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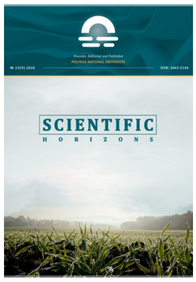

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Features of growth and development of *Lavandula angustifolia* when grown under drip irrigation conditions in the Southern Steppe zone of Ukraine

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Abstract. In the context of climate change, agriculture must respond to new challenges – one of them is the search for and adaptation of new plant varieties in areas where they have not been grown on an industrial scale. The research aims to investigate the effect of biological treatment on the growth and development of *Lavandula angustifolia* under different irrigation methods to increase the efficiency of its use as an industrial crop in the Southern Steppe zone of Ukraine. The species *L. angustifolia* is primarily important as an essential oil crop and is used in the preparation of food and beverages, perfumery, medicine, pharmacy, cosmetics, industry, for air purification from particulate matter in urban plantations, as a honey plant and for decorative purposes. In the research. A randomized scheme of blocks with a 2x2 factorial arrangement was used with two bacterial preparations ("Azogran A" and "Biocomplex BTU") and two moisture levels (80-70-70% MHC and 90-80-70% MHC) in triple repetition. Plants in the 1st, 2nd, and 3rd year of vegetation were analysed following several factors, such as the beginning and end of the vegetative phase, the beginning of the budding phase, the flowering period, and the ratio of these indicators to the amount of heat received during the growing season. Phenotypic characteristics, green and dry mass yields, percentage of essential oils, and conditional yields were also evaluated under all the studied conditions. Overall, it was established, that the biggest stimulative effect on the growth of *L. angustifolia* was found when growing lavender under the irrigation

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regime of 90-80-70% MHC with double top dressing of plantings in the budding phase "Biocomplex BTU" – these plants were the most developed and had noticeably higher dry mass and theoretical yield. Therefore, the control of irrigation and treatment with biological products makes the prospect of industrial lavender cultivation in the Southern Steppe of Ukraine more accessible

Keywords: lavender; moisture level; bio-fertilizers; yield; essential oil content

INTRODUCTION

Climate change, as well as the plowing of virgin steppe and massive deforestation, complicated agriculture in South Ukraine. Annual precipitation in this region decreased by 71 mm compared to 2010, and air temperature increased by 2.0°C, which led to an additional increase in water evaporation from the soil (Vozhegova *et al.,* 2021). In these conditions, the problem of finding crops that can adapt to a lack of moisture has become apparent. One of the available options is essential oil crops, which are characterized by drought tolerance. In addition to the demand in the domestic market and the high cost of raw materials, another factor that favours the choice in favour of these crops is that many of them have already been widely distributed as industrial crops on the Crimean Peninsula. Some are still grown in Ukraine, albeit in much smaller volumes. The authors of the study on the assessment of varietal diversity of essential oil crops suitable for cultivation in the Southern Steppe zone identified varieties of the *L. angustifolia* species as the most promising in this area. The structuring and analysis were based on the official Register of Varieties of Ukraine (Vozhegova *et al*., 2021).

Currently, the volume of lavender cultivation allows to produce up to 1,500 tons of essential oils annually. However, the share of production of *L. angustifolia* varieties accounts for only about one-third of this amount (Zigene *et al.,* 2018; Crișan *et al.,* 2023). This species originates from the regions of France and Italy, and its oil is considered to be of the highest quality (Despinasse, 2020). In Italy, the cost of agronomic products of this species is about 5.8 thousand euros per hectare (Fichera *et al.,* 2013). Currently, the largest suppliers are Bulgaria, France, and China.

In Ukraine, as of 2018, lavender cultivation was estimated at 1 thousand hectares and 10-15 tons of essential oils per year (Giray, 2018; Kokovihin & Vozhegova, 2018). Until 2014, the first number was 3 thousand hectares, and the main plantations were located in Crimea, in areas with a climate close to the Mediterranean. Due to the loss of the peninsula, the production of raw materials for essential oil crops decreased and could not meet domestic needs. However, climate change trends determine the possibility of expanding the cultivation of *L. angustifolia* in the steppe zone of Ukraine. In 2014-2018, the Institute of Horticulture began breeding varieties adapted to the Ukrainian climate by order of the President. The resulting variety is currently undergoing certification and has not yet been approved for commercial use (Rudnik-Ivashchenko & Kremenchuk, 2019).

