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Research Article

Agronomic Performance of Lavender after Application of a Novel PGRs

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Abstract
In recent years, interest in lavender has been increasing, as it has become not only a subject of agronomic research but also a significant economic factor for various regions, particularly in countries with a Mediterranean climate. To achieve high yields and quality products, it is essential not only to choose the right variety and consider the climatic conditions of the year, but also to implement appropriate sustainable agronomic practices. The present study aims to evaluate how two novel plant growth regulators are affecting the quantitative and qualitative parameters of the lavender variety Yubileyna. The experiment was conducted with a lavender plantation located in the region of the village Tazha (42°38'42.0"N 25°04'49.8" E) over a period of three years (2023-2025). The trial was organised according to the randomised complete block design in three replications and an individual plot size of 25m^2. Both plant growth regulators, Speed^B® applied in a dose of 3 l ha^{-1} and Alga900® applied in a dose of 250g ha$^{-1,}$ were introduced three times in the spring with the start of the active vegetation before the flowering stage at an interval of 10 days. During the trial period, the products have a positive effect on lavender biometric parameters and productivity by an average of 8% (Speed^B®) to 12% for Alga900® compared to the control. Gas chromatographic analysis shows that the product Alga900 improves the quality of the essential oil by helping to synthesise the largest amount of linalyl acetate.

Keywords: essential oil, lavender, plant growth regulators.

Introduction

Lavender is one of the most widely used aromatic and medicinal plants with significant economic value for the pharmaceutical, food, cosmetic, and perfume industries [1]. The genus *Lavandula* comprises 39 species, numerous hybrids, and approximately 400 officially registered cultivars, which are cultivated worldwide and highly valued in many industrial sectors due to the high content and quality of the essential oil extracted primarily from the flowers. Only three lavender species have commercial value: *Lavandula angustifolia* Mill, *Lavandula latifolia* L, and *Lavandula x intermedia*, a sterile hybrid developed by crossing *L. angustifolia* x *L. latifolia*. The chemical composition of the essential oil of the Lavandula species is the same, but with different ratios of the compounds [2]. The levels of linalool, linalyl acetate, and camphor in it determine the quality of the essential oil. As per ISO 3515:2002, lavender essential oil includes between 25-38% linalool, between 25-45% linalyl acetate, and between 0.5-1% camphor [2]. Compounds such as linalyl acetate, linalool, 1,8-cineole, terpinen-4-ol, and camphor have been reported to possess antimicrobial, antioxidant, and anticholinesterase activities [3]. Many studies in recent years have evaluated the insecticidal activity of essential oils against plant pests [4] and stored-product pests [5]. Several researchers have investigated the composition of essential oil and the antioxidant activity of lavender [6, 2]. Antioxidants neutralise free radicals, protect cellular molecules, and preserve food quality for a longer time [7]. In

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conditions of cold winter, short spring, and hot summer, the lavender plants are developing very rapidly. The fact that the crop can be successfully grown in soils with a poor nutritional regime makes it attractive to many farmers [8]. New research [9, 10] stated that representatives from the *Lamiaceae* family could protect soil from erosion. Nowadays, the agricultural sector faces a lot of challenges as climate change, soil degradation, and loss of biodiversity. In recent years, the dynamics of climate change have had a negative effect not only on productivity but also on the quality of essential oil [8]. The implementation of adaptive, environmentally friendly technology for cultivation based on modern methods of intensification, including the application of growth regulators, will help optimise the realisation of the genetic potential of plants [11]. Several authors have established that growth regulators can increase yields, improve quality, and enhance resistance to stress factors, while simultaneously reducing the doses of pesticides [12, 13]. All commercial plant growth regulators (PGRs) nowadays include substances as auxins, gibberellins, cytokinins, ethylene and abscisic acid [14]. The present study aims to evaluate how two novel plant growth regulators are affecting the quantitative and qualitative parameters of lavender.

