

Influence of organic biostimulant “Atlas Universal” on economic indicators of Oil-bearing rose (*Rosa damascena* Mill.)

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Abstract

Badzhelova, V., Mineva, R. & Dermendzhieva, D. (2025). Influence of organic biostimulant “Atlas Universal” on economic indicators of Oil-bearing Rose (*Rosa damascena* Mill.). *Bulg. J. Agric. Sci.*, 31(5), 924–932

The influence of the biostimulant “Atlas Universal” on the economic performance of the Bulgarian oil-bearing rose has been studied. “Atlas Universal” is obtained through the processing of sludge from urban wastewater treatment plants using an innovative zero-waste technology and contains a rich range of essential nutrients.

The application of the biostimulant improved the economic characteristics of the crop as well as its resistance to adverse climatic changes. Following its use, both flower yield and extracted rose oil increased in all tested variants, with the most significant improvement observed in those where it was applied in combination (both foliar and soil application). The best results were obtained in Variant I (foliar application at a dose of 2 L/ha and soil application at a dose of 50 L/ha), where the increase in flower yield was 27%, and in oil yield, it was 33% compared to the control plots.

Chemical analysis showed that the use of the biostimulant maintained the quality parameters of the essential oil within the standard for Bulgarian rose oil.

Keywords: oil-bearing rose; biostimulant; yield; essential oil

Introduction

Essential oils and medicinal plants play a critical role in our lives. They find applications in medicine, cosmetics, the food industry, and other areas of modern life. In Bulgaria, the oil-bearing rose has been extensively studied for over a century, with a focus on aspects such as selection, variety maintenance, and cultivation practices. (Kovatcheva et al., 2011; Badzhelova, 2017; Mineva et al., 2020; Dobрева and Nedeltcheva-Antonova, 2023).

The pursuit of higher yields often leads to the irrational and intensive use of pesticides. Their application results in long-term water contamination with nitrates and alters soil structure. The production of various types of mineral fertilizers (Santos et al., 2012), obtained through chemical

processes, pollutes the atmosphere and water with nitrogen compounds (Saidi and Omri, 2020; Zhang et al., 2021), but soils, as the most difficult-to-renew natural resource in the environment, remain the most contaminated and damaged.

Aggressive urbanization in recent years, combined with the long-term application of conventional agriculture in Bulgaria, has already led to a significant shortage of beneficial substances in the soil. The application of organic fertilizers and plant biostimulants during active plant vegetation has been proven to increase biochemical, physiological, and economic indicators in many crops (Lambev, 2011; Vlahova et al., 2011; Stoyanova and Kuneva, 2018; Pashev and Badzhelova, 2019; Stoyanova et al., 2019).

In this context, an innovative solution has been proposed for treating sludge from urban wastewater treatment plants,

which preserves nutrients and allows them to be returned to agroecosystems (Ricci et al., 2019; Mejias et al., 2022; Hao et al., 2024). The developed solution is a multi-component liquid plant biostimulant, a suspension containing humic acids, organic substances, and micro- and macro-elements. The product “Atlas Universal” is produced using completely waste-free technology, is environmentally friendly, and is free of heavy metals and microbiological or parasitological contaminants.

The application of the product in agriculture is expected to achieve significant savings on expensive mineral fertilizers; the possibility of restoring the disrupted balance of organic matter in the soils; improving plant resistance to abiotic stress (Ugena et al., 2018); ensuring plants with micro and macro elements; increasing the effectiveness of plant protection products and reducing phytotoxic stress when used; extending the shelf life after harvest (Mancuso et al., 2006; Craigie, 2011; Mattner et al., 2013). However, to date, there is no publicly available published information on its application or effects on other crops.

In this sense, the primary objective of this study is to investigate the impact of the organic product “Atlas Universal” on the economic indicators of the Bulgarian oil-bearing rose.

