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AGRICULTURAL PERFORMANCE OF OIL-BEARING ROSE UNDER ORGANIC FERTILIZATION

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Abstract. *Scientists today are focusing on new agricultural practices to enhance the yield and quality of medicinal plants. The products derived from these plants are valuable raw materials for the pharmaceutical and cosmetic industries, and ensuring their organic origin is a top priority. The use of organic farming practices corresponds to the objectives of the Green Deal and helps to provoke the natural fertility of the soil. In a dynamically changing climate, proper and appropriate fertilisation contributes to the better adaptation and development of crops. This study aims to examine whether different organic fertilizers affect the productivity and quality of essential oil in Damask rose. The experiment was conducted using a randomized complete block design with three replications for three years. The following organic fertilizers were utilized: dried poultry manure Polynamatura NP, bone meal OrgaNexport N:P 10:8, and vermicompost Biohumus, each applied at their respective doses. Results showed that fertilization with these organic products significantly increased the productive potential and the quality of oil-bearing roses. Among the fertilizers, bone meal had the most positive impact on productivity and essential oil yield. The highest essential oil quality was obtained from the variants treated with bone meal and vermicompost, and they could be recommended for sustainable rose production.*

Keywords*: Damasc rose, essential oil, organic fertilizer, productivity*

INTRODUCTION

The production and processing of oil-bearing roses in Bulgaria is based on tradition and dates back 300 years (Todorova et al., 2020). The genus *Rosa* unites more than 200 species, but only a few representatives are used because of the high quality of their essential oils (Kovacheva et al., 2010). Rosa Damascena is undoubtedly the brightest representative of the family, which is grown on the most considerable areas (Kovacheva et al., 2010). The species originates from the Middle East (Toluei et al., 2019; Nasiri et al., 2021) and is also cultivated in India, Morocco, Southern France, China, Southern Italy, Libya, Southern Russia, Ukraine (Ucar et al., 2017), but its main producers are Turkey and Bulgaria (Rusanov et al., 2009). The Damasc rose is a key plant for producing volatile oils, with its flower petals and related products utilized in the flavoring, perfumery, cosmetic, aromatic, and pharmaceutical industries. (Thakur and Kumar, 2020). Its essential oil is an expensive and high-quality natural product with unique properties (Cebi et al., 2021). The essential oil contains more than 300 different constituents, whose amount and composition can vary widely depending on the cultivar, ecotype, climate conditions, and production technology (Toluei et al., 2019). When determining the quality index and the smell of damasc rose oil, the amount and ratio of the acyclic monoterpene alcohols, such as citronellol. Nerol, geraniol, and the long-chain hydrocarbons as tricosane, heneicosane, eicosane and nonadecane are very important (Seify et al., 2018; Farahani et al., 2020). The petals contain various components such as terpenes, flavonoids, glycosides, polyphenols, and anthocyanins (Liu et al., 2020; Nasiri et al., 2021). Volatile oil extracted from the pelats is an essential raw material for the pharmaceutical industry because of its analgesic, hypnotic, antioxidant, laxative, cardiovascular, and

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anticonvulsive properties (Hamedi et al., 2022a). On the other side, the lipid-soluble components are responsible for the aforementioned pharmacological effect (Shabbir et al., 2020). Several authors reported that genetic factors and abiotic factors (climate, agronomic practices) and their interactions can affect the growth, productivity, and the essential oil composition of Damasc rose (Emami Bistgani et al., 2018; Farahani et al., 2020). In aromatic herbs, the plant nutrition affects the aroma profile and the active substances composition (Pandey and Patra, 2015). Recognizing the plant nutrition system is crucial for attaining high quantity and quality yields in both agronomic and horticultural crops (Hamedi et al., 2022a). In organic farming systems, biological additives and fertilizers are important sources of plant nutrients, which can improve the overall performance of the crop by increasing the productivity and quality of the production (Hamedi et al., 2022a).
Research that provides information on the application of organic products on the productivity and quality of oil is scarce (Samani et al., 2021). In this regard, the study of organic rose-growing systems requires scientific support to achieve the goal of sustainable agriculture. The current research work aims to compare the effectiveness of three organic fertilisers on the productivity of Damasc rose and the quality of its essential oil.

