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The effect of plant growth regulators on productivity of lavender (*Lavandula angustifolia* Mill.) in the conditions of the Southern Steppe of Ukraine

T. Manushkina[1,*], T. Kachanova[1] and M. Samoilenko[2]

[1]Mykolayiv National Agrarian University, Faculty of Agricultural Technologies, Department of Agriculture, Geodesy and Land Management, George Gongadze Str., 9, UA54008 Mykolayiv, Ukraine
[2]Mykolayiv National Agrarian University, Faculty of Agricultural Technologies, Department of Viticulture and Horticulture, George Gongadze Str., 9, UA54008 Mykolayiv, Ukraine
[*]Correspondence: latushkina2004@gmail.com

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Abstract. The current state of the essential oil industry in Ukraine requires the expansion of areas for essential oil crops. Nowadays, the demand for natural vegetable raw materials and lavender essential oil is growing. Therefore, the aim of the research was to study the morpho-biological features and productivity of lavender plants by treatment with plant growth regulators Radostim and Stimpo during the third-fifth years of the growing season in the Southern Steppe of Ukraine. The research was conducted during 2018–2020. The material for the research work was lavender plants such as *Lavandula angustifolia* Mill., the varieties of Sinieva and Vdala. The field experiment was done with the method of split randomized blocks. The research was accompanied by phenological, biometric, structural and laboratory observations in accordance with generally accepted methods. Treatment with the growth regulator Stimpo has the greatest stimulating effect on the processes of growth and productivity in lavender plants. Using this method, the highest yield was formed in all years of vegetation from 6.70 to 7.90 t ha^{-1} at standard humidity, which is by 14.8–21.1% more than in the control. The mass fraction of essential oil in vegetable raw materials is quite high (1.85–2.32%), it differs in lavender varieties and does not depend on treatment with plant growth regulators. The largest harvest of essential oil in all years of vegetation was obtained by treating plants with the growth regulator Stimpo from 137.30 up to 147.36 kg ha^{-1}, which is by 15.9–16.7% more than in the control.

Key words: english lavender, essential oil, frost resistance, harvest, plant growth regulator.

INTRODUCTION

Lavender (*Lavandula angustifolia* Mill.) is a shrub of the family Lamiaceae, native to the Mediterranean region, the Arabian Peninsula and Africa (Basch et al., 2004). English lavender, also known as medicinal lavender, true lavender, or common lavender (*Lavandula angustifolia*, *L. officinalis*, *L. vera*), is an evergreen perennial plant (Lis-Balchin, 2002). Lavender is native to the Mediterranean region (France, Spain, Andorra, and Italy) (Prusinowska & Śmigielski, 2014), but is grown in many other countries of the world, including southern Europe through northern and eastern Africa and Middle Eastern countries to southwest Asia and southeast India (Woronuk et al., 2011), USA (Adam, 2018), Morocco (Messaoudi et al., 2017), Turkey (Küçük et al., 2018), Poland (Smigielski et al., 2009), Bulgaria (Minev et al., 2022), Ukraine (Pokajewicz et al., 2021). The material used for herbal purposes includes lavender flowers (Lavandula flores) containing essential oil (3%), anthocyanins, phytosterols, sugars, minerals, and tannins. The essential oil contains over 300 chemical compounds. The dominant components are linalool, linalyl acetate, terpinen-4-ol, acetate lavandulol, ocimene, and cineole. Lavender is widely used in the cosmetic, perfume, food, and aromatherapeutic industries (Adaszyńska-Skwirzyńska et al., 2014; Adam, 2018).

Now in the agricultural sector of Ukraine, the issue of growing crops which provide competitive advantages in the face of climate change, along with preserving and restoring soil fertility, is acute. Plants of the Lamiaceae family help protect soils from erosion and create stable phytocenoses in anthropogenically transformed territories (Dobrovolskyi et al., 2021; Crisan et al., 2023).