Materials and Methods

The field experiment, conducted from 2021 to 2022 and spanning two harvest seasons, was carried out on a population of 16-year-old Kazanlak oil-bearing rose plants (*Rosa damascena* Mill.) cultivated under non-irrigated conditions on leached forest soils typical of the Kazanlak Rose Valley.

Biostimulant “Atlas Universal” is a commercial product of “Atlas Agro Science” Ltd., Bulgaria. Utility Model Patent No. Protects the product. PTBG202000000157151, as well as by novelty patent No. PTBG202000000154304, issued on 17.01.2020. It is manufactured by these patent rights and complies with the innovation standards established by the developer.

- Chemical composition (mg/L):
 - Macronutrients and micronutrients:
 - N – 61 593.3
 - P (P₂O₅) – 17 124.2
 - K (K₂O) – 1245.4
 - Ca (CaO) – 128.2
 - Mg (MgO) – 25.7
 - S (SO₄) – 1669
 - Fe – 216
 - Mn – 6.90
 - Zn – 26
 - Cu – 6.62

- Humic acids – 35.1%

- Application method:

“Atlas Universal” was applied twice, targeting two key phases determining the rose flower yield:

- First application – beginning of vegetation (leafing)
- Second application – flower bud formation (buttoning)

The experiment was established using five plants per variant, arranged according to the long plot method, which involves the use of extended plots to minimize the influence of soil heterogeneity and to achieve greater accuracy in field trials (FAO, 1993).

- Application scheme:
 - Variant I – 2 L/ha foliar + 50 L/ha soil application
 - Variant II – 3 L/ha foliar + 50 L/ha soil application
 - Variant III – 4 L/ha foliar + 50 L/ha soil application
 - Variant IV – 2 L/ha foliar application
 - Variant V – 3 L/ha foliar application
 - Variant VI – 40 L/ha soil application
 - Variant VII – 50 L/ha soil application
 - Variant VIII – untreated control plot.

A concentration of 1:1000 was applied, using a planting scheme with 0.6 m intra-row spacing and 3 m inter-row spacing.

Economic indicators

- *Number of flower buds per bush*: The number of formed flower buds per plant was recorded for each variant, and the average number per variant was determined over the entire study period;
- *Yield*: The rose flowers were harvested manually throughout the flowering phenophase.

The yield was recorded daily and accumulated over the reporting period.

Distillation: The quantity of the obtained essential oil was determined using a Clevenger-type apparatus, modified to allow the return of the distillation water — a design developed by Balinova and Diakov (1974), under the following parameters:

- Raw material: 200 g;
- Hydromodule: 1:4;
- Duration: 2.0 h.

Gas Chromatographic Analysis: The chemical composition of the essential oils was determined using an “Agilent Technologies 7820A GC System” with a flame ionization detector (FID) under the following working conditions:

- Capillary column: HP-5 column (Agilent Technologies), 30 m length, 320 µm internal diameter, 0.25 µm film thickness, stationary phase: 5% phenyl – 95% methylpolysiloxane

- Oven temperature program: initial temperature 60°C (held for 2 min), ramped at 5°C/min to 300°C (held for 10 min)
- Injector temperature: 250°C
- Detector temperature: 300°C
- Carrier gas: hydrogen, constant flow rate of 0.5 ml/min
 - Identification of components: based on comparison with authentic reference standards and mass spectral data from the NIST library
 - Quantitative Analysis:

The qualitative analysis of the obtained oil was conducted by estimating the peak area of each observed component, referenced to 100%, with an injected volume of 0.1 µL into the GC system.

- Identification Procedure:

Identification of the analyzed compounds was performed by comparing their retention times with those of authentic reference standards for the main components. For the remaining compounds, identification was based on calculated retention indices and comparison with values reported in the literature. The identity of the components was confirmed when the deviation of the retention time was within the acceptable limits.

Data analysis

The results were summarized into two groups:

- “Atlas” group – with applied biostimulant
- “Control” group – without applied biostimulant

The leading economic indicators were quantitatively analyzed, including essential oil yield, flower yield, and the number of flower buds.