The experience of growing *L. angustifolia* in Tuscany confirms the possibility of using so-called marginal lands for cultivation of this species, i.e., lands unsuitable for growing other crops. However, the analysis of oil obtained from raw materials of 1-4 years old showed that its composition does not meet European quality requirements (Aprotosoaie *et al.,* 2017; Najar *et al.,* 2022). Prolonged drought can also negatively affect product quality. The oils of plants grown in comfortable conditions and with a moisture deficit of 25, 50, and 75%, respectively, had different pharmaceutical effects, the strength of which is directly proportional to the satisfaction of moisture needs (Hasibi *et al.,* 2022). In addition to the deterioration of essential oil quality, its quantity also decreases as several studies show, photosynthetic activity and growth are also significantly reduced with a lack of moisture (Szekely-Varga *et al.,* 2020, Radu *et al.,* 2020, García-Caparrós *et al.,* 2019). The systematization of materials by Ukrainian land reclamation scientists has shown that irrigation is one of the solutions to this problem.

Given that drought is estimated to account for 10% of all adverse abiotic factors, other ways to preserve yields have been identified. For example, applying certain elements, such as boron (Abdel & Manal, 2018) and iron nanoparticles (Adrees *et al.,* 2020; Paraskevopoulou *et al.,* 2020), or compounds such as chitosan (Behboudi *et al.,* 2019), under the root. Another option is spraying abscisic acid, which is also often called a stress hormone (Gorgini *et al.,* 2021). An approach based on the use of endosymbiotic bacteria is similar in the mechanism of action. Thus, bacteria living in plant tissues are not always parasites. Some of them help the plant to adapt to unfavourable conditions, in particular to a lack of moisture, using various molecular and genetic mechanisms. The most studied are the mechanisms of synthesis by the bacteria themselves or stimulation of the synthesis of phytohormones, including abscisic acid, by plant cells. They can also act as antagonists of parasitic bacteria or fungi. Bacteria that have a positive effect on plant growth and development are called growth-regulating bacteria (Yoshida *et al.,* 2019, White *et al.,* 2019; Ghaderi-Far *et al.,* 2021).

There is a lot of evidence that symbiotic bacteria improve the morphological and physiological characteristics of the host plant, making it more adaptable to environmental factors (Saberi *et al.,* 2021, de Vries *et al.,* 2020, Zia *et al.,* 2021). These and other bacteria that are useful for human economic activity can be included in biological products.

A biological product is a culture of one or more strains of microorganisms and auxiliary substances necessary for their growth, development, or involvement in certain metabolic processes. Such products are often used as biological fertilizers or for the prevention of plant diseases (Das, 2019; Abdelaal *et al.,* 2021). In the Mykolaiv region, there have already been attempts to use bacterial products in lavender cultivation. The treatment of different varieties of *L. angustifolia* with Radostim and Stimpo did not show any changes in the relative proportion of oil in the raw material, but the actual yield for all three varieties was higher when treated with Stimpo, which proves the effectiveness of such products (Manushkina, 2019).

The research aims to select the optimal moisture regime for the *Stepova* variety, to determine whether there is a correlation between the average daily temperature and growth stages, and to supplement data on the prospects for the use of biological products and their impact on plant growth and development.

MATERIALS AND METHODS

The experimental part of the study lasted from 2019 to 2021 in the Mykolaiv region. The soil of the experimental field is southern low-humus dusty-heavy loamy black soil on carbonate loess. As this region belongs to the Southern Steppe zone, it has a sharp continental climate. This means hot summers with frequent dry winds and rather warm winters. The temperature ranges from 3-5°C to 21-23°C. The sum of positive temperatures above 10°C reaches 3000-4100°C. The first frosts begin in the last third of October, and the last ones stop in early April or May at the latest.

Mykolaiv region is located in a zone of insufficient moisture, where the hydrothermal coefficient during the growing season is only 0.6-0.7, and the amount of precipitation during this time reaches 260-285 mm. This leads to the need for the irrigation of crops.