MATERIAL AND METHODS

Field experiment

The experiment was set in the region of the village of Rozovo (W: 42.565657, L: 25.416037), part of the Rose Valley of Bulgaria, on five-year-old Damascena rose plantations. The study was arranged according to the randomized complete block design in three replications for the period 2022-2024. Each experimental plot had an area of 18 m^2 and covered two rows with 21 rose plants. The distance between the rows was 3m, and the bushes were located 0.40m apart. The following fertilizers have been included in the experimental setup: dried poultry manure (DPM) Polynamatura NP (organic nitrogen 2%; P_20_5 2.5%, K_2O 2%; MgO 2%, CaO 12%; B 0.004%, Mn 0.04%; Zn 0.02%, organic carbon 20%) in a dose of 60 kg ha^{-1}; bone meal (BM) OrgaNexport N:P 10:8 (meal from bones, horns and hooves, organic nitrogen 10%, organic carbon 40%, P_20_5 8%) in a dose of 50 kg ha^{-1}, vermicompost (VC) Biohumus (organic manure 50-60%, organic carbon 35%, organic nitrogen 3%, P_20_5 2.2%, K_2O 1.2%, CaO 8.31%) applied in a dose of 1l per bush. All variants were compared to an unfertilized control. The products were applied in autumn before the last tillage.

Rose flowers were harvested by hand in the spring (April ,May) and the essential oil content was determined with the Clevenger type distillation apparatus. A mixed sample of 1000g of raw material collected from each variant was mixed with water and subjected to a boiling process for 4 hours. At the end of the process, the water is separated from the essential oil by decantation. The obtained essential oil was stored in the refrigerator (4 ^{0}C) until the gas chromatograph analysis. The rose flower essential oil was examined using a Hewlett Packard 6890 gas chromatograph equipped with an autosampler. The carrier gas was helium, flowing at 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 carried out using a split ratio of 60:1 with a volume of 0.5 µL, at an inlet temperature of 220 °C. The oven temperature program started at 60 °C for 1 minute, increased by 10 °C/min to reach 250 °C. The column used was HP-INNOWAX (cross-linked polyethylene glycol), measuring 30 m x 0.32 mm x 0.5 µm, and the flame ionization detector operated at a temperature of 275 °C. The gas chromatograph analysis detected and identified 11 different compounds in the Damask rose oil: Linalool, Geraniol,

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Eugeniol, Geranyl acetate, Methyl eugenol, Citronellol, Nerol, Heptadecane, Nonadecane, Heneicosane, and Phenylethanol.

Data were statistically processed using ANOVA, with differences among variants identified via the multi-rank LSD test.

Soil and climatic conditions of the region

The dominant soil type of the region is represented by deluvial noncalcareous sediments, which classified the soils as *Fluvosoils* (Todorova et al., 2020). A defining trait of these soils is the rapid loss of organic matter. To monitor the soil stock of key chemical elements, soil samples were collected each year from the 0-30 cm depth layer. The data are presented in Table 1.

Table 1.

Agrochemical analysis of the soil during the study period.

Year	pH	Mineral nitrogen, mg/kg soil	P_2O_5, mg/100 g	K_2O, mg/100 g	SOC mg g^{-1}
2022	4.20	14.58	11.40	15.60	13.52
2023	4.80	15.14	12.85	16.60	14.87
2024	5.10	16.42	13.57	17.50	16.30

The pH values fluctuated from 4.20 in the initial year to 5.10 in the third year of the study. Humus content measured by Turin (Trendafilov and Popova, 2007) varied from 3.10% to 4% throughout the research period. For determining the mineral nitrogen content, the Kjeldahl method (Goyal et al., 2022) was utilized, with values ranging from 14.58 mg kg^{-1} in the first year to 16.42 mg kg^{-1} in the third year. The potassium and phosphorus content were assessed using the Egner-Riem method (GOST 26208-91, 1993). Potassium levels ranged from 15.60 mg/100 g to 17.50 mg/100 g. Throughout the study, mobile phosphorus content fluctuated from 11.40 mg/100 g in the first year to 13.57 mg/100 g in the third year. Soil organic carbon (SOC) levels were determined using the Nikitin-modified Tyurin method (Slepetiene et al., 2023), showing values between 13.52 mg g^{-1} and 16.30 mg g^{-1}.