The influence of climate on economic indicators was analyzed using average temperature values and precipitation amounts.

The following methodology was used:

- Comparisons across years, groups, and variants
- Statistical analyses: Correlation was performed using Pearson’s method, and analysis of variance (ANOVA) was conducted. All statistical calculations

were performed using IBM SPSS Statistics, version 27, Release 27.0.1.0.

Climatic Data

The climatic data were collected from a mobile weather station (Meteobot® Pro), installed in the experimental field.

Results and Discussion

A comparative analysis of the data presented in Table 1 indicates a consistent increase in yield across all measured indicators for the Atlas treatment group compared to the Control. To quantify this difference, the following mathematical model was applied to estimate the average relative increase over the study period:

$$\frac{\left(\frac{oneone1}{m}\right) \sum_{y=1}^m \left(\left(\frac{1}{n} \right) \sum_{v=1}^n A_{v,y} \right) - \left(\frac{1}{m} \right) \sum_{y=1}^m C_{1,y}}{\left(\frac{1}{m} \right) \sum_{y=1}^m C_{1,y}},$$

where:

$A_{v,y}$ – the value of the evaluated indicator for variant v from the Atlas group in year y ;

$C_{1,y}$ – the value of the same indicator for the single Control variant in year y ;

n – number of variants in the Atlas group;

m – number of experimental years;

$y \in 1, 2, \dots, n$ – denotes the year of the field trial;

$v \in 1, 2, \dots, n$ – denotes the variant index within the Atlas group.

This model enables the evaluation of application efficacy by accounting for interannual variability and multiple variants within the treatment group.

By applying the described model to each indicator, flower bud formation increased by 39.9%, rose flower yield by 35.4%, and essential oil yield by 16.8%.

Figure 1 presents the average values calculated as the arithmetic mean of the eight treatment variants for each in-

Table 1. Key indicators

Variant	Total number of buds, pcs.		Total of rose flowers, kg		Total essential oil, ml	
	2021	2022	2021	2022	2021	2022
I	11713	10773	25.957	27.751	0.31	0.36
II	9496	7232	26.100	20.432	0.29	0.26
III	9977	7314	28.979	20.719	0.32	0.28
IV	9869	7170	25.345	19.606	0.33	0.27
V	10004	7578	25.895	20.463	0.32	0.26
VI	9792	7150	25.586	21.060	0.3	0.27
VII	7842	6935	20.205	20.409	0.30	0.30
VIII	7042	5500	20.283	14.341	0.24	0.27

indicator (number of rose buds, rose flower yield, and essential oil yield), separately for 2021 and 2022. The number of rose buds was scaled by a factor of 1:10 000, the rose flower yield by a factor of 1:100, while the essential oil yield was presented without scaling. In the calculation of aggregated quantitative averages, standard deviation is not presented, as it is not applicable in this context.

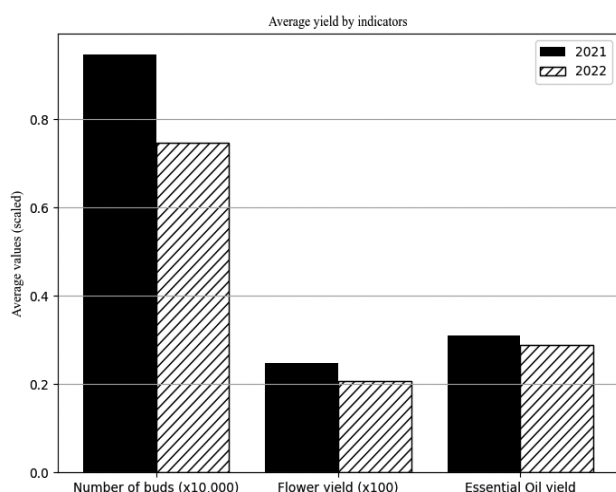


Fig. 1. Comparative characteristics by year

Climatic conditions are a key factor influencing crop cultivation and serve as a basis for determining the effects of all other factors. In this context, the climatic data for

the experimental period are presented in Table 2, while the results for the two years of the study are summarized in Table 1. A noticeable decline in yield indicators was observed during the second year of the study (Figure 1), attributed to less favorable climatic conditions, as demonstrated by the comparison of their average annual values.