Material and methods

Experimental setup

The experiment was conducted with a lavender plantation located in the region of the village Tazha (42°38'42.0"N 25°04'49.8" E) over a period of three years (2023-2025). The trial was organised according to the randomised complete block design in three replications and an individual plot size of 25m^2. Prior to the tillage in the autumn, the soil was fertilised with organic manure at a rate of 20t ha^{-1}. Ammonium nitrate was applied in two equal split rates (100 kg ha^{-1} in total) in spring, beginning of March and beginning of May. Two plant growth regulators Speed^B® (Macronutrients: Nitrogen - 6.1%, Potassium - 4.2%, Boron - 0.65%Humic acids 2.2%, Amino acids 2.2%Micronutrients: Boron 0.01%, Copper 0.02%, Iron 0.02%, Manganese 0.01%, Zinc 0.002%, Molybdenum 0.001%, Cobalt 0.002%) applied in a dose of 3 l ha^{-1} and Alga900® (cytokinins, gibberellins, auxins, abscisic acid and betaine at 600 ppm; mannitol 3%; amino acids >2.2%; N 0.5 – 0.8%; P_2O_5 1%; K_2O 17 – 19%; Mg 0.5 – 0.8%; Ca 0.6 – 1.8%; S 1%; Fe 0.15 – 0.3%; Cu 25 – 45 ppm) applied in a dose of 250g ha^{-1} were included in the study. The products were introduced three times in the spring with the start of the active vegetation before the flowering stage at an interval of 10 days. To determine the chemical composition of the essential oil, fresh plant material was harvested during the flowering stage. The oil was extracted through hydro distillation using a Clevenger-type apparatus. Fifteen grams of lavender flowers were distilled with 240 mL of water in 105 minutes. This process was repeated three times for each sample. The extracted essential oil was stored at 4 °c in the refrigerator until analysis by gas chromatography. The lavender oil was analysed with a Hewlett-Packard 6890 gas chromatograph fitted with an autosampler, employing helium as the carrier gas at a flow rate of 40 cm/s, with a pressure of 11.7 psi at 60 °C, and a constant flow rate of 2.5 mL/min. The injection was split at a 60:1 ratio with a 0.5 µL volume, and the inlet temperature was set to 220 °c. The oven was programmed to start at 60 °C for 1 minute, then ramped at 10 °C/min to 250 °c. The column used was HP-INNOWAX (cross-linked polyethene glycol), measuring 30 m x 0.32 mm x 0.5 µm. The flame ionisation detector was set at 275 °c. The analysis revealed and identified 13 distinct compounds in the lavender essential oil.

Wheater conditions

The climate data allows to conclude that a persistent trend of increasing average monthly temperatures is established in the area, as during the study period this indicator exceeds the values of the region's climatic norm (Table 1). During the study period, the amount of precipitation was significantly lower than the multi-year average.

Data Analysis

The data were analysed with one-way ANOVA and Duncan's multiple range test (P = 0.05) to identify significant differences among the means.

Results and discussion

Biometric parameters of lavender varied due to the contrast conditions of the year and the application of the plant growth regulators (Table 2). The highest values were recorded in the second year of the study, when the average monthly temperatures were higher and the amount of rainfall was distributed evenly. During the first year, the plants produced the fewest flowers, with values between 345 for the untreated control to 416 for the variant treated with Alga900®. As a result of the more favourable conditions of the year 2024, the values of the indicator under the control scenario increased on average by 49%. The highest number of flowers per plant was formed as a result of treatment with Alga900® (577 flowers), followed by the variant treated with Speed^B® (556 flowers). As a result of treatment with growth regulators, the average number of flowers per plant over the period increased by up to 12% for the variant treated with Alga900® and up to 8% for the variant treated with Speed^B®. The diameter of the lavender plant varied between 60 cm in 2023 by the untreated control to 80 cm in 2024 by the variant treated with Alga900®. During the trial period, the lowest height of 58 cm was recorded in the control variant during the first year, while the highest was observed in the variant treated with Alga900® in 2024 (72 cm).

Table 1. Climate conditions during lavender vegetation

Year	Temperature (^{0}C)											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
2023	2.8	4.3	7.5	9.3	13.4	20.5	24.8	24.7	19.4	14.7	9.5	5.7
2024	3.2	7.1	10.2	12.0	16.0	22.7	26.0	26.5	20.0	12.4	10.2	4.5
2025	1.5	6.4	7.6	10.5	14.3	21.6	25.2	24.8				
long-term average	0.5	2.2	5.1	10.0	16.5	20.8	24.5	24.5	17.4	14.3	8.5	2.0
	Precipitation (mm)											
2023	52.7	41.3	34.5	55.2	82.5	67.8	36.2	38.8	87.5	77.0	65.3	45.2
2024	36.8	35.2	53.2	48.3	64.8	6.0	0	40	95.4	82.0	45.7	35.5
2025	42.2	46.0	38.6	8.0	19.7	32.0	15.7	5.2				
long-term average	70.0	80.4	72.8	72.0	110.4	50.5	40.0	50.5	100.2	80.0	115.0	90.0