The current state of the essential oil industry in Ukraine requires the expansion of areas for essential oil crops. Nowadays, the demand for natural vegetable raw materials and lavender essential oil is growing. The zone of the Southern Steppe of Ukraine with a temperate-continental climate can be suitable with natural and climatic conditions for growing this crop (Manushkina, 2019). One of the important reasons for limiting the spread of lavender is the freezing and death of plants in the winter, and sometimes in the spring period, the air temperature from -25 to -30 °C and below is critical for narrow-leaved lavender. In the presence of snow cover, the lavender plantation tolerates lower temperatures. Late spring frosts can have a detrimental effect (Lis-Balchin, 2002). At the same time, in the conditions of climate change, positive results have been obtained for the cultivation of lavender in the area of the west (Tsvilynyuk, 2018) and Forest-steppe of Ukraine (Rudnik-Ivashchenko & Kremenchuk, 2019).

The yield, qualitative and quantitative composition of the essential oil of lavender is variable and depends on genotype, growing location, climatic conditions, propagation, and morphological features (Lawrence, 1993). For effective use of the biological potential of lavender, it is important to develop and implement into the production the adaptive environmentally friendly growing technology using modern intensification factors, including plant growth regulators (PGR). PGRs contribute to the optimization of the realization of the genetic potential of plants. The use of growth regulators can increase yields, improve the quality of grown products, increase plant resistance to disease and stress factors, and reduce using pesticide rates (Kolupayev, 2001; Wilkinson et al., 2012; Lymperopoulos et al., 2018). The increase in yield, when it is treated with plant growth regulators, is due to increased cell activity in the plant body by stimulating biochemical processes, which leads to the optimization of photosynthesis, respiration and nutrition (Egamberdieva et al., 2017).

The quality and method in obtaining planting material is also important. Propagation by seed is not recommended for commercial lavender production (Mason, 2014). Plants grown from seed are variable in growth habit, colour and essential oil composition. Tissue culture methods are used for the mass propagation of lavender from selected mother plants. It produces disease-free, genetically identical plants (Nabin et al., 2018). Lavender seedlings of the highest quality are obtained by microclonal propagation in vitro (Manushkina, 2017). Another important factor is that lavender plants of the first or second year have low productivity, and the maximum yield can be obtained only from plants which are 4–5 years old and more (Andriychenko et al., 2020). Therefore, the aim of the research was to study the morpho-biological features and productivity of lavender plants by treatment with plant growth regulators during the third-fifth years of the growing season in the Southern Steppe of Ukraine.

MATERIALS AND METHODS

The material for the research work was lavender plants such as *L. angustifolia* Mill., the varieties of Sinieva and Vdala.

The field experiment was done with the method of split randomized blocks. The research was accompanied by phenological, biometric, structural and laboratory observations in accordance with generally accepted methods (Ushkarenko et al., 2016).

The frost resistance of plants was determined by the field method as the number of viable plants that overwintered, as a percentage of the total number of plants in the registration area, taken into account in autumn. The yield was recorded in the phase of technical maturity, when the presence of 50% of blooming flowers in the ear was noted. The raw material was cut by hand and weighed in the field. Gross harvest was taken into account by weighing raw materials from the entire area. Recalculation of raw material yield per 1 ha was led to a standard humidity of 70%.

Determination of the mass moisture fraction in vegetable raw materials was carried out by the thermostatic-weight method. A laboratory sample of the raw material weighing 10.00 ± 0.01 g was placed in a Petri dish, which was pre-weighed together with the lid. Dishes with raw materials and removed lids were placed in a drying oven preheated to 150 ± 2 °C. Drying of the raw material was carried out at a temperature of 145 ± 2 °C for 1 hour after setting the temperature in the drying oven. Two parallel measurements were performed. The mass fraction of moisture in the raw material Ww,%, was calculated by the formula

$$W_w = \frac{m - m_1}{m - m_2} \cdot 100 \quad (1)$$

where m – the mass of the dish with the laboratory sample before drying, g; m_1 – the mass of the dish with a laboratory sample after drying, g; m_2 – the mass of the predried dish, g; 100 – percentage conversion factor.