Analysis of the climatic data for 2022 revealed the following trends:

- Higher average temperatures compared to 2021;
- Approximately 50% lower total rainfall;
- Greater annual temperature fluctuations negatively impact yield formation;
- Significant temperature variations between January and May resulted in frost damage to some rose bushes.

Figure 2 presents the yield indicators by treatment group (“Atlas” and “Control”) and by year (2021 and 2022), calculated as the arithmetic mean for each group. The number of rose buds was scaled by a factor of 1:10,000, the rose flower yield by 1:100, and the essential oil yield was presented without scaling. As the values represent aggregated averages per group, no standard deviation is presented.

The charts demonstrate the superior results of the “Atlas” group compared to the “Control” group. Notably, even in 2022, the yields of the “Atlas” group were higher than those of the “Control” group in 2021, despite the worse climatic conditions in 2022. This is most likely due to the accumulation of biostimulant components from the previous year, which suggests that its use increases the values of the

Table 2. Climatic data for the study period

Months	Climate data 2021				Climate data 2022				A multi-year period	
	Average daily t°C	Max. t°C	Min. t°C	Precipitation L/m ²	Average daily t°C	Max. t°C	Min. t°C	Precipitation L/m ²	Precipitation for 30 years period L/m ²	Temperature for a 30-year period t/°C
January	2.2	7.1	2.8	97.2	5	6.8	-3.3	20.2	31	-0.3
February	6.0	11.6	-2.9	22.5	3.9	10.6	-1.8	9.7	33	1.5
March	4.6	10.9	-1.2	42.8	3.1	9.0	-2.3	14.4	35	5.3
April	9.4	15.8	2.5	56.9	10.5	17.9	3.1	67.0	42	10.7
May	16.6	23.1	8.1	52.9	16.2	24.0	5.3	10.6	71	15.3
June	19.0	25.3	12.5	54.9	21.1	27.2	13.6	68.3	73	18.8
July	23.8	31.4	14.4	32.7	24.3	31.2	13.8	2.1	59	20.8
August	23.5	32.0	14.0	120.2	24.1	31.0	16.5	74.8	73.5	20.2
September	16.4	24.0	9.6	20.3	12.5	25.3	9.9	23.3	34	16.4
October	9.3	15.6	4.3	79.3	17.4	21.9	4.5	3.1	37	10.6
November	6.9	13.4	2.1	13.6	9.1	15.7	3.8	22.0	45	5.8
December	3.5	7.7	-1.9	83.8	5.2	10.2	1.8	28.8	41	1.8
Average:	11.77	18.16	5.36	56.43	12.7	19.23	5.41	28.69	47.88	10.58

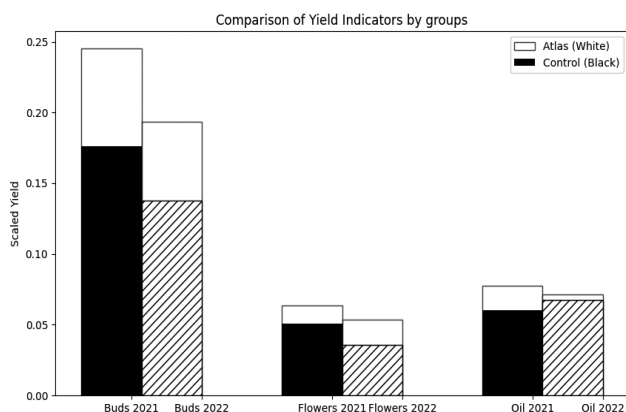


Fig. 2. Average yield by groups and indicators

studied indicators and largely compensates for the negative impact of climate conditions in the second year.

