of foliar fertilization (FV) to 75.0 cm in the 3rd variant. The higher values during this vegetation were due to the larger size of the plants, which is an age specific feature. Foliar fertilization, with few exceptions, had a positive effect on the height of the bushes, compared to the control, which was statistically significant. Concerning bush diameter, the results were similar to the previous ones. Higher values of the indicator were reported in 2020 compared to 2019.

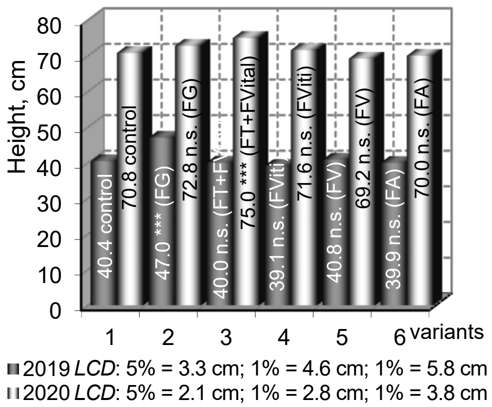

Figure 5, a. Yield components (bush height) of lavender 'Jubileyna' variety.

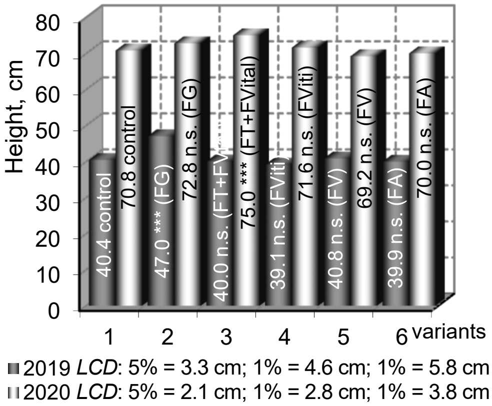

Figure 5, b. Yield components (bush diameter) of lavender 'Jubileyna' variety.

In the first year of the experiment, the largest bush diameter was found in the fertilization variant with FT + FVital, but in the second year - in the fertilization variant with FG, 74 cm and 124 cm, respectively.

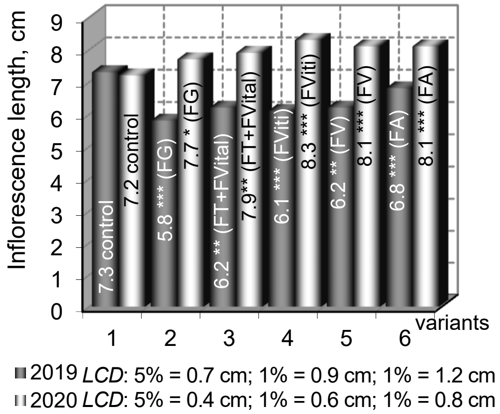

Figure 5, c. Yield components (inflorescence length) of lavender 'Jubileyna' variety.

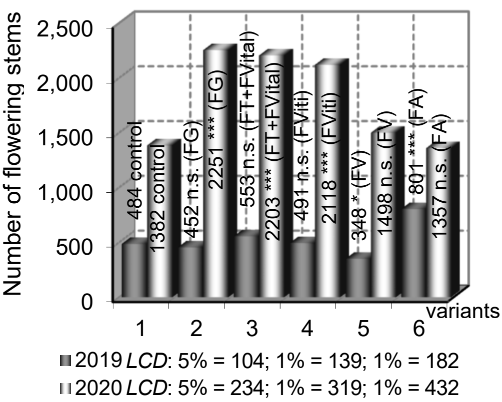

Figure 5, d. Yield components (number of flowering stems) of lavender 'Jubileyna' variety.

The foliar application of all tested preparations in 2020 significantly increased the bush diameter, compared to the untreated variant. The differences between the control and the variants treated with FG, FViti and FV were insignificant during 2019. This is most likely due to the after-effects of the foliar-applied products during the next lavender vegetation.The inflorescence length in the first experimental year was affected negatively by the applied foliar fertilization, and in all studied variants the results were lower compared to the control. A different trend was found in the second year of the study. The length of the inflorescence increased within 0.5–1.1 cm, compared to the unfertilized variant, which was statistically significant. The variants with the application of FV and FA had an influence on the values of this indicator. The application of FViti had the most significant effect on it (Fig. 5, c).

The application of foliar feeding in the second year of the experiment led to an increase in the inflorescence length in lavender by 7% to 15% in the different variants of foliar fertilization. The increase was statistically significant.