Table 2.

Climatic conditions during the vegetation period.

Year	temperatures (^{0}C)											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
2022	3,2	7,1	9,2	12	16	22,7	26	26,5	20	12,4	10,2	4,5
2023	1,5	6,4	9,6	14	17,3	24,2	28	28,3	21,7	15	13,4	4,6
2024	4,4	9,4	13,4	19	22,5	25,3	27,4	26,3	19	14,6	9,5	3,2
Climatic norm	0,5	2,2	5,1	10	16,5	20,8	24,5	24,5	17,4	14,3	8,5	2
	precipitations (mm)											
2022	55,1	36	58	62,3	68,8	62	41,7	45.3	85,4	92	78,7	105,5
2023	61	73	90,2	80	120,2	115,4	60,3	62,2	95,8	103,9	62,3	92
2024	60,6	68	73,2	72,5	90,1	54,2	37,4	48,7	103	77,3	93,1	89
Climatic norm	70	80	72,8	72	110,4	50,5	40	50,5	100,2	80	115	90

During the study period, the temperature values and the amount of precipitation have changed dynamically (Table 2). In the first year, annual rainfall was 186.7 mm lower than the climatic norm of the region. In the same period, precipitation was more evenly distributed. In the second year, precipitation exceeded the values of the long-term average by 84 mm. In terms of rainfall amount, the last year was closest to the climatic norm of the region.

RESULTS AND DISCUSSIONS

The highest percentage of essential oil in the flowers was recorded in the first year, which is the most favourable in terms of climate (Figure 1). The lowest amount of 0.042% was reported by the control, and the highest value of 0.053% was realised as a result of fertilisation with bone meal. In the second year, the abundant and prolonged rainfall period prevents the accumulation of essential oil in the flowers, and the values are significantly lower. The minimum amount of essential oil was reported in the variant fertilised with dried poultry manure (0.028%), while bone meal again helped to achieve the highest results (0.041%). The values of the indicator in the third year occupy an intermediate position compared to the other two years.

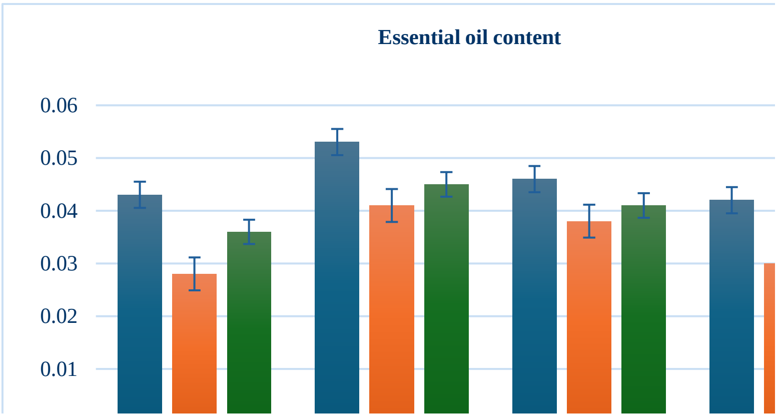

Figure 1. Content of essential oil (%).

Ucar et al.(2017) observed that different nitrogen doses did not affect significantly the rose oil content in the petals. Kovacheva et al. (2010) noted that the oil yields varried from 0.045% to 0.05%. While using different irrigation treatments Nedkov et al. (2014) observed that oil yields varried between 0.22 kg ha $^{-1}$ to 1.48 kg ha $^{-1}$. The rose oil yield and quality are influenced by a numerous factors such as environmental conditions, variety, harvest time, as well as the distillation technology (Baser and Arslan 2014; Misra et al., 2002; Ucar et al., 2017; Zekavati and Zadeh 2013). Todorova et al. (2020) reported that rose essential oil productivity in conventional farming in statistically proven higher than in organicly maintained plantations, with an average values of 0.038% versus 0.026% for the biological one. Moreover the authors observed that agricultural system of cultivation by *R. damascena* has an effect on the essential oil content. By essential oil crops nutrition can effectively increase the oil yield and quality (Todorova et al., 2020). The yield of fresh rose petals changes dynamically during the test period under the influence of climatic conditions and applied fertilisation (Table 3). The highest yields were recorded in the first year, when climatic conditions are close to optimal for the development of the crop.