Table 3 presents the correlations between the average daily temperatures, the average amount of precipitation, and the yield of the two groups.

It can be observed that average daily temperatures are inversely proportional to the formation of flower buds and the yield of flowers. In other words, an increase in temperature hurts these indicators. The Pearson correlations for the “Atlas” and “Control” groups are, respectively, for flower buds (-.365 and -.727) and flower yield (-.320 and -.761). Comparing these values, it is evident that daily temperatures have almost twice as weak an impact on the results of the “Atlas” group.

A similar pattern is observed with precipitation, but in this case, the relationship is directly proportional. Since the data are based on a two-year observation, and the trends for temperature and precipitation are opposite (logically, rising temperatures are associated with less rainfall and drought), their absolute values are identical. The Pearson correlations for flower buds are (.365 and .727), and for flower yield

(.320 and .761), respectively for “Atlas” and “Control,” with a high level of statistical significance in both cases.

The data for rose oil yield do not show a strong dependence on the studied climatic factors. Regarding rose oil yield, it is worth noting that it is an indicator influenced by a complex set of factors that determine its yield and is not linearly related to flower yield. When conducting field trials, human factors such as harvesting time, storage duration, and processing stability significantly impact the yield of essential oil. Therefore, it is logical that the impact of climate on rose oil yield is not as pronounced.

Based on the results discussed so far, an analysis of the relationship between the applied variants and the economic indicators has been conducted.

The data from Table 4 indicate that at statistical significance values of 0.044 for bud formation and 0.056 for flower yield, even within the short study period, we can observe a powerful influence of the biostimulant and its method of application.

Given the recognized complexity and inherent variability of agricultural systems, particularly in field trials involving perennial crops such as oil-bearing rose, the strict application of a 5% significance level ($p \leq 0.05$) may not always capture biologically meaningful trends.

Environmental factors such as soil heterogeneity, microclimatic fluctuations, and biological variability often necessitate the acceptance of a higher threshold of significance, such as 10% ($p \leq 0.10$), in agronomic research (Ohio State University, 2020; Shrestha, 2022). Accordingly, the p-value of 0.151 observed in this study, while not statistically significant by conventional standards, indicates a potential trend toward treatment differentiation. This supports the need for prolonged biostimulant application and expanded experimental datasets to confirm and better characterize its effects.

In 2016, in experimental rose fields at IREMK, Badzhelova et al. (2016) also studied the effect of another organic prod-

Table 3. Climatic correlations of yield

		Correlations					
		Flowers yield		Essential oil yield		Formed buds	
Atlas		Control	Atlas	Control	Atlas	Control	
Average_daily_t	Pearson Correlation	-.320*	-.761*	-.232	.378	-.365**	-.727*
	Sig. (2-tailed)	.016	.028	.085	.356	.006	.041
	N	56	8	56	8	56	8
Precipitation	Pearson Correlation	.320*	.761*	.232	-.378	.365**	.727*
	Sig. (2-tailed)	.016	.028	.085	.356	.006	.041
	N	56	8	56	8	56	8

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed)

Table 4. Statistical analysis of the impact of variants on yield

		ANOVA				
		Sum of Squares	df	Mean Square	F	Sig.
buds	Between Groups	6920873.984	7	988696.283	2.239	.044
	Within Groups	24730727.625	56	441620.136		
	Total	31651601.609	63			
flowers	Between Groups	32.836	7	4.691	2.117	.056
	Within Groups	124.061	56	2.215		
	Total	156.896	63			
ess_oil	Between Groups	.002	7	.000	1.613	.151
	Within Groups	.009	56	.000		
	Total	.011	63			

uct—the microbial fertilizer “Ecosist-Arbanasi,” consisting of *Bacillus subtilis*, *Bacillus licheniformis*, *Azotobacter chroococcum*, and *Azotobacter vinelandii* – on the growth and productivity of Damask rose (*Rosa damascena* Mill.). It was established that the application of microbial fertilizer increased both the yield of blossoms and the quantity of essential oil extracted from them (Badzhelova et al., 2016).