The Ginsberg method was used to determine the mass fraction of essential oil in vegetable raw materials. The method is based on the distillation of essential oil from raw materials by hydrodistillation on a laboratory distillation apparatus and measurement of the volume of separated (decanted) essential oil in the graduated part of the Ginsberg receiver. Two parallel measurements were performed. The mass fraction of E_{raw} essential oil,%, based on the raw weight of the raw material was calculated by the formula

$$E_{raw} = \frac{n \cdot \alpha \cdot \rho}{m} \cdot 100 \quad (2)$$

where n – the number of divisions in the receiver, which occupies the decanted essential oil; α – the price of division in the graduated part of the receiver, cm^3; ρ – the density of the essential oil of the corresponding type of raw material, g cm^{-3}; m – the mass of the sample, g; 100 – percentage conversion factor.

The experimental data were processed by the standard procedure of ANOVA within MS Excel software. The significance of the differences was proved for the reliability level of 95% (LSD_{05}).

The research was conducted during 2015–2020 at Mykolayiv National Agrarian University on the basis of the research field of the farm 'Agrolife' in Mykolayiv district of Mykolayiv region (the branch of the Department of Agriculture, Geodesy and Land Management) and the research laboratory of the Department of Agriculture , Geodesy and Land Management. Research areas are located at the 46°49′32″ Nw. 32°08′28″ El. The average height above the sea level is 44 m.

The soil of the experimental area is Southern chernozem. Humus content is 2.8% (average), easily hydrolyzed nitrogen (due to Cornfield) is 105 mg kg^{-1} of the soil (low), mobile phosphorus (due to Machigin) is 45 mg kg^{-1} (increased), mobile potassium (due to Machigin) is 360 mg kg^{-1} (high), pH of the salt extract is 7.2 (close to neutral). The indicators of soil fertility of the experimental area were compared with the optimal parameters and grouping of soils according to the properties established by DSTU 4362: 2004.

Climatic conditions in the research area during 2018–2020 were favorable for the cultivation lavender in terms of temperature indicators, but the amount of precipitation, their distribution by months and soil moisture did not provide optimal water regime (Table 1).

The average air temperature 12 to during the research years ranged from 15 °C, the soil temperature ranged from 13 to 15 °C. The maximum air temperature was 37–38 °C in all years of research, the minimum air temperature ranged from -15 to -16 °C in 2018 and 2019, to -8 °C was in 2020. The minimum soil temperature was -3 to -7 °C. The 2018 and 2019 were more favorable years in terms of both the amount and uniformity of precipitation, while in the first ten months of 2020 had only 108 mm of precipitation, with the driest April (5 mm of precipitation) and August (6 mm of precipitation), when lavender begins the phases of spring and autumn regrowth of shoots. The average soil moisture was 18–22%, but from July to November the lowest humidity was 8–14%.

Table 1. Climatic conditions in the years of research

Indicators	2018	2019	2020[1]
Average air temperature, °C	12	13	15
Maximum air temperature, °C	37	38	38
Minimum air temperature, °C	-16	-15	-8
Average soil temperature, °C	13	13	15
Minimum soil temperature, °C	-7	-6	-3
Amount of precipitation, mm	398	353	108
Soil moisture, %	20	18	22

[1] Data for January – October 2020.

The weather conditions in the years of the research (2018–2020) thoroughly reflected the meteorological characteristic of the Southern Steppe of Ukraine that made it possible to obtain reliable experimental data, draw conclusions and offer recommendations for agricultural production in the given conditions.

The following factors and their variants were included in the research scheme:

Factor A – variety: Sinieva, Vdala;

Factor B – plant growth regulator (PGR): water (control), Radostim (NE ISTC 'Agrobiotech', Ukraine), Stimpo (NE ISTC 'Agrobiotech', Ukraine);

Years of plant vegetation: the third (2018), the fourth (2019), the fifth (2020).