Table 2. Quantitative parameters of lavender

Variant	Number of flowers/plant			Diameter of the plant, cm			Plant height, cm		
	2023	2024	2025	2023	2024	2025	2023	2024	2025
Control	345^a	515^a	482^a	60^a	71^a	65^a	58^a	65^a	62^a
Speed^B®	373^b	556^b	521^b	65^b	77^c	70^b	63^c	69^b	67^b
Alga900®	416^c	577^c	540^c	72^c	80^d	73^c	65^c	71^c	69^c

*Different lowercase letters within columns represent significant differences at $P < 0.05$.

Table 3. Productivity of variety Yubileyna over the period

Variant	Flower yield, kg ha^{-1}			Oil content, %			Oil yield, kg ha^{-1}		
	2023	2024	2025	2023	2024	2025	2023	2024	2025
Control	3108^a	5485^a	4203^a	2.73	2.96	2.84	65.31^a	85.40^a	73.25^a
Speed^B®	3357^b	5924^b	4539^b	2.95	3.20	3.07	70.53^{bc}	92.23^c	79.11^c
Alga900®	3482^b	6143^c	4707^c	3.06	3.32	3.18	73.15^c	95.65^c	82.04^d

*Different lowercase letters within columns represent significant differences at $P < 0.05$.

The productivity indicators of lavender changed dynamically under the influence of the year's climatic conditions and the applied treatment (Table 3). The lowest productivity was recorded in the first year by the untreated control, where the yield of fresh flowers was 3108 kg ha^{-1}, oil content- 2.73%, and oil yield was 65.31 kg ha^{-1}. The low indicator values could be explained by the lower average monthly temperatures combined with heavy rainfall during the flowering period, which adversely affected productivity. The highest productivity was recorded during the second harvest year, which was the most favourable in terms of climate. In 2024, under the control variants, the yield of fresh flowers increased on average by 76%, the oil content in the flowers by 9%, and the oil yield by 31%.In terms of productivity, the third year occupied an intermediate position. During the trial period, the highest flower yields were recorded in the variants treated with Alga900®, with values ranging between 3482 kg ha^{-1} and 6143 kg ha^{-1} for the first and second year, respectively. In the variant treated with Speed^B®, the indicator increased on average by up to 8% compared to the control. The highest essential oil content of 3.32% for the testing period was recorded as a result of the treatment with the product Alga900®. Similar to the other parameters, the highest yields of essential oil were recorded in the second year, with a maximum of 95.65 kg ha^{-1} achieved as a result of the application of Alga900®. During the trial period, the lavender responded positively to treatment with $Speed^{B}$®, and the values of the indicators for flower yield, content, and oil yield exceeded the control.

The findings of the present study are in line with the observations of other researchers. Sönmez et al. [15] reported that the annual yield in a study conducted in Turkey varied between 3975 and 14 990 kg ha^{-1}. In the study of Minev et al. [16] foliar application with plant growth-stimulating products FG and FT+FVital increased the yield of fresh lavender inflorescences by 6.1% and 3.7% respectively. Audriychenko et al. [17] noted that treatment with biological preparations resulted in a yield increase of 0.20-0.52 t ha^{-1}. The highest yields of fresh inflorescences of 1.73 t ha^{-1} and the highest yields of essential oil of 27.78 kg ha^{-1} were achieved after the treatment with Biocomplex of BTU under an irrigation regime of 90-80-70 l. In the study of Manushkina et al. [11], the treatment with the PGR Stimpo had the greatest stimulating effect on productivity (by up to 21% more than the control). The highest amount of essential oil from 137.30 to 147.36 kg ha^{-1} was obtained after the treatment with Stimpo. Giannoulis et al. [18] investigated the effect of the bio-stimulators amalgerol applied in a dose of 15000 mL ha-1, Millerplex applied in a dose of 450 mL ha-1 and sugar Xpress in a dose of 12000 mL ha-1 on the flower and essential oil yield of lavender and noted that the application of the products helped the plants to increase their productivity under stress conditions. Moreover, the application of bio-stimulators affected the composition of the essential oil. In the same study, the positive effect of the plant growth stimulators was more pronounced during the first year, as in the second year, the productivity decreased rapidly due to fungal infection and lower precipitation. Even under these conditions, the values of the variants treated with biostimulants exceed the control and show a satisfactory effect during drought [18]. In terms of the percentage content of essential oil in the flowers during the second year, the treatment with amalgerol managed to maintain stable values, while in the control group, due to stress conditions, the essential oil content decreased by up to 60%.