In the same year, Mineva and Nedkov studied the impact of the universal organic fertilizer “Siapton” on the productivity of the Kazanlak oil-bearing rose and the quality of the obtained rose oil. It was found that “Siapton” had a positive effect on the observed parameters, increasing the flower yield in all tested variants (Mineva and Nedkov, 2016).

A few years later, a team of researchers conducted a sim-

ilar study using ginger extract (GE) and fulvic acid (FA) to determine the influence of plant-based biostimulants on the growth and productivity of *Rosa damascena* Mill. var. *Trigintipetala* in the Taif province of Saudi Arabia. They also found improvements in growth, flower yield, and oil yield, achieved through enhanced phytochemical and nutritional profiles of the plants (Ali et al., 2022).

In a 2023 review, the foliar application of various biostimulants, microelements, and growth regulators, such as silicon, salicylic acid, and amino acids, improves flower yield, essential oil content, and the resistance of Damask rose (*Rosa damascena* Mill.). According to Kant et al. (2023) the application of silicon leads to an increased accumulation of active compounds. At the same time, salicylic acid enhanc-

Table 5. Chemical composition of oils in 2021

Compounds	2021 Ingredients in % by variant								ISO 9842:2003
	I	II	III	IV	V	VI	VII	VIII	
Ethanol	0.16	0.04	0.20	0.17	0.16	1.31	0.62	0.67	≤ 2.0%
Limonene	0.04	0.04	0.03	0.02	0.03	0.04	0.01	0.02	
Linalool	0.38	0.52	0.48	0.46	0.44	0.39	0.48	0.47	
Phenylethanol	1.02	0.97	1.10	1.19	1.31	1.35	1.36	0.95	≤ 3.5%
Cis-rose oxide	0.50	0.21	0.14	0.29	0.18	0.36	0.31	0.18	
Trans-rose oxide	0.24	0.11	0.08	0.14	0.10	0.17	0.15	0.09	
Citronellol + Nerol	37.26	29.18	25.33	36.07	28.11	32.78	31.65	25.40	25.0% – 46.0%
Geraniol	9.12	19.94	25.89	17.98	27.11	15.69	21.48	18.54	15.0% – 22.0%
Eugenol	0.40	0.52	0.92	0.51	0.60	0.60	0.42	0.53	
Methyl eugenol	1.31	0.75	0.33	1.09	0.53	0.75	0.65	0.85	
Heptadecane	2.32	2.09	2.02	1.83	1.65	1.78	1.87	2.29	1.0% – 2.5%
Farnesol	0.96	1.70	2.43	1.15	2.02	1.16	1.71	1.61	
Nonadecene	4.36	3.87	3.58	3.36	2.90	3.30	3.08	3.83	
Nonadecane	17.62	16.39	15.43	14.92	13.68	14.99	15.30	19.08	8.0% – 15.0%
Eicosane	1.60	1.46	1.38	1.33	1.22	1.37	1.33	1.65	
Heneicosane	6.68	6.13	5.76	5.82	6.03	5.97	5.82	7.73	3.0% – 5.5%
Tricosane	1.60	1.38	1.32	1.32	1.54	1.42	1.33	1.42	
Pentacosane	0.69	0.55	0.54	0.52	0.61	0.56	0.51	0.67	
Heptacosane	0.61	0.43	0.51	0.49	0.56	0.52	0.44	0.58	