The object of research was a medium-ripened variety "Stepova", which had a light lilac colour of the Corolla. The experiment scheme included two factors: factor A (treatment of plants with Biopreparations): Control (without treatment), treatment of plants with "Biocomplex BTU", treatment of plants with "Azogran A". According to factor B (irrigation modes), two levels of crop moisture were studied: 80-70-70% MHC (main hydrophysical factor) and 90-80-70% MHC. Treatment with bacterial fertilizers "Biocomplex BTU" and "Azogran a" (2 l/ha) was performed twice with an interval of 14 days. The treatment was aimed at top dressing of plants, protecting them from diseases, and increasing their adaptive potential.

Bacterial fertilizer "Biocomplex BTU" contains cells of bacteria *Bacillus subtilis* (40±10%), *Azotobacter* (30±10%), *Paenibacillus polymyxa* (10±5%), *Enterococcus* (10±5%), *Lactobacillus* (10±5%), macro- and microelements, biologically active products of bacterial vital activity: nicotinic and pantothenic acids, pyridoxine biotin, heteroauxins, gibberellins, cytokinins, enzymes, fungicidal and bactericidal substances, etc. "Azogran A" is a nanocomposite complex bacterial preparation of highly active strains of nitrogen-fixing bacteria *Azotobacter vinelandii* IMV B7076 and phosphate-immobilizing bacteria *Bacillus subtilis* IMV B-7023 with bentonite nanoparticles.

Its predecessor was early potatoes. Lavender seedlings were planted manually in the autumn of 2017 according to the experiment scheme, the row spacing was 50 cm wide. The area of plant nutrition was 1x0.6 m. the total area of the experimental site was 1411 m^2. The planting area of the plot was 35 m^2. The area of the accounting plot was 25 m^2. The repetition was threefold, and the placement of sections was randomized. Mowing of the ground mass was carried out during the mass flowering phase and dried under shelter. Typical methods for crop production were used in the research. Statistical data processing was performed by the dispersive analysis method.

RESULTS

Climatic conditions during the study period were favourable for the vegetation of *L. angustifolia*. In particular, fears of tissue freezing or plant death in autumn and winter did not come true. In terms of moisture availability, the last years of observation were optimal, 2018 was dry, and 2019 was medium-dry. However, every year there was a drying of the upper soil layers, which began in the second half of April with an increase in temperature and a decrease in air humidity. To maintain favourable conditions for lavender, drip irrigation systems were launched in late April.

A lavender awakening occurred when the average daily air temperature remained at least 10…14°C for some time. Depending on the year, this was around March-April. The awakening of lavender in Ukraine occurs in March-April, when the average daily air temperature steadily passes through 10… 14°C. The full spring of 2019 year came very early, in the first days of March, periods of warm weather were often replaced by rain, but all this happened against the background of positive air temperatures. The resumption of lavender vegetation was observed on March 30. Spring 2020 also came early, but in the second half of March, frosts of varying intensity were noted: in the air they were from -0.4 down to -4.0°C; and at a height of 2 cm from the soil surface they were from -3 down to -8°C. Restoration of vegetation of lavender plants was recorded on April 10. Spring 2021 was characterized as late, cold, and prolonged, the awakening of lavender plants was recorded on April 17. The duration of the vegetative stage of development in 2- and 3-year-old plants was different and amounted to 64-66 days in 2020 and 55-57 days in 2021, respectively (Table 1).

***Table 1.** Phenological features of Lavandula angustifolia plants depending on the experimental variants in the first, second and third years of vegetation*