Lavender plants were treated with growth regulators according to the following scheme:

The first year of cultivation:

the first treatment – on the day of planting seedlings in open ground;

the second treatment – in two weeks;

the third treatment is the budding phase.

The second and subsequent years of cultivation:

the first treatment – a phase of spring regrowth;

the second treatment – in two weeks;

the third treatment is the budding phase.

Radostim and Stimpo are plant growth regulators of a wide range of application, recommended for pre-sowing treatment of cereals seeds, legumes, oilseeds, vegetables, for plant treatment during the growing season, as well as for spraying lawn grasses, introduction of large trees and shrubs; used in industrial cultivation of mushrooms, vegetables and berries, forestry and biotechnology.

Radostim, Water-Alcohol Solution (WAS), the National Enterprise 'Interdepartmental Science & Technology Center 'Agrobiotech'' was created by National Academy of Sciences and Ministry of Education and Science of Ukraine of Ukraine, a plant growth regulator. Application rate for spraying crops is 50 mL ha^{-1} (working solution - 200–300 L ha^{-1}).

Stimpo, WAS, the National Enterprise 'Interdepartmental Science & Technology Center 'Agrobiotech'' (NE ISTC) was created by National Academy of Sciences and Ministry of Education and Science of Ukraine of Ukraine, a plant growth regulator. Application rate for spraying crops is 20 mL ha^{-1} (working solution - 200–300 L ha^{-1}).

The cultivation methods in the research corresponded to the essential oil crops in the Southern Steppe of Ukraine and were applied on a high agro-technological level. Seedlings of the 1st commodity variety (DSTU 3658-97 (GOST 3579- 98)), which were obtained in the laboratory of clonal micropropagation and adapted to the environment, were used for laying the experimental plots. The main tillage consisted of peeling, plowing to a depth of 25–27 cm, under which was added $N_{60}P_{60}K_{60}$. After plowing, cultivation was carried out with harrowing to a depth of 8–10 cm. The seedlings were planted in October 2015. Planting scheme was 1.2 x 0.5 m. Care of plantations included loosening between rows, weed control and drip irrigation. Soil moisture in the layer of 30–40 cm was maintained at the level of 90–80–70% of the lowest moisture content; watering was stopped 14 days before harvesting of flower raw materials. The area of the accounting plot was 30 m^2, the experiment was repeated four times. This work includes data from analyzes of three-five-year-old plants, which were determined in 2018–2020.

RESULTS AND DISCUSSION

Frost resistance was one of the main criteria for assessing the adaptive potential and possibility of introduction of lavender into the Southern Steppe zone of Ukraine. Lavender plants from the third to the fifth year of cultivation were characterized by a fairly high frost resistance (82.7–98.5%) (Fig. 1).

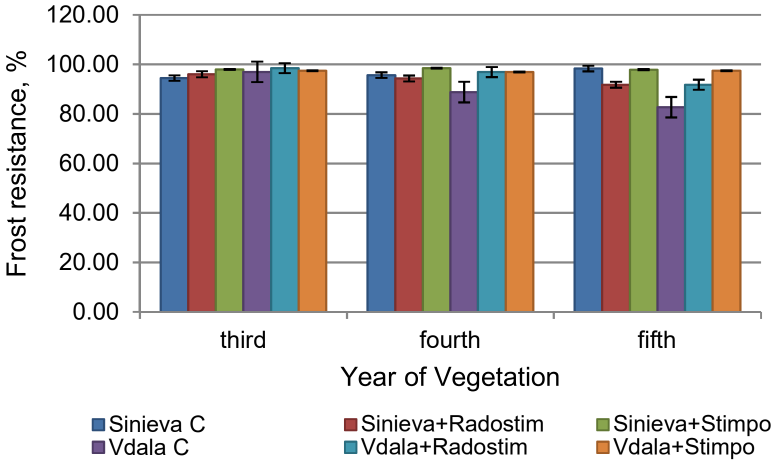

Figure 1. Frost resistance of the lavender plants depending on the application of growth regulators. Error bars indicate standard error.