Table 6. Chemical composition of oils in 2022

Compounds	2022 Ingredients in % by variant								ISO 9842:2003
	I	II	III	IV	V	VI	VII	VIII	
Ethanol	0.57	0.48	1.01	0.01	0.32	0.51	0.02	0.22	≤ 2.0%
Limonene	0.03	0.06	0.08	0.04	0.06	0.05	0.04	0.05	
Linalool	0.49	0.47	0.74	0.48	0.56	0.26	0.43	0.73	
Phenylethanol	1.15	0.92	1.21	0.43	0.92	0.87	0.73	1.05	≤ 3.5%
Cis-rose oxide	0.36	0.16	0.22	0.07	0.13	0.20	0.24	0.20	
Trans-rose oxide	0.17	0.08	0.11	0.04	0.07	0.10	0.12	0.10	
Citronellol + Nerol	37.40	29.01	27.77	15.22	24.24	30.79	31.55	27.09	25.0% – 46.0%
Geraniol	15.90	21.52	24.20	21.57	23.81	16.32	17.18	23.11	15.0% – 22.0%
Eugenol	0.88	0.80	0.70	0.43	0.95	0.46	0.50	0.88	
Methyl eugenol	0.98	0.45	0.17	0.87	1.54	0.93	0.70	0.57	
Heptadecane	1.65	1.48	1.32	3.19	2.19	1.54	1.77	1.44	1.0% – 2.5%
Farnesol	1.26	2.10	2.61	1.85	1.81	1.66	1.68	2.19	
Nonadecene	2.81	2.50	2.14	5.15	3.28	2.79	2.96	2.48	
Nonadecane	12.85	13.95	12.57	20.00	14.49	14.51	15.28	13.09	8.0% – 15.0%
Eicosane	1.28	1.42	1.29	1.79	1.29	1.42	1.48	1.31	
Heneicosane	4.81	6.39	5.75	7.31	5.30	6.26	6.44	5.58	3.0% – 5.5%
Tricosane	1.05	1.57	1.43	1.52	1.17	1.49	1.49	1.23	
Pentacosane	0.63	0.80	0.65	0.85	0.66	0.84	0.70	0.66	
Heptacosane	0.36	0.50	0.45	0.53	0.44	0.51	0.46	0.39	

es plant resistance to abiotic stress, including drought and temperature extremes. These findings underscore the significance of innovative technologies in enhancing the quality and productivity of essential oil crops (Kant et al., 2023).

The cited studies largely agree with the present research. The results of our study confirm the positive effects of organic fertilization on the Bulgarian oil-bearing rose. A trend is observed towards improved economic indicators of the crop when biostimulants are applied at the appropriate growth phase and an optimal concentration of the applied stimulant.

The primary criterion for commercializing oil-bearing rose raw material is the quality of the essential oil obtained.

The conducted gas chromatographic analysis of the rose oils indicates that the content of the main components is within the standard for Bulgarian rose oil. The analysis data for 2021 and 2022 are presented in Tables 5 and 6.

Since we have already established that the “Atlas” group has better yield indicators, the analysis will focus on selecting the best variant from the group to be recommended for use.

For this purpose, the stability of each variant in terms of yields, as well as their summarized quantitative characteristics, has been examined.

The results were assigned a rating based on a scale determined by their position in a sorted list of values for each criterion.

To determine stability, the average coefficient of variation in percentages over the two years was used as follows:

$$CV = \left(\frac{s}{\bar{x}} \right) \times 100,$$

where:

- s is the sample standard deviation calculated using the formula $s = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}}$;
- x_i represents each value;
- $\bar{x}$ is the sample mean;
- n is the number of observations.

The calculated coefficients of variation and their corresponding ratings are presented in Table 7.

The result was determined as the sum of the ratings based on criteria in each yield category. The criteria for the sorted rating lists include:

- Coefficient of variation in the group for 2021;
- Coefficient of variation in the group for 2022;
- Coefficient of variation of the variant over both years;
- Yield quantities.

The quantitative characteristics of the yields were evaluated based on the data in Table 1. The variant with the highest score was selected as the most suitable for application. The summarized ratings for stability and productivity of the variants from the “Atlas” group are presented in Table 8.