Bio-fertilizer treatment	**Date of phenophase onset**					
	Restoration of vegetation	**Complete regrowth**	**Budding**	**Beginning of flowering**	**Mass flowering**	**End of flowering**
15.10.2018 – planting of seedlings						
2019						
Moisture level (B) – 80-70-70% MHC						
1. Control	30.III	1.VI	21.VI	30.VI	15.VII	27.VII
2. “Biocomplex BTU”	30.III	1.VI	21.VI	28.VI	12.VII	22.VII
3. “Azogran A”	30.III	1.VI	21.VI	28.VI	12.VII	22.VII
Moisture level (B) – 90-80-70% MHC						
1. Control	30.III	4.VI	23.VI	3.VII	18.VII	30.VII
2. “Biocomplex BTU”	30.III	4.VI	23.VI	1.VII	14.VII	27.VII
3. “Azogran A”	30.III	4.VI	23.VI	1.VII	14.VII	27.VII
2020						
Moisture level (B) – 80-70-70% MHC						
1. Control	10.IV	5.VI	14.VI	26.VI	4.VII	25.VII
2. “Biocomplex BTU”	10.IV	5.VI	14.VI	24.VI	1.VII	21.VII
3. “Azogran A”	10.IV	5.VI	14.VI	24.VI	1.VII	21.VII
Moisture level (B) – 90-80-70% MHC						
1. Control	10.IV	7.VI	16.VI	28.VI	6.VII	25.VII
2. “Biocomplex BTU”	10.IV	7.VI	16.VI	26.VI	4.VII	23.VII
3. “Azogran A”	10.IV	7.VI	16.VI	26.VI	4.VII	23.VII
2021						
Moisture level (B) – 80-70-70% MHC						
1. Control	17.IV	2.VI	10.VI	20.VI	8.VII	27.VII
2. “Biocomplex BTU”	17.IV	2.VI	10.VI	21.VI	5.VII	25.VII
3. “Azogran A”	17.IV	2.VI	10.VI	21.VI	5.VII	25.VII
Moisture level (B) – 90-80-70% MHC						
1. Control	17.IV	2.VI	12.VI	26.VI	10.VII	30.VII
2. “Biocomplex BTU”	17.IV	2.VI	12.VI	27.VI	7.VII	27.VII
3. “Azogran A”	17.IV	2.VI	12.VI	27.VI	7.VII	27.VII

***Source:** compiled by the authors*

The beginning of the vegetation phase did not occur simultaneously in different years of vegetation. For the crops of the second and third years of life (2020-2021) it was noted in the middle of June (from 10.06 to 16.06). Plants of the first year (2019) entered this phase an average of 5-9 days later (for different options – from 21.06 to 23.06). A similar trend was observed for other phases of ontogeny, such as the beginning of flowering, mass flowering, and the end of flowering. Some lag observed in biennial plants was attributed to the physiological stress caused by their first wintering, as well as the lack of a developed adaptive mechanism in young plants.

All lavender plants had a long flowering period. For annual plants in 2019, it was 25-27 days, and for two-year ones it was 28-30 days, for three-year ones it was 30-37 days. It was determined that the duration of the life cycle (from the resumption of vegetation to the phase of mowing ripeness) of *Lavandula angustifolia* in the conditions of the Southern Steppe of Ukraine was

115-123 days in 2019, 103-107 days in 2020, and 98-103 days in 2021.

The research established that irrigation regimes somewhat affected the passage of phenophases by lavender plants: in areas with an irrigation regime of 80-70-70% MHC, plants began flowering 2-3 days earlier compared to the irrigation regime of 90-80-70% MHC. When plants were treated in the budding phase with bio-fertilizers, flowering was reduced by 2-5 days.

On average, for 2019-2021, the growing season of lavender plants under the irrigation regime of 80-70-70% MHC was 109 days, and under the irrigation regime of 90-80-70% MHC, the growing season of plants was reduced by four days (105 days). The shortest growing season was observed under the irrigation regime of 80-70-70% MHC with the treatment of plants with biofertilizers as it was 103 days.

Data analysis of Table 2 shows how significant the influence of weather conditions of a particular growing season is on the timing of the onset of the main phenophases of plant development. Complete regrowth of lavender is determined by the average sum of active positive temperatures above +10°C in the range from 779 up to 1080 degrees, for the onset of the budding phase, the required amount should approach the values of 966-1478. Mass flowering occurs when the sum of active temperatures exceeds 1400 degrees and approaches 2300°C.

Table 2. *The sum of positive active temperatures on an accrual basis (∑t>10), which is necessary for development of Lavandula angustifolia in the southern steppe of Ukraine, °C*

Years	Phase		
	Complete regrowth	Budding	Mass flowering
Moisture level (B) – 80-70-70% MHC			
2019	955	1428	1968
2020	779	966	1404
2021	1080	1219	2298
Moisture level (B) – 90-80-70% MHC			
2019	1020	1478	2020
2020	818	1010	1467
2021	1080	1257	2327
Mean value	955	1226	1914
V, %	13.7	17.1	20. 8

Source: *compiled by the authors*

Another factor that illustrates the biological features of Lavandula angustifolia plant development is the characteristic changes in its biometric characteristics. As the total results show, the influence of biological fertilizer and moisture levels is clearly traced (Table 3).