There is a tendency to increase frost resistance under the application of growth regulators, but mathematical processing revealed that the difference between frost resistance and growth regulators in current study was not significant. There was also no significant difference in frost resistance between the studied varieties and the years of research.

In the process of research, the parameters of the yield structure of lavender were determined depending on the application of growth regulators. The optimal parameters were formed in lavender plants by the use of the growth regulator Stimpo: inflorescence length was 7.3–8.1 cm, the number of rings in the inflorescence was 6.3–7.5 pieces. Treatment with biostimulants did not significantly affect the number of flowers in the semi-ring, this figure in the varieties ranged from 4.3 to 5.1 pieces.

The yield of lavender over the years of vegetation depended on the variety and treatment of plants with growth regulators (Table 2). The yield of the Sinieva variety was higher compared to the Vdala variety during all years of the research and for all variants of the experiment. The difference between the varieties in the control variant was 0.55–0.92 t ha^{-1}, with Radostim treatment it was 0.43–0.93 t ha^{-1}, with Stimpo it was 0.51–1.08 t ha^{-1}. The highest yield of lavender was formed in the plant variant which was treated by the growth regulator Stimpo: in the Sinieva species the yield was 7.38–7.90 t ha^{-1}, in the Vdala species it was 6.70–7.27 t ha^{-1}. The increase till the control version was 0.95–1.33 and 0.99–1.17 t ha^{-1}, respectively, according to varieties.

Table 2. The yield of lavender depending on the application of growth regulators at standard humidity, t ha^{-1}

Variety (factor A)	PGR (factor B)	Year of vegetation		
		third	fourth	fifth
Sinieva	C	6.45	6.74	6.43
	Radostim	6.72	7.16	6.95
	Stimpo	7.78	7.90	7.38
Vdala	C	5.53	6.11	5.88
	Radostim	5.79	6.73	6.10
	Stimpo	6.70	7.27	6.87
LSD_{05} A		0.26	0.25	0.24
B		0.32	0.30	0.29
AB		0.45	0.43	0.42
V, %		12.00	8.95	8.67

Radostim treatment of plants also showed a stimulating effect on increasing the yield of lavender plants. The yield in the Sinieva variety was 6.72–7.16 t ha^{-1}, in the Vdala variety it was 5.79–6.73 t ha^{-1}. However, there was a significant increase according to the control version in the Sinieva variety for the fourth (0.42 t ha^{-1}) and the fifth (0.52 t ha^{-1}) years of vegetation, in the Vdala variety it was only for the fourth year (0.62 t ha^{-1}). At the same time, the yield from treatment with the growth regulator Stimpo was significantly higher compared to the treatment with Radostim. The difference between the variants was 0.43–1.06 t ha^{-1} in the Sinieva variety and 0.54–0.91 t ha^{-1} in the Vdala variety.

Analysis of lavender yield during the years of vegetation showed that the highest rate was in the plants of the fourth year (6.11–7.90 t ha^{-1}), which is by 0.12–0.94 t ha^{-1} more than in the plants of the third year, and by 0.23–0.63 t ha^{-1} more than in plants of the fifth year. The yield of lavender in the fifth year was higher compared to the plants of the third year by 0.17–0.35 t ha^{-1}, except for the Sinieva variety, in which the difference in the control was insignificant, and in the variant with Stimpo treatment was lower by 0.40 t ha^{-1}. The revealed dynamics of productivity is connected both with climatic conditions in the period of carrying out researches, and with development of plants during the years of vegetation. As 2018 and 2019 were favorable for the growth of lavender, and the plants of the fourth year formed a larger number of shoots, the yield increased from the third to the fourth year of the growing season by 1.5–16.2%. In 2020, only 108 mm of precipitation fell, and it was in the phase of spring regrowth of shoots, which significantly affects the formation of productivity, the lowest amount of precipitation (5 mm) was observed in this phase. Although the experimental lavender plants were grown under the drip irrigation, it is not possible to fully compensate the insufficient amount of soil and atmospheric moisture, so the yield for the fifth year of vegetation was lower by 3.9–10.3% compared to the fourth year. In general, the yield according to the experiment was quite high (5.53–7.78 t ha^{-1}) for the third year of vegetation, 6.11–7.90 t $ha^{-1}$was for the fourth year, 6.10–7.38 t ha^{-1} was for the fifth year.