The data indicate that Variant I achieved the highest score. Variants I to III have a total score of 120 points, which

Table 7. Coefficients of variation and their ratings by indicators

Variant	CV buds			CV flowers			Cv averaged		
	2021 (CV:Pts.)	2022 (CV:Pts.)	2021/2022 (CV:Pts.)	2021 (CV:Pts.)	2022 (CV:Pts.)	2021/2022 (CV:Pts.)	2021 (CV:Pts.)	2022 (CV:Pts.)	2021/2022 (CV:Pts.)
I	9.65:6	12.56:6	5.91:6	10.91:4	12.19:6	11.55:5	8.45:2	8.67:4	8.56:2
II	11.9:1	18.71:3	19.14:4	10.85:5	16.56:2	13.7:2	9.03:0	12:0	10.52:4
III	11.33:4	18.5:4	21.78:2	9.77:6	16.33:4	13.05:0	8.18:3	11.14:2	9.66:3
IV	11.45:3	18.87:2	22.4:0	11.17:1	17.26:0	14.22:1	7.94:4	11.56:1	9.75:1
V	11.3:5	17.86:5	19.51:3	10.93:3	16.54:3	13.74:3	8.18:3	12:0	10.09:0
VI	11.54:2	18.92:1	22.05:1	11.07:2	16.07:5	13.57:4	8.73:1	11.56:1	10.14:5
VII	14.41:0	19.51:0	8.68:5	14.01:0	16.58:1	15.3:6	8.73:1	10.4:3	9.57:6

Note: CV – Coefficient of Variation; Pts. – rating points; 2021 – Value in the group for 2021; 2022 – Value in the group for 2022; 2021/2022 – Value of the variant over both years.

Table 8. Evaluation of variants

Variant	Buds		Flowers		Oils		Result
	Yield	CV	Yield	CV	Yield	CV	
I	6	18	5	15	4	8	56
II	1	8	3	9	0	4	25
III	4	10	4	10	3	8	39
IV	3	5	1	2	3	6	20
V	5	13	2	9	2	3	34
VI	2	4	3	11	1	7	28
VII	0	5	0	7	3	10	25

Note: Yield – total yield score, CV – total stability score.

is greater than the total of all other variants combined. This suggests that the combined application method (soil and foliar) is the most effective. It should also be noted that there is a positive trend in the changes of key chemical indicators (aroma carriers) of the oil in Variant I. Without delving into a detailed analysis, some notable improvements from 2021 to 2022 are:

- Linalool: 0.38% → 0.49%;
- Geraniol: 9.12% → 15.9%;
- Citronellol + Nerol: 37.26% → 37.4%.

All of the above give us reason to believe that oil-bearing roses respond positively to organic fertilization, which is usually manifested in an increase in the number of formed flower buds, the amount of harvested fresh flowers, and the quantity and quality of the obtained essential oil.

Conclusions

A comparison between the average results from the two years of the study revealed an increase in all yield indicators for the group treated with the biostimulant, compared to the control group. Specifically:

- Flower bud formation increased by 39.9%;

- The rose flower yield increased by 35.4%;
- and essential oil yield increased by 16.8%.

The use of the biostimulant enhances the crop's resistance to climatic changes. The combined application of “Atlas” yielded the best results; however, it can be applied at a minimum solely to the soil.

Variant “I” (2 L/ha foliar application + 50 L/ha soil application) was identified as the most effective.

After the application of the biostimulant, the essential oil quality parameters remained within the standard for Bulgarian rose oil.

A more extended period of application in production is necessary to further validate the study results.

Conflict of interest

The authors declare that they have no financial or non-financial competing interests related to this publication.

Funding

This research received no specific grant from any funding agency, whether commercial or not-for-profit.

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Received: March, 17, 2025; Approved: May, 12, 2025; Published: October, 2025