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EFFECTS OF FOLIAR FERTILIZATION ON GROWTH, DEVELOPMENT AND PRODUCTION OF FLOWERS AND ESSENTIAL OIL ON LAVENDER (*Lavandula angustifolia* Mill.)

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Abstract

The purpose of this study was to determine the effect of foliar fertilization on the growth, development and productivity of lavender Jubileyna variety - the first and second year of cultivation. It is known that the soil and climate conditions are major factors in terms of growth and productivity in lavender. Important for science and practice is to determine the effect of different combinations of nutrients on yield and its components for this essential oil culture. They are used fertilizers with a different composition in terms of macro and micronutrients. The variants of the experiment are four (three leaf fertilizers + untreated controls) and the size of the experimental plot is 500 m^2. The application of leaf fertilizers is carried out in the budding phase of lavender. The results of some of the products show that foliar fertilization has a significant impact on the growth and productivity of the lavender. Some nutrients help to overcome physiological stress due to adverse weather factors. This leads to the formation of higher yields of flowers and oil of lavender.

Key words: *lavender, lavender fertilization, essential oil crops.*

INTRODUCTION

Lavender (*Lavandula angustifolia* Mill.) is one of the most widely grown plants with essential oil in the world. Lavender (*Lavandula angustifolia*) is a shrub of the *Lamiaceae* family and originated in the Mediterranean region. The material used for herbal purposes includes lavender flowers (Lavandula flores) containing essential oil (3%), anthocyanins, phytosterols, sugars, minerals and tannins. The qualitative and quantitative composition of lavender essential oil is different and depends on the genotype, place of cultivation, climatic conditions, reproduction and morphological features. The essential oil contains over 300 chemical compounds. Dominant components are linalool, linalilatsetat, terpinene-4-ol, acetate lavandulol, ocimene and cineole. The essential oil of lavender has a good antioxidant and antimicrobial activity and significant positive effect on the digestive and nervous system. Lavender extract prevents dementia and can inhibit cancer cell growth, while lavender hydrolate is recommended for treating skin problems and burns. Lavender essential oil is widely used in aromatherapy as a holistic relaxant, antioxidant and antimicrobial agent (Sabara and Kunicka-Styczynska, 2009). The industrial cultivation of lavender (*Lavandula angustifolia* Mill.) and the production of lavender essential oil in Bulgaria has grown rapidly over the last 10 years (Stanev et al., 2013).

The genetic characteristics of plants vary under the influence of many environmental factors (Sevik et al., 2016; Ozel et al., 2015). Probably among the most important of these factors is the content of nutrients in the soil and the methods of fertilization that change soil fertility. Problems arise in the development of plants when soil nutrients are deficient and in this case need to add nutrients to the soil. In this case, the content of nutrients in the soil can be increased by importing various fertilizers. The effect of fertilizers on the yield of flowers and essential oil and its components, is little known. The application of fertilizers and the absorption and accumulation of minerals are some of the most important factors that increase the yield and productivity of plants (Almeida et al., 2015).The production of essential oil in aromatic plants can be influenced positively or negatively by the form, type and quantity of fertilizers (Yadegari, 2015).

According to a Biesiada et al. (2008), the most appropriate level of N for the yield of lavender has an average N application 100 kg N/ha. The author notes the importance of an appropriate ratio of minerals (N: K, N: P) for plant nutrition. In various regions of the world with heavy fertilizer use (given the capacity to retain ions soil), overuse of N leads to groundwater pollution, i.e. nitrates, the most mobile form of N in any ecosystem.

High concentrations of P generally have a positive effect on plant growth parameters. Plants grown at the highest P concentration (70 mg/L P) show the highest biomass of 19.47 g/plant, while plants grown at 40 mg/L P show the lowest biomass, 12.69 on average g/plant. Application of 50 mg/L P keeps and increases root fresh weight and dry matter content, but reduce the ratio of overhead biomass/root system. Furthermore, plant height, length of the leaves and the thickness of the stem have not been influenced by the increased concentration of P in the nutrient solution. The leaf biomass of sage (S. of inalcinalis L.) and essential oil content increased with the addition of P fertilizer (Nelletal, 2009), as reported at 70 mg/L P in this study. It has been found that high concentrations of P in *Calendula officinalis* (L.) do not increase the yield of the flowers, but instead produce considerably more biomass of leaves (Stewart and Lovett-Doust, 2003). Lavender plants grown at different concentrations of P represent the following sequencing order of accumulation of macronutrients: N> K> Ca> Mg> P> Na and trace elements: Fe> Al> Mn> B> Zn> Cu. It is reported that the concentrations of P (5, 30 and 60 mg/L) in the solution affect the extraction of essential oil in O. dictamnus (Economakisetal., 2002). The application of phosphorus significantly increases the content of basil essential oil, but the fresh and dry weight of the above-ground mass remains unchanged (Ramezanietal., 2009).