The number of flowering stems was significantly affected by the foliar feeding, with more significant differences in the second experimental year, when the values of the indicator ranged from 1,357 in the 6th fertilization variant (FA) to 2,251 in the 2nd variant (FG). Compared to the control, the number of flowering stems increased by 62.9%; 59.4% and 53.3%, respectively, when fertilizing with FG, FT + FVital and FViti. The differences between the control and treated with FV and FA variants were insignificant. This is most likely due to the nitrogen content in these products. Regarding the number of flowering vertebrae, similar trends were found. Higher values of the indicator were found in the second experimental year compared to the first and the positive influence of the applied leaf fertilizers was established, the differences being statistically significant.

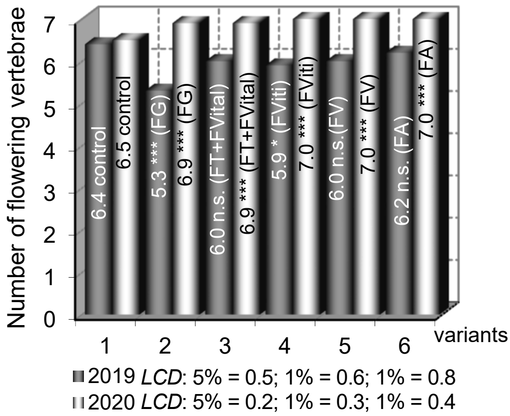

Figure 5, e. Yield components (number of flowering vertebrae) of lavender 'Jubileyna' variety.

The yield of fresh inflorescences (Table 1) in the first year of the study varied from 5,892 kg ha^{-1} for the 4th fertilization variant (FViti) to 6,659 kg ha^{-1} for the 6th variant (FA). Statistically significant differences in lavender productivity were not found only between the control and FV variant.

A significant difference in the values of the indicator was found in all the other products for foliar feeding, compared to the untreated variant. The yield of fresh inflorescences increased significantly compared to the control - by 450 kg ha^{-1} when fertilizing with FA, which is 7.2% more, and, decreased when fertilizing with FViti and FV by 317 kg ha^{-1} and 55 kg ha^{-1}, respectively. In 2020, the difference in the yield of fresh inflorescences between the control and FViti, FV and FA variants was significant. It was negative. The application of FG and FT + FVital foliar fertilizers increased the productivity of the crop by 6.1% and 3.7%, compared to the control, which was statistically significant.

Table 1. The yield of fresh lavender inflorescences

Variants	2019				2020			
	kg ha^{-1}	± kg ha^{-1}	% to the control	Significance	kg ha^{-1}	± kg ha^{-1}	% to the control	Significance
control	6,209	0.0	100.0	control	9944	0.0	100.0	control
FG	6,330	121.0	101.9	*	10547	603.0	106.1	**
FT + FVital	6,556	347.0	105.6	***	10313	369.0	103.7	*
FViti	5,892	-317.0	94.9	***	8337	-1,607.0	83.8	***
FV	6,154	-55.0	99.1	n.s	6013	-3,931.0	60.5	***
FA	6,659	450.0	107.2	***	6134	-3,810.0	61.7	***
LCD	5% = 109; 1% = 151; 0.1% = 209 kg ha^{-1}				5% = 345; 1% = 477; 0.1% = 659 kg ha^{-1}			

Table 2. Yield of lavender essential oil

Variants	2019				2020			
	kg ha^{-1}	± kg ha^{-1}	% to the control	Significance	kg ha^{-1}	± kg ha^{-1}	% to the control	Significance
control	86.0	0.0	100.0	control	159.0	0.0	100.0	control
FG	99.0	13.0	115.1	***	184.1	25.1	115.8	***
FT + FVital	110.0	24.0	127.9	***	183.3	24.3	115.3	***
FViti	115.0	29.0	133.7	***	168.3	9.3	105.8	**
FV	59.0	-27.0	68.6	***	115.6	-43.4	72.7	***
FA	70.0	-16.0	81.4	***	125.9	-33.1	79.2	***
LCD	5% = 0.2; 1% = 4.8; 0.1% = 6.7 kg ha^{-1}				5% = 6.0; 1% = 8.3; 0.1% = 11.5 kg ha^{-1}			