The use of bio-fertilizers accelerates biochemical processes, enhances the growth and development of plants. As such, observations of the dynamics of the height of lavender plants showed that starting from the budding phase, the positive effect of the studied fertilizers and drip irrigation can be traced. In 2019, in the first year, lavender developed slowly, plants reached 24.9-38.2 cm in height, depending on the treatment of the experiment. The second-year plants grew up to 36.2-45.4 cm, in the third year it increased to 44.4-57.3 cm. Average for irrigation regimes for 2019-2021 in the control, this indicator was 37.9 cm, when treated with "Biocomplex BTU" it was 43.8 cm, with "Azogran A" it was 41.2 cm, that is, the use of bacterial fertilizers increased the height of plants by 9-16% compared to the control. Optimization of the irrigation regime helped to increase the height of plants by 15-18% (Table 3).

Table 3. *Effect of bio-fertilizers on indices of some quantitative traits of lavender plants (2019-2021)*

Bio-fertilizers (A)	Plant height, cm	Bush diameter, cm	Number of side shoots, PCs.		Inflorescence length, cm
			in total	including with inflorescences	
Moisture level (B) – 80-70-70 % MHC					
1. Control	35.2	28.0	30.3	26.7	4.9
2. "Biocomplex BTU"	40.5	34.3	41.4	37.7	6.6

Table 3, Continued

Bio-fertilizers (A)	Plant height, cm	Bush diameter, cm	Number of side shoots, PCs.		Inflorescence length, cm
			in total	including with inflorescences	
3. "Azogran A"	37.7	33.6	37.7	34.7	5.6
Moisture level (B) – 90-80-70% MHC					
1. Control	40.5	32.1	34.1	31.0	5.9
2. "Biocomplex BTU"	47.0	40.1	47.8	40.3	7.3
3. "Azogran A"	44.6	36.9	38.5	35.7	6.5
Mean value	40.9	34.2	38.3	34.4	6.1
Range (max–min)	47.0-35.2	40.1-28.0	47.8-30.3	40.3-26.7	7.3-4.9
S	4. 6	4. 4	6. 0	6. 2	0. 9
V, %	11.5	13.0	15.7	16.8	13.8

Source: *compiled by the authors*

In the formation of the habit of a lavender bush, there is a direct relationship between its width and the number of stems. The wider the bush, the more branches it forms. So, in the third year of vegetation, when treating plants with bacterial fertilizers, the Stepova variety formed the habit of a bush with a width of more than 45 cm, which is by 22-26% higher than this indicator in the control. At the same time, the number of stems per plant ranged from 1.2-1.5 times higher than in the control.

On average, from 2019 to 2021, the diameter of the lavender bushes ranged from 28.0 to 40.1 cm, depending on the experimental variant, and the total number of branches per plant ranged from 26.7 to 43.3, 90% of these branches formed inflorescences. In terms of the range of variation, the latter indicator was less stable than the others as the coefficient of variation was 16.8%.

Due to the top dressing of plants with bio-fertilizers, the best development of lavender plants was observed, in particular, the total number of stems increased by 4-14 PCs per plant, including the number of flowering stems increased by 4.7-11.0 PCs per plant, inflorescence length increased by 0.5-1.7 cm, plant height increased by 2.5-6.5 cm, bush diameter increased by 4.8-8.0 cm in comparison with a control sample, which was not cultivated. This was most noticeable when the moisture level of lavender plantings was at 90-80-70% of MHC. In this variant, when treating plants with bio-fertilizer "Biocomplex BTU", there were 47.8 stems on one plant, including 40.3 PCs with flowers. The height of the plants was 47.0 cm, the diameter of the bush was 40.1 cm, the length of the inflorescence was 7.3 cm (average for 2019-2021 years).

The yield of dry flower raw materials *Lavandula angustifolia* in the first year of vegetation was low as 11.6-18.3 c/ha depending on the experimental variants, in 2020 the plants showed more intensive development and higher productivity, resulting in a yield increase of 1.6 to 1.8 times. In the third year of lavender cultivation, the yield of flowers was maximum as 43.7-57.1 c/ha, depending on the experimental variants, which was 3.1-3.8 times higher compared to the first year of vegetation.