In all years of vegetation the highest yield of lavender was formed during the treatment of plants with the growth regulator Stimpo (6.70–7.90 t ha^{-1}), which is by 14.8–21.1% more than in the control. The dominant influence on the yield of lavender in the conditions of the Southern Steppe of Ukraine was exerted by the growth regulator treatment (41-60%), the influence of the variety (21–41%) was also significant.

The mass fraction of essential oil in vegetable raw materials differed in varieties of lavender (Fig. 2).

A larger mass fraction of essential oil was recorded in the Vdala variety which was 1.98–2.32%. In the Sinieva variety, this indicator ranged from 1.85 to 1.98%. Significant differences between varieties were found in the third and fifth year of the growing season. In the third year of the growing season Vdala accumulated more essential oil by 0.38–0.40% (20.0–24.1%) and in the fifth year it was by 0.23–0.30% (11.8–15.4%) compared to the Sinieva variety. The exception was the fourth year of vegetation, when the variety Vdala showed a decrease in the mass fraction of essential oil in inflorescences by 0.27–0.30% (13.6–14.9%) compared to the third year. However, in the variety of Sinieva this indicator did not differ from other years of cultivation. As a result, the difference between the varieties was insignificant. This may be a manifestation of individual plasticity of varieties to the climatic conditions of the year of cultivation. The dependence of the mass fraction of essential oil in vegetable raw materials on treatment with growth regulators was not revealed. The fluctuations between the control and experimental variants in the years of research were not more than 0.07%, which is evidence of the genetic conditionality of the quality trait mass fraction of essential oil in lavender plants.

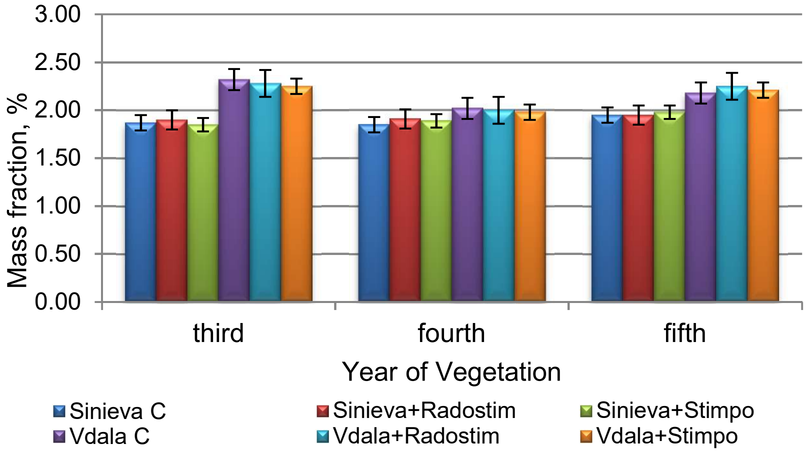

Figure 2. Mass fraction of essential oil in raw lavender, %. Error bars indicate standard error.

An important indicator in the evaluation of varieties and elements of technology for growing lavender is harvesting essential oil from the certain area. This indicator is derived from the yield and mass fraction of essential oil, taking into account the moisture content in vegetable raw materials. The harvest of essential oil from 1 ha did not significantly differ between the varieties Sinieva and Vdala (Table 3).