Several studies show that the application of organic fertilizers in different crops increased the yield and quality of essential oils. For example, that was observed in balm (Sodré et al., 2011), mint (Marotti et al., 1994), thyme (Juárez-Rosete et al., 2014) and basil (Bufalo et al., 2015; El-Naggar et al., 2015). The essential oil yield for the entire experimental period of the present study varied from 59 kg ha^{-1} to 183.3 kg ha^{-1} (Table 2). In 2019, the oil yield in the untreated variant was 86 kg ha^{-1}, while in 2020 it was significantly higher - 159 kg ha^{-1}, which is an age specific characteristic. It was found that the treatment with FG, FT + FVital and FViti led to a significant increase in the essential oil yield compared to the untreated variant, while the application of the foliar fertilizers FV and FA led to a decrease in the amount of oil, regardless of the year of cultivation. The decrease was by 27 kg ha^{-1} and 16 kg ha^{-1} in 2019 and by 43.4 kg ha^{-1} and 33.1 kg ha^{-1} in 2020, respectively. Due to the favourable combination between the microelements B and Mo, the highest values of the indicator were reported in the variant treated with FG - 184.1 kg ha^{-1}, exceeding the control by 15.8%. The amount of essential oil (Fig. 6) increased with the increase of the flower

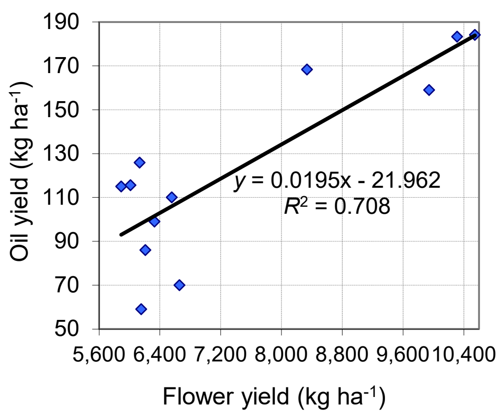

Figure 6. Relationship between flower yield and oil yield of lavender 'Jubileyna' variety.

yield in lavender, and the relationship between the two indicators was linear at $R^2 = 0.708$.

Based on the data for flower and oil yields, as well as for the structural elements of the yield in all the variants for both experimental years, the correlations between them were established. The results are presented in Table 3. According to the values of the correlation coefficients, the yield was strongly influenced by bush height and diameter. Oil yield was strongly correlated with the height and diameter of the bush, as well as with the number of flowering stems and the number of flowering vertebrae. The inflorescence length also affected flower and oil yields, although to a lesser degree.

Table 3. Correlation matrix (Pearson)

Yield components	Bush height, cm	Bush diameter, cm	Number of flowering stems	Inflorescence length, cm	Number of flowering vertebrae	Yield of fresh flowers, kg ha^{-1}	Yield of essential oil, kg ha^{-1}
Bush height	1,000	**0.934**	**0.898**	0.633	0.593	**0.688**	0.842
Bush diameter		1,000	**0.923**	0.638	0.633	**0.656**	**0.851**
Number of flowering stems			1,000	0.650	0.649	0.533	**0.887**
Inflorescence length				1,000	**0.770**	0.425	0.608
Number of flowering vertebrae					1,000	0.461	0.618
Yield of fresh flowers						1,000	**0.841**
Yield of essential oil							1,000
Significant correlation at $p < 0.05$ (bold)							

CONCLUSIONS

The foliar application of all the tested products increased the photosynthetic activity of lavender. The positive effect was better expressed when using the preparations FV, FViti and FT + FVital. The application of foliar fertilizers in the budding stage had a certain positive effect on the chlorophyll content, more significant increase being reported in the variants treated with FT + FVital and FViti in the second growing year. That was probably due to the K_2O content in those preparations, which can mitigate the adverse effects of abiotic stress (low air temperature and precipitations during the flowering period).

Foliar fertilization had a positive effect on the height and diameter of the lavender bushes, better expressed during the second growing season. During the first experimental year (second vegetation), the effect of FG, FViti and FV was weak. Inflorescence length was also not affected by the applied foliar fertilization during the first experimental year. During the second experimental year it increased. The most significant changes were reported in the plants treated with FViti, FV and FA. As a result of the foliar fertilization, the number of flowering stems and vertebrae increased more significantly during the third vegetation. FV and FA preparations had practically no effect on the number of flowering stems.

The yield of fresh inflorescences, was positively influenced by the application with FG and FT + FVital. Treatment with the boron containing products FG, FT + FVital and FViti led to a significant increase in the essential oil yield, while the application of the foliar fertilizers FV and FA reduced it. Based on those results, the first three products are recommended.

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