Experiments were conducted in order to determine the effect of the amount of potassium (K: 275-300-325-350-375 mg L^{-1}) on the morphological and biochemical characteristics of lavender grown hydroponic (Antonios Chrysargyris et all). The main components of the essential oil from the leaves (1,8-cineol, borneol, camphor, α-terpineol, mirtenal) and mineral accumulation is influenced by ottretiraniyata K. This study found that lavender treated with 300 mg L^{-1} of K is suitable for the production of essential oil, while 325 mg L^{-1} of K is more suitable for growing lavender for flowers use in fresh and dry condition. Minerals such as nitrogen (N), phosphorus (P) and potassium (K) can affect the growth and synthesis of an essential oil in aromatic plants and are used by plants to build many organic compounds such as amino acids, proteins, enzymes and nucleic acids. These mineral elements affect the function and levels of the enzymes involved in terpenoid biosynthesis (Hafsietal, 2014). Monovalent cations such as K, in the activation of enzymes that play a role in helping to substrate binding by lowering the energy barrier and/or transition states, and not causative of causing catalysis (Pageand Di Cera, 2006).

From an reference shows that the effect of the application of mineral fertilizers on the yield of the flowers and essential oil and its constituents is poorly known, as almost no literature regarding the effect of leaf nutrition on lavender.

The aim of this work is to determine the effect of foliar fertilizers on growth, development and productivity in lavender.

MATERIALS AND METHODS

The experiment was carried out during the period 2018-2019 in Agricultural University of Plovdiv with lavender Jubileyna variety. A production experiment with a plot size of 0.05 ha is carried out, with the following scheme: 1) Untreated control; 2) Fertiactyl Trium + Fertileader Vital - 1.5 + 1.5 l/ha; 3) Fertileader Vital - 3 l/ha; 4) Fertileader Alpha - 3 l/ha. The treatments were made in two successive vegetations of lavender. The first was carried out in the first growing year after transplanting, and the second in the following growing season.

Plant material

The lavender plantation was established in November 2017 with certified seedlings of the Bulgarian Jubileyna variety using conventional technology. The number of plants planted per 1 ha is 20000, with an interlinear space 35 cm and inter-row distance of 1.4 m. Due to the quality of seedlings in the autumn and due to the optimum rainfall during the autumn-winter period of 2017-2018, the plant cover rate was quite high - 96-97%. Jubileyna variety is created through hybridization. There are rounded tufts, up to 56 cm high with about 460 stalks, dark purple flowers. The average yield of fresh flowers is 5540 kg/ha, the content of essential oil in flowers averages 2% and the yield is 52.8.

Used fertilizers

To test the effect of foliar fertilization of lavender were used the following commercial products:

1) Fertiactyl Trium (5% N; 5% P_2O_5; 7% K_2O; 1.5% Zn)

2) Fertileader Vital (9% N; 5% P_2O_5; 4% K_2O; 0.02% Fe; 0.01% Mo; 0.05% Zn; 0.1% Mn; 0.05% B)

3) Fertileader Alpha (6% N; 12% P_2O_5; 4.2% B)

In November, in both experimental years, the granular product TOP 34 (5% N; 19% P_2O_5; 10% K_2O; 19% SO_3; 0.1% Zn; 0.1% B) is imported to the entire experimental area. The dose is 200 kg/ha. Spring nitrogen feeding is done with the Sulfamo product (25% N; 27% SO_3; 4% MgO). The dose for the first vegetation is 30 kg/ha and for the second one - 60 kg/ha. Leaf fertilizers in corresponding doses are imported in phase budding of lavender.

Soil analyses

Mineral nitrogen (ammonium and nitrate) in extraction with 1% KCl; Mobile phosphates by Egner-Reim method; Digestible potassium in extraction with 2N HCl acid; Soil reaction (pH) - potentiometrically in water extraction.