On average, from 2019 to 2021, when growing *Lavandula angustifolia* at a moisture level of 80-70-70% MHC, the absolute dry mass weight was 28.2 c/ha, and if the regime of 90-80-70% MHC the yield was observed 31.3 c/ha (Table 4). So, comparing irrigation modes with each other, it should be noted that the irrigation mode of 90-80-70% MHC in the technology of growing lavender was more effective, although lavender belonged to plants that were unpretentious to moisture.

Table 4. *Influence of biopreparations and irrigation regimes on plant productivity Lavandula angustifolia Mill. (2019-2021)*

Bio-fertilizers (A)	Yield dry weight, c/ha	Essential oil content, %	Conditional oil yield, kg/ha	Deviation from control, ± kg/ha
Moisture level (B) – 80-70-70% MHC				
1. Control	25.4	1.52	38.56	-
2. "Biocomplex BTU"	30.3	1.68	50.95	+12.39
3. "Azogran A"	28.8	1.65	47.58	+9.02
Mean value	28.2	1.62	45.69	+10.71
Moisture level (B) – 90-80-70% MHC				
1. Control	26.8	1.41	37.83	-

Table 4, Continued

Bio-fertilizers (A)	Yield dry weight, c/ha	Essential oil content, %	Conditional oil yield, kg/ha	Deviation from control, ± kg/ha
2. "Biocomplex BTU"	34.3	1.60	54.83	+17.00
3. "Azogran A"	32.8	1.52	49.86	+12.03
Mean value	31.3	1.51	47.50	+14.52
LSD_{05} for yield on Factors: A –1.15; B – 0.95; AB – 1.64.				

Source: *compiled by the authors*

The period of intensive growth and, accordingly, accumulation of biomass occurs in Lavender in the month of June. Therefore, until then, it is necessary to create the most favourable conditions for the growth and development of plants, including planning such an agrotechnical event as top dressing. In our studies, positive results were obtained as a result of double foliar top dressing with "Azogran A" and "Biocomplex BTU" bio-fertilizers at a dose of 2 l/ha (with an interval of 14 days) in the branching and budding phase of plants. Spraying with bacterial fertilizers increased the yield of *Lavandula angustifolia* flower mass: the yield increase was 3.5-7.5 c/ha compared to the untreated control. The highest yield of 34.3 c/ha was obtained in the variant where the fertilizer "Biocomplex BTU" was applied while observing the irrigation regime of 90-80-70% MHC.

DISCUSSION

Complex research on the effect of drip irrigation and stimulation of *L. angustifolia* plants of Stepova variety under conditions of the Southern Steppe of Ukraine was conducted. The results showed that the most effective was the complex effect of irrigation and treatment, and in the variant where irrigation was more intensive.

The benefits of irrigation in the South of Ukraine have been described both in the context of steppe land exploitation during climate change (Vozhegova *et al.,* 2021) and in the results of studies on the increase in oilseed yields, where flax that was irrigated produced more than 1.7 times more oil than the control group. In contrast, in the absence of moisture, seeds cannot germinate, and plant growth, as well as photosynthesis, slows down, leading to the loss of part or even the entire crop (Szekely-Varga *et al.,* 2020, Zia *et al.,* 2021).

The effects of drought can be alleviated with the help of various substances: chemical elements, organic and inorganic compounds, biologically active substances, etc., but also to reduce plant stress, biological products containing endosymbiotic or rhizosphere bacteria or their metabolites are increasingly used. They penetrate plant tissues and adjust the plant's response from within so that it can function more efficiently and respond to environmental changes. Such products were used in this study (Vozhegova *et al.,* 2020).

According to the results of experimental studies, plants in all variants of the experiment, on average for three years of research, showed an absolutely expected result in terms of oil content: as the higher it was the productivity of plants, as the higher it was the yield of essential oil as a percentage. The control variant produced raw materials with an essential oil content of 1.47% without bio-fertilizer treatment, while the application of "Azogran A" increased the content to 1.59% (average for irrigation modes). Furthermore, the use of "Biocomplex BTU" improved the content by an additional 0.05-0.17%. The highest content of essential oil was found in *L. angustifolia* plants grown under irrigation following the 80-70-70% GHX method and with "Biocomplex BTU", where it was 1.68 % (Rennenberg, 2018).