Table 3.

Yield of fresh flowers (kg ha^{-1}).

Variants/Years	Flower yield, kg ha^{-1}		
	2022	2023	2024
1. DPM	4536^{b}	2912^{a}	3745^{b}
2. BM	4830^{c}	3024^{b}	3850^{b}
3. VC	4662^{b}	3080^{c}	3990^{c}
6. Control	4200^{a}	2800^{a}	3500^{a}
LSD 5%	*245*	*128*	*187*

*Values with the same letters do not differ significantly.

By the control variant, the yield is 4200 kg ha^{-1}. As a result of the applied fertilisation, the values of the indicator increase between 8% by the variant treated with poultry manure to 15% by the variant fertilized with bone meal. The values between the individual treatments are statistically significant and proven. In the second year, the unevenly distributed and abundant rainfall had a negative impact on the yield, and the control variant showed a decrease of 5% compared to the previous period. The application of dried poultry manure led to a 4% increase in productivity; however, the differences compared to the control variant are not statistically significant. In contrast, fertilizing with vermicompost raised the average yield to 3024 kg per hectare, while the application of bone meal achieved the highest yield, reaching 3080 kg per hectare. In terms of productivity, the third year occupies an intermediate position with a variation in yields from 3500 kg ha^{-1} by the unfertilised variant to 3990 kg ha^{-1} by the variant fertilised with bone meal.The two-factor analysis confirms the independent influence of the year's climatic conditions and the applied fertilisation on the yield of rose petals (Table 4). Still, the interaction of the two factors remains unproven.

R. damascena flower yield varries depending on the climate conditions (Ucar et al., 2017). Fertilization application after the harvest affects the yield and quality of the flowers in the upcoming year (Ucar et al., 2017). In *Rose alba* the same authors reported that under non-irrigated conditions, the flower yield varried from 2070 to 5030 kg ha^{-1}. According to the observations of Kovacheva et al. (2010) the yield on not well mantained plantations varried between 1000 and 1500 kg ha^{-1} compared to 4000-5000 kg ha^{-1} yield of petals coming from well maintained plantations. While Baser and Arslan (2014) reported a flower yield of 5000 kg ha^{-1} under non-irrigated conditions. Different climate conditions and cultivation technology can affect the yield (Misra et al., 2002). In the present study the yield was affect from the climate conditions and the applied fertilization, as the average yields for the study period are between 3500 kg ha^{-1} (control) and 3910 kg ha^{-1} (variant fertilized with bone meal). On the other hand Zekavati and Zadeh (2013) reported that pruning method and time can significantly affect the flower yield.

Table 4.

Two-way ANOVA analysis of variance.

Source of variation	SS	df	MS	F	P-value	F crit.
Years	16913356	2	8241122	320.70	0.00*	3.14
Fertilization	8575656	3	2751145	102.62	0.00*	2.76
Interaction	125622	6	20011	0.68	0.55^{ns}	2.25
Within	930085	36	25001			
Total		48				

* - significance at 0.05 level; ns – no significance.