Plant analyses

The plant samples were taken in the full flowering phase of the inflorescences (95-100%). The fresh flowers are harvested manually, weighed and distilled by steam distillation separately for each variant of the experiment. For this purpose, a specially adapted device with a capacity of 100 l is used and florentine vessel for separating essential oil from water. The distillation time is 80 minutes in all variants of the experiment.

In the phenological phase of full flowering, biometric parameters were also considered by variants, namely: shrub height (cm), shrub diameter (cm), number of flowering stems, length of inflorescence (cm) and number of flowering vertebrae.

Harvest index

The Harvest index (HI) is an indicator that shows what percentage or what proportion of all raw materials used have been converted into the desired pure product.

Soil and Climatic Characteristics

The soil in the Training-and-Experimental Fields of the Agricultural University of Plovdiv is alluvial-meadow. Geographically the site is located in the Thracian-Strandja region. The alluvial-meadow soils are formed on sandy-loam and sandy-gravel quaternary deposits. According to the International Classification of FAO they refer to Mollic fluvisol. They are formed on alluvial deposits, they have a well-formed humus-accumulative horizon, which gradually passes into 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 not high - no more than 1-2%.

The contents of the digestible forms of the nutrients nitrogen, phosphorus and potassium, as well as the soil reaction during the two years of the experiment are presented on Table 1.

Based on the generally accepted limits for contents of macronutrients to the soil, it was found that it is poor to average stock with nitrogen and well-stocked with phosphorus and potassium. It is also noteworthy that soil acidity has fallen by almost half a point as a result of intensive fertilization, which must be taken into account when lavender is grown on more acidic soils.

Table 1. Soil reaction, mineral nitrogen content and mobile forms of phosphorus and potassium

Depth, 0-30cm	pH water	NH_4-N mg/kg	NO_3-N mg/kg	Nmin mg/kg	P_2O_5 mg/100g	K_2O mg/100g
2018	7.93	14.0	16.8	30.8	20.0	36.0
2019	7.6	8.30	33.2	41.50	28.2	56.0

The climate in the region of Plovdiv is transitional-continental. Climatic conditions have a decisive influence on productivity in lavender. The total precipitations amount in the January-July period for 2018 and 2019 is 517.4 and 418.9 mm, respectively, which characterizes them as relatively humid compared to the 1971-2000 multi-year period (307.9 mm). In the first experimental year with precipitations above normal are February, May, June and July, which largely coincides with the active growing season and flowering lavender (Figure 1). However, the relatively dry weather during the first two days of June for southern Bulgaria creates favorable conditions for timely and quality color harvesting. The second year is also characterized by precipitation above normal. It was particularly rainy in June with 196mm, which was four times more than the average quantity in the period 1971-2000. This coincided with the period of mass flowering and had an adverse effect on the harvest and on the yield.

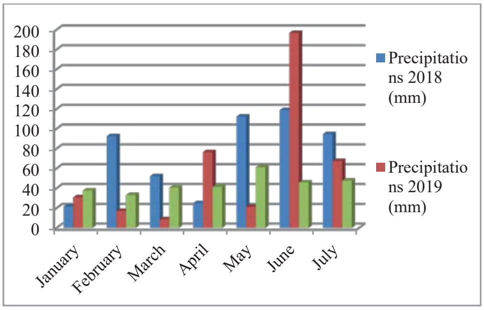

Figure 1. Amount of monthly precipitation during the study period

The reported temperature sums by the months (Figure 2) are similar to those of the multiannual period tended with slightly increase. Because of thermophilic nature of lavender this is beneficial in terms of accumulating the required temperature sum for the formation of higher yields of essential oil per unit area.

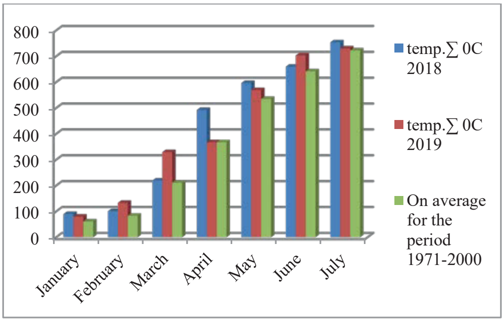

Figure 2. Average monthly temperatures during the study period

RESULTS AND DISCUSSIONS

In both experimental years (2018 and 2019) biometric indicators are established in the mass flowering phase of lavender. Were measured height and diameter of the bush (Table 2) as well as the parameters of the yield - number of floral stems, length of the inflorescence and the number of flowering vertebrae (Table 3).