The same trend continued for the release of essential oil from dry bio-raw materials. On average, for 2019-2021, plants in the control group had an average conditional essential oil yield of 38.19 kg/ha. This indicator in the variant with top dressing "Biocomplex BTU" was the highest for both irrigation modes. Thus, at a moisture level of 80-70-70% MHC, it was 50.95 kg/ha, and at 90-80-70% MHC it was 54.83 kg/ha. The conditional yield of essential oil from plants treated with "Azogran A" was higher than the control and reached 47.58 up to 49.86 kg/ha. Furthermore, heterogeneity of yield indicators depending on the year of vegetation was noted. The yield was about 1.5-2 times higher in the second year and 3-4 times higher in the third year, which is consistent with the cultivation of lavender in the Mediterranean region (Barut *et al.*, 2022). Other studies have also explored finding the optimal irrigation method.

One of the similar studies (Manushkina, 2019) also studied the effect of 2 biological products – Radostym and Stimpo – on the development of three varieties of *L. angustifolia* – Vdala, Syneva, and Stepova – for 3 years. Additional irrigation was not carried out. As a result, as in the present study, the relative mass fraction of essential oil after treatment did not change but varied depending on the variety, and the actual yield increased significantly compared to the control. In addition, the variety Stepnaya under the treatment with Stimpo gave a significantly higher average oil yield (137.36 kg/ha) than under the study of the effect of "Biocomplex BTU", which showed the best result in this study (54.83 kg/ha).

Among similar studies, the effect of inoculation with *Bacillus thuringiensiss* strain IAM 12077 of plants related to the species *L. dentata* studied in this work showed an increase in the absorption and assimilation of microelements by plants and an increase in green mass by more than 65.8%. A doubling in the activity of arbuscular mycorrhiza formation was also observed, which increased the absorption area and, accordingly, the availability of water, which is one of the explanations for the reduction of drought stress in plants, which was also observed in the treatment with bacterial products in this study. At the same time, inoculation with *B. thuringiensiss* did not affect the composition of endophytic and rhizobial microorganism's characteristic of this lavender species in the study area (Armada *et al.,* 2018).

An interesting study was conducted to determine the effectiveness of using biological products based on fungi prone to the formation of arbuscular mycorrhiza (AMF) in the cultivation of lavender. Thus, *L. angustifolia* plants treated with biological products showed an increase in green mass of about 17-20% compared to the untreated control. An increase in leaf surface area and flowering intensity was also observed. Also, most fungi induced an increase in the synthesis of chlorophylls *a* and *b*, as well as some carotenoids. AMF-S and AMF-C showed the best results (Popescu & Popescu, 2022). Similar results have been obtained in other studies (Binet *et al.*, 2020, Pirsarandib *et al.,* 2022), in particular, a positive effect on the composition of essential oils during AMF treatment was found (Akachoud *et al.,* 2022). This indicates the feasibility of conducting research in this area to increase the efficiency of lavender cultivation in the Southern Steppe of Ukraine and reduce the impact of drought on plant growth and development and the quality content of essential oils.

Another interesting aspect was the issue of frost resistance of lavender. Depending on the variety, the proportion of surviving plants by the third year increased by 4-6% and ranged from 88% to 97%. This is another aspect that indicates the suitability of lavender for cultivation in these conditions (Manushkina, 2019).

The question remains whether the studied system of irrigation and application of products harms the production and composition of essential oils. After all, an important point that has not yet been studied much is the assessment of the quality of essential oils obtained from varieties grown in the Southern Steppes zone and their compliance with international standards.

A rather large-scale study conducted at the Rice Institute of the National Academy of Sciences of Ukraine was devoted to the analysis of the composition of essential oils of 13 varieties of *L. angustifolia,* conducted during 2016-2018. All the studied varieties were obtained as a result of selection in domestic institutes for cultivation in Ukraine, half of them is already grown for commercial purposes. The data obtained showed that none of the essential oils analysed during the three years of work met the quality criteria of the European Pharmacopoeia. At the same time, the essential oils of one of the varieties can be used in pharmacy, but only for purposes for which the α-terpinol content is not critical, 6 more are suitable for use in perfumery and related industries, and the authors recommend using the rest in landscaping and for decorative purposes. It is important to note that the "Stepova" variety was not considered in this study (Pokajewicz *et al.,* 2021). There is a study confirming a slight improvement in lavender essential oils under irrigation conditions, but the observed increases are rather minor (Sałata *et al.,* 2020).