Table 4. Chemical composition of lavender essential oil through GC-MS

Compound	RT (min)[a]	%[b]		
		Control	$Speed^{B}$®	Alga900®
Linalool	25.2	29.35	32.20	33.84
Linalyl acetate	34.8	31.10	34.52	38.10
cis-β-Ocimene	22.3	6.46	7.20	7.31
Lavandulol, acetate	38.2	3.62	3.92	4.20
Terpinen-4-ol	29.8	3.80	3.85	3.87
trans-β-Ocimene	22.0	2.75	2.64	2.72
3-Octanone	28.7	1.32	1.52	1.63
α-Terpineol	31.3	1.55	1.52	1.20
Limonene	18.8	0.55	0.87	1.03
Lavandulol	49.8	1.62	1.82	1.87
1,8-cineole	18.5	0.96	1.08	1.05
β-phellandrene	49.2	0.33	0.30	0.32
Camphor	28.4	0.15	0.14	0.15

[a] Retention time.
[b] Relative proportions of the essential oil constituents.

Gas chromatographic analysis identified 13 components in the essential oil (Table 4). Linalool and linalyl acetate were the main components of the essential oil. The quality of the essential oil is determined based on the levels of linalool, linalyl acetate, and camphor, as the high content of linalyl acetate corresponds to a higher quality of the product. As a result of foliar treatment, the values of linalyl acetate increased from 31.10% in the control to 34.52% in the variant treated with $Speed^{B}$® and to 38.10% in the variant treated with Alga900®. The linalool values ranged on average for the period between 29.35% (control) and 33.84% (Alga900®). The percentage content of camphor was not affected by the applied foliar treatment. Some authors have established that the use of growth regulators can influence the quantity and composition of essential oil in lavender [19-21] reported that even a trace amount of plant growth regulators (PGRs) applied externally influenced the physiological activities of plants. The content of essential oil could be influenced not only by genetic (plant species and phenological phase) [22], but also by various abiotic (age of the plantation, temperature, precipitation, soil conditions) and biotic (attack by diseases and insects) factors [23, 24].

According to Hajisamadi et al. [25] and Shampur et al. [26] the administration of regulators and the chemicals added during the distillation process could also affect the chemical profile of the essential oil. Based on contemporary international standards ISO 8902:2009a and ISO 3515:2002, the content of linalool in lavender oil is between 25 and 28% [27]. The high amount of camphor worsens the qualities of the oil, but is of primary importance for the antiseptic, antifungal, and antibacterial properties of lavender oil [20]. Renaud et al. [28] observed that lavender essential oil quality decreased with an increase in the amount of camphor. Karik et al. [29] reported variable essential oil composition depending on the variety. The same authors noted differences in the components of the essential oil based on the PGRs application, harvest time and the environmental conditions. The application of the PGRs and the harvest time also affected the amount of the components. Izmirli and Yildirim [14] confirmed that different concentrations of GA_3 changed the quality and quantity of lavender. In addition, these treatments, together with the harvest time, had a significant impact on essential oil chemical composition. The increase in productivity resulting from the application of growth regulators was attributed to enhanced cellular activity and stimulation of biochemical processes, leading to optimised photosynthesis, nutrition, and respiration [30].

Conclusions

Lavender variety Yubileyna showed high responsiveness to the use of foliar fertilisers and biostimulators. The studied products for foliar application increased productivity and the essential oil content. The biometrical parameters of the variants treated with the plant growth regulators exceeded the untreated control. For the experimental period, the increase in lavender productivity after the foliar application of the products ranged between 8.0% to 12% compared with the control. The highest yield of fresh flowers was reported in the variant treated with Alga900® at the rate of 6143 kg ha^{-1} in the second year. Regarding the essential oil content, the highest values were obtained when using Alga900® – 3.32% and the product $Speed^{B}$®- 3.30%. The product Alga900 improves the quality of the essential oil by helping to synthesise the largest amount of linalyl acetate.

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