Table 2. Height and diameter of the shrubs, cm in lavender Jubileyna variety

Variants	**Shrub height, cm**		**Shrub diameter, cm**	
Year	**2018**	**2019**	**2018**	**2019**
Control variant	23.7	40.4	25.6	64.9
FeriactylTrium+Fertileader Vital	24.9	40.2	25.0	73.7
Fertileader Vital	25.4	40.0	24.3	54.6
Fertileader Alpha	24.9	39.9	30.9	72.0

The results show that the foliar treatment with different products does not significantly influence the height of the lavender plants. However, the diameter of the bush is affected by the use of leaf fertilizers. The variation of this indicator is better expressed in the second year of the experiment (Table 2) with the variants Feriactyl Trium + Fertileader Vital 1.5 + 1.5 l/ha and Fertileader Alpha - 3 l/ha the width of bushes increases by 13.6 and 10.9% respectively. This is due to the positive influence of these fertilizers in the first year of the experiment and led to the formation of a greater number of branches and, hence, a greater number of flowering stems in these variants (Table 3). It was with Fertileader Alpha and with the combination of Feriactyl Trium + Fertileader Vital that the highest lavender flower yields, respectively, were 6659 and 6556 kg/ha, or 7.2 and 5.6%, respectively more fresh flowers compared to the untreated variant (Table 4).

The positive effect of the Feriactyl Trium + Fertileader Vital combination as well as the Fertileader Alpha leaf preparation is most likely due to the increased amounts of P_2O_5 and K_2O applied to the leaves in the budding phase. Also a positive influence on the second leaf fertilizer turns and the combination of phosphorus and boron. These two elements are synergistic and in the conditions of a more alkaline soil, such as the one in experimental field of Agricultural University - Plovdiv, their impact on the branching and flower formation processes is quite effective.

Table 3. Yield parameters - Number of inflorescences, Length of inflorescences (cm). Number of flowering vertebrae in lavender Jubileyna variety

Variants	Number of inflorescences		Length of inflorescences, cm		Number of flowering vertebrae	
Year	2018	2019	2018	2019	2018	2019
Control variant	75.6	504.6	6.0	6.6	5	6.4
Feriactyl Trium+Fertileader Vital	88.3	551.7	6.3	6.2	6	6.1
Fertileader Vital	101.8	347.9	6.0	6.2	6	6.0
Fertileader Alpha	95.6	801.3	6.1	6.8	6	6.2

Therefore, adequate foliar application of certain macro and micronutrients during the first year may have an indirect effect on the degree of the flower formation and the yield of fresh flowers during the next growing season of lavender.

The length of the inflorescence and the number of flowering vertebrae are not significantly affected by the applied leaf fertilizers. The results in terms of these indicators have varied over the years of the experiment and no finding can be made as to their values.

The amount of essential oil can be influenced by a number of factors such as genotype, environmental factors, fertilization and more. The time of distillation can also significantly change the yield and composition of the essential oil of lavender (Zheljazkovet et al., 2013).

Table 4. Yield of inflorescences and essential oil in lavender Jubileyna variety, kg/ha

Variants	Inflorescences yield, kg/ha				Essential oil yield, kg/ha			
Year	2018		2019		2018		2019	
Control variant	703	100%	6209	100 %	15	100%	86	100 %
Fetriactyl Trium+Fertileader Vital	910	129.4 %	**6556**	105.6 %	**21**	**140%**	**110**	**127.9%**
Fertileader Vital	897	127.6 %	6154	99.1 %	**23**	**153,3 %**	59	68.6 %
Fertileader Alpha	880	125.2 %	**6659**	107.2 %	**22**	**146,7 %**	70	81.4 %

From the analysis of the results in Table 4, it is clear that the higher amount of lavender flowers produced does not mean a greater amount of essential oil. Fertilizers applied into the budding phase have a significant effect on the yield of flowers and essential oil during the first vegetation of the lavender. The average increase in flower yield is from 25.2 to 29.4% and that of oil from 40 to 53.3% above the values of the untreated variant. However, a detailed review of the results of the first experimental year shows that despite the lower flower yield (897 kg/ha) of the Fertileader Vital treated plants, 13.3% more essential oil was obtained compared to the Feriactyl Trium + Fertileader Vital combination (910 kg/ha flowers).