That is, there are prerequisites for further research aimed not at studying the possibility of growing lavender in the Southern Steppe zone of Ukraine, but at determining the composition of essential oils obtained during cultivation with the involvement of various factors and the prospects for further improving their quality and compliance with internationally recognized standards.

CONCLUSIONS

Based on the conducted experimental studies, it was established that lavender plants of the third year of cultivation were characterized in the conditions of the Southern steppe of Ukraine by the duration of the growing season (from the resumption of vegetation to mowing ripeness) from 105 up to 111 days. The shortest growing season was observed under the irrigation regime of 80-70-70% MHC with the treatment of plants with bio-fertilizers as it was 103 days. The main factor determining the beginning of the development of lavender plants is the air temperature. Accelerated plant development begins at an average daily air temperature of +10°C and above. Mass flowering occurs when the sum of active temperatures passes through 1400°C and approaches 2300°C.

With the drip method of irrigation and top-dressing plants with bio-fertilizers, optimal conditions were created for the growth and development of *Lavandula angustifolia*. The most developed plants were recorded when growing plants with the maintenance of a moisture level of 90-80-70% MHC during the period of full regrowth-flowering with the treatment of crops in the budding phase "Biocomplex BTU". In this variant, the largest number of stems per plant was counted (47.8 PCs, including with flowers – 40.3 PCs), the height of the plants was 47.0 cm, the diameter of the bush was 40.1 cm, the length of the inflorescence was 7.3 cm (average for 2019-2021). This variant provided a dry raw material yield of 34.3 c/ha and an essential oil yield of 54.83 kg/ha.

Prospects for further research are to study the morphological and biological features, adaptive properties of lavender plants of new varieties during different years of cultivation and optimize the technology of growing crops in irrigated and non-irrigated conditions of the southern steppe zone of Ukraine.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Особливості росту і розвитку лаванди вузьколистої при вирощуванні в умовах краплинного зрошення в Південному Степу України

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Анотація. В умовах зміни клімату сільське господарство має реагувати на нові виклики - одним з них є пошук та адаптація нових сортів рослин у регіонах, де вони не вирощувалися в промислових масштабах. Мета роботи – дослідити вплив біологічного обробітку на ріст і розвиток *Lavandula angustifolia* за різних способів зрошення для підвищення ефективності її використання як промислової культури в зоні Південного Степу України. Вид *L. angustifolia* має перш за все значення як ефіроолійна культура і використовується в приготуванні продуктів харчування та напоїв, парфумерії, медицині, фармації, косметиці, промисловості, для очищення повітря від твердих частинок в міських насадженнях, як медонос і в декоративних цілях. У дослідженнях. Використовували рандомізовану схему блоків з факторним розміщенням 2x2 з двома бактеріальними препаратами («Азогран А» і «Біокомплекс БТУ») і двома рівнями вологості (80-70-70 % НВВ і 90-80-70 % НВВ) у триразовій повторності. Рослини 1-го, 2-го і 3-го року вегетації аналізували за кількома факторами, такими як початок і кінець вегетативної фази, початок фази бутонізації, період цвітіння, а також співвідношення цих показників з кількістю тепла, отриманого за вегетаційний період. Також оцінювали фенотипові ознаки, врожайність зеленої та сухої маси, відсоток ефірної олії та умовну врожайність за всіх досліджуваних умов. Загалом встановлено, що найбільший стимулюючий вплив на ріст *L. angustifolia* виявлено при вирощуванні лаванди за режимом зрошення 90-80-70 % НВВ з дворазовим підживленням рослин у фазу бутонізації «Біокомплексом БТУ» – ці рослини були найбільш розвиненими і мали помітно вищі показники сухої маси та теоретичної врожайності. Таким чином, контроль зрошення та обробка біопрепаратами робить перспективу промислового вирощування лаванди в умовах Південного Степу України більш доступною

Ключові слова: лаванда; рівень вологості; біодобрива; урожайність; вміст ефірної олії