The fluctuation according to this indicator was 0.3–6.4%, in the Vdala variety this indicator was in the third and fifth years of the growing season by 2.2–6.4%, and in the Sinieva variety was higher by 0.3–4.0% in the fourth year of the growing season. The growth regulator treatments of lavender plants have increased the harvest of essential oil. The largest indicator was after the treatment of plants with the growth regulator Stimpo during the all years of the growing season. In the Sinieva variety, the harvest of essential oil was 137.30–144.17 kg ha^{-1}, which is by 18.92–25.13 kg ha^{-1} (15.9–20.6%) more than in the control. In the Vdala variety this indicator fluctuated in the range of 141.18–147.36 kg ha^{-1}, which is by 19.75–21.06 kg ha^{-1} (16.2–16.7%) more than in the control. The treatment of plants with the growth regulator Radostim also showed an increase in the harvest of essential oil in lavender varieties compared to the control, but their indicators were lower than in the version with the Stimpo treatment. In the Siniev variety, this indicator was 125.12–135.03 kg ha^{-1}, which is by 6.74–13.29 kg ha^{-1} (5.7–10.9%) more than in the control. In the Vdala variety this

Table 3. The harvest of lavender essential oil depending on the application of growth regulators, kg ha^{-1}

Variety (factor A)	PGR (factor B)	Year of vegetation third	fourth	fifth
Sinieva	C	118.38	121.74	122.05
	Radostim	125.12	135.03	132.18
	Stimpo	137.30	146.87	144.17
Vdala	C	125.73	121.43	126.30
	Radostim	129.57	131.95	135.84
	Stimpo	146.15	141.18	147.36

indicator fluctuated in the range of 129.57–135.84 kg ha^{-1}, which is by 19.75–21.06 kg ha^{-1} (16.2–16.7%) more than in the control.

According to the years of vegetation, the average harvest of essential oil did not vary significantly. There was 130.38 kg ha^{-1} in the third year, 133.03 kg ha^{-1} was in the fourth year, 134.65 kg ha^{-1} was in the fifth year. The fluctuation according to this indicator in variants was in the range of 0.57–9.91 kg ha^{-1} (0.5–7.9%). Despite the highest yields of plants in the fourth year of vegetation, the mass fraction of essential oil in vegetable raw materials did not change in the variety Sinieva or decreased in the variety Vdala, so the harvest of essential oil did not differ significantly compared to the third and fifth years of vegetation. Such data indicates the stability of plant production processes from the third to the fifth years of cultivation and the possibility of effective operation at lavender plantations with the Sinieva and Vdala varieties using the growth regulator Stimpo for treating plants.

A comparative analysis of the parameters of growth, development and productivity of lavender with indicators obtained in our studies in different climatic conditions (Tsvilynyuk, 2018; Rudnik-Ivashchenko & Kremenchuk, 2019) shows that lavender is well adapted to the climatic conditions of the Southern Steppe of Ukraine and can be recommended for cultivation in this zone.

Lavender plants of the third-fifth years of vegetation are characterized by rather high frost resistance from 82.7 up to 98.5%. The formation of a protective response in lavender to the effect of low temperatures is caused by compounds of the main and secondary metabolism, which perform protective and antioxidant functions: free proline, soluble carbohydrates, phenolic compounds and ascorbic acid. The obtained results indicate about high adaptability of lavender to low negative temperatures observed in the studied area (up to -16 °C of the air temperature and up to -7 °C of the soil temperature. Similar results were obtained in the west of Ukraine. Here it goes through the full cycle of development, blossoms, propagates by seeds and does not freeze (Tsvilynyuk, 2018). Adaptation capabilities of plants in the winter period, in addition to the frost resistance indicator, are also evaluated by winter resistance. A high winter resistance of 8 points was shown in the new lavender variety Mriya for cultivation in the forest-steppe zone of Ukraine (Rudnik-Ivashchenko & Kremenchuk, 2019).

The use of PGR is a modern promising measure to increase the productivity of many crops. Treatment with the growth regulator Stimpo has the stimulating effect on the productivity in lavender plants is by 14.8–21.1%. Increased yield may be associated with increased cell activity in plants by stimulating biochemical processes, which leads to the optimization of photosynthesis, respiration and nutrition (Egamberdieva et al., 2017; Lymperopoulos et al., 2018). Minev et al. (2022) also showed that the application of bio stimulants for foliar application FG and FT + FVital increased the yield of fresh inflorescences by 6.1% and 3.7%.