During the first vegetation of the lavender, the flowerers are harvested in dry and hot weather conditions, while in the second year the extreme rainfall coincides with the mass flowering and harvesting of the lavender flower (Figure 1). The established yield of fresh flowers in the second experimental year is truly impressive - from 6209 kg/ha under control to 6659 kg/ha under the Fertileader Alpha variant. However, significant amount of precipitations has a clear negative impact on the oil formation process. From the results presented in Table 4 it can be seen that in the Fertileader Alpha and Fertileader Vital lavandulus plants treated, the yield of essential oil is significantly lower than that of the untreated variant. The exception is made only combination Feriactyl Trium + Fertileader Vital. The combined foliar application of these two fertilizers causes an increase in oil yield of 27.9% (24 kg/ha) above the control values. This is most likely due to the increased potassium content whose total amount for this combination was 11%.

Therefore, it can be stated that in conditions of adverse environmental factors such as increased humidity and lower temperatures, the foliar application of higher concentrations of potassium plays the role of an anti-stress factor and leads to a more optimal flow of the lavender oil-forming process.

The Harvest index (HI) is an indicator that shows what percentage or what proportion of all raw materials used have been converted into the desired pure product. In our case, this indicator shows how much kilograms of flowers are required to produce one kilogram of lavender essential oil (Figure 3). The analysis of the data shows that the yield is influenced by both environmental factors (humidity, temperature, wind during harvest, etc.) and the fertilizers applied during budding. It can be seen that in the conditions of quiet, hot, dry and sunny weather during flowering and flower harvesting in 2018, the Harvest index on the variants treated with Fertileader Alpha and Fertileader Vital is below 40 (39.1 and 39.4). In unfavorable for flowering and synthesis of essential oil 2019 required raw material for the production of one kilogram of lavender oil for the variant Fertileader Vital was over 100 kg. However, the application of the Feriactyl Trium + Fertileader Vital combination gives a significant reduction in the amount of flowers (59.6) required to produce one kilogram of essential oil.

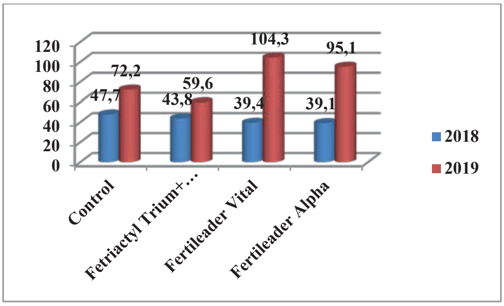

Figure 3. Harvest index for treated variants (2018 and 2019 year)

CONCLUSIONS

The application of Feriactyl Trium + Fertileader Vital 1.5 + 1.5 l / ha and Fertileader Alpha - 3 l/ha leaf fertilizers increased by 13.6% and 10.9%, respectively. This is due to the positive effect of these fertilizers during the first year of the experiment and consequently leads to the formation of a greater number of branches and, hence, a greater number of flower stalks in these variants.

Fertileader Alpha and the combination of Feriactyl Trium + Fertileader Vital have the highest lavender flower yields of 6659 and 6556 kg/ha, respectively, with 7.2 and 5.6% more fresh flowers than the untreated variant.

Appropriate foliar application of certain macro and micronutrients during the first year may have an indirect effect on the degree of flower formation and the yield of fresh flowers during the next growing season of lavender.

The leaf fertilizers applied in the budding phase have a significant effect on the yield of flower and essential oil during the first vegetation of the lavender. The average increase of flower yield is from 25.2 to 29.4% and oil from 40 to 53.3% above the values of the untreated variant.

Simultaneous foliar application of Feriactyl Trium + Fertileader Vital results in an increase in oil yield of 27.9% (24 kg/ha) above the control values under unfavourable flowering and oil-forming conditions. This is probably due to the increased potassium content, whose total amount in this combination is 11%. Therefore, it may be considered that, in adverse environmental conditions, the foliar application of higher potassium concentrations plays the role of an anti-stress factor and leads to a more optimal flow of lavender oil synthesis.

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