In the work of Andriychenko et al. (2020) showed that the treatment of lavender crops biological preparations ensured a yield increase of 0.20–0.52 t ha^{-1}. The highest yield of 1.73 t ha^{-1} and essential oil collection of 25.78 kg ha^{-1} Stepova lavender variety was formed by spraying the Biocomplex of BTU with compliance with the irrigation regime of 90–80–70% of the lowest moisture content during the growing season. This is significantly less than in our research (yield from 6.70 to 7.90 t ha^{-1} at standard humidity, collection of essential oil 137.30 up to 147.36 kg ha^{-1}) because one- and two-year plants were studied, and in our work plants of the third, fourth and fifth year of vegetation.

The mass fraction of essential oil in vegetable raw materials is quite high (1.85–2.32%). Similar ones were obtained for growing lavender in the Forest-steppe of Ukraine - 1.55–2.45% (Rudnik-Ivashchenko & Kremenchuk, 2019).

The prospect of further research is related to the agroecological aspects of growing narrow leaved lavender which are relevant in the modern world:

1. The use of lavender inflorescences and essential oil in cosmetology, medicine and pharmacology makes it necessary to develop methods for organic cultivation of crops in order to obtain environmentally safe raw materials.
2. Analysis of the biological characteristics of lavender shows that the Southern steppe zone of Ukraine is a promising region for its cultivation. Lavender is a light-loving, drought-resistant and heat-loving plant. At the same time, it is characterized by high frost resistance. It can withstand winters with frosts up to –20 °C, and in the presence of snow cover with a thickness of 25 cm up to -28 °C. Seedlings in the phase of 4–5 pairs of leaves can withstand frosts up to -8–10 °C.
3. Lavender can be grown on unproductive, rocky, gravelly and eroded lands where other crops do not yield. It is an anti-erosion perennial crop.
4. The expansion of the biodiversity of agroecosystems of the Southern Steppe zone of Ukraine is possible due to the economically profitable lavender culture.
5. In modern conditions of greening the human lifestyle, lavender is a spectacular ornamental plant in landscape and interior design compositions.
6. Lavender fields can be objects of ecological and green tourism.

It is known that the maximum realization of the potential of cultivated plants is possible to achieve the ecological unity of abiotic, biotic and anthropogenic factors as an integral indicator of the productivity of agroecosystems (Crisan et al., 2023). Therefore, the further task of our research will be to study the genotype and create a collection of varieties of *L. angustifolia*, study of morphological, physiological and adaptive processes under the influence of agricultural techniques that help increase crop productivity. Research is aimed at developing resource-saving environmentally friendly technologies for growing lavender in the agro-climatic conditions of the Southern Steppe of Ukraine.

CONCLUSIONS

Lavender plants of the third-fifth years of vegetation are characterized by rather high frost resistance from 82.7 up to 98.5%.

Treatment with the growth regulator Stimpo has the greatest stimulating effect on the processes of growth and productivity in lavender plants. Using this method, the highest yield was formed in all years of vegetation from 6.70 to 7.90 t ha^{-1} at standard humidity, which is by 14.8–21.1% more than in the control.

The mass fraction of essential oil in vegetable raw materials is quite high (1.85–2.32%), it is differs in lavender varieties and does not depend on treatment with plant growth regulators.

The largest harvest of essential oil in all years of vegetation was obtained by treating plants with the growth regulator Stimpo from 137.30 up to 147.36 kg ha^{-1}, which is by 15.9–16.7% more than in the control.

The stability of production processes of lavender plants from the third to the fifth year of cultivation indicates for the possibility of effective operation of lavender plantations and allows recommending the varieties Sinieva and Vdala for cultivation in the Southern Steppe of Ukraine with using the growth regulator Stimpo.

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