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In the study of Hamedi et al. (2022b) applied organic fertilization influenced the flower yield of *R. damascena*, as the highest yields of fresh and dry flower petals were recorded after application of vermicompost, followed by the variants fertilized with horse dung manure and the conventional combined N-P-K fertilizer. Organic matter in manure and vermicompost increases the microbial activity, maintains soil moisture and helps to better absorbtion of nutrients (Hamedi et al.,2022b). Organic fertilizers increase number of flowers per plant, fresh flower weight and diameter, which results in a general flower yields increase (Abbaszadeh, 2018; Kumar et al., 2017). Hamedi et al (2022a) stated that higher yields recorded in variants fertilized with vermicompost can be related to higher amounts of nutrients especially N,P,K. Essential oil content of *R. damascena* collected from the mountain region of Iran varried from 0.08% to 0.13% (Ghavam et al., 2021). In the study of Hamedi et al. (2022b) the maximum essential oil content was obtained after application of conventinal N-P-K fertilizer and vermicompost. Kumar et al. (2017) and Abbaszadeh (2018) observed that conventinal fertilizer improved the essential oil content of *R. damascena*. Organic fertilizers create a balance between the absorption of the essential elements in the roots, increase the photosynthetic rate, stimulate the growth and phytochormons biosynthesis (Khalvandi et al., 2019). Thakur and Kumar (2020) indicated that foliar spraying with methyl jasmonate and diphenyl urea improved the content of essential oil by Damasc rose. The authors stated that jasmonate probably induced signals for secondary metabolites biosynthesis, which increased the density of oil glands in leaf and regulated the polyphenol oxidases accumulation. In some research works vermicompost increased the population and activity of beneficial soil microorganisms and enabled the better absorption of P and N (Amooaghaie and Golmohammadi, 2017; Kumar et al., 2017). According to Hamedi et al.(2022b) organic amendments can modify the chemical composition of the essential oil. The variations are assiciated with changes in the synthesis pathways and the role of the components in the plant physiology. Organic manures contain significant amounth of macro- and microelements and when applying to the soil they are improving its chemical and physical properties, microbial biomass, water holding capacity, which enhances the quality and quantity of the production (Rostaei et al., 2018). Samani et al. (2021) reported that application of biological amendments in soil can improve yield of specific metabolites in medicinal plants.

The components that occur in the highest concentration in the essential oil of Rosa damascena belong to the group of monoterpene alcohols (Table 5). Under the influence of climatic conditions and applied fertilization, the composition of the essential oil changes dynamically. The ratio is most balanced in the first year, when during the flowering period the temperatures are moderate and the precipitation is more evenly distributed. These conditions extend the flowering period and help to accumulate higher-quality oil in the flowers.During the test period, the lowest content of monoterpene alcohols was measured in the control, followed by the variant fertilized with dried poultry manure.Bone meal fertilization helped accumulate the most linalool, geraniol, nerol, and citronellol throughout all three years of the study.The application of vermicompost also positively affected the composition of the essential oil during the test period. The results from the present study confirm that fertilization can influence the rose oil yields and quality. Rose oil contains high percentage of monoterpen alcohols like citronellol, nerol, geraniol, linalool and phenylethyl alkohol (Baydar and Baydar, 2004). These constituents determine the high vaue of rose oil for the perfume industry (Baser, 1992; Bayrak and Akgül, 1994). Harvest date can influence all components of the essential oil (Baydar and Baydar, 2004). In the study of Baydar and Baydar (2004) geraniol was the main component accounting for 41.36% to 44.44% of the total essential oil. Citronellol/geraniol ratio is used for evaluating the odor quality of rose oil and the best odor is obtained when the ration is between 1.25 and 1.30 (Baser, 1992).

Table 5.

Essential oil composition of Damask rose

Compound	Variants											
	Control			DPM			BM			VC		
	2022	2023	2024	2022	2023	2024	2022	2023	2024	2022	2023	2024
Linalool	0.07	0.03	0.05	0.08	0.05	0.13	2.11	1.85	1.90	1.56	1.22	1.34
Geraniol	22.5	20.17	21.8	18.81	17.03	17.12	24.09	22.73	23.24	23.87	22.62	23.12
Eugeniol	1.55	1.32	1.48	1.56	1.34	1.50	1.93	1.75	1.88	1.66	1.60	1.63
Geranyl acetate	0.15	0.17	0.17	0.13	0.12	0.13	0.38	0.19	0.25	0.32	0.24	0.28
Methyl eugenol	0.35	0.18	0.2	0.21	0.16	0.17	0.33	0.21	0.25	0.35	0.25	0.25
Citronellol	26.52	25.12	26.4	26.74	25.12	26.0	31.14	27.01	28.3	30.03	25.10	27.2
Nerol	12.84	11.21	11.5	7.87	7.01	7.3	6.45	5.21	6.22	5.78	5.04	5.38
Heptadecane (C_{17})	0.08	0.03	0.05	0.09	0.06	0.07	1.02	0.07	0.08	0.09	0.05	0.07
Nonadecane (C_{19})	12.87	11.08	12.1	11.35	9.89	10.09	6.63	6.04	5.52	4.86	3.87	4.48
Heneicosane (C_{21})	10.12	8.86	9.03	3.60	2.57	3.03	2.79	1.90	2.25	4.00	3.12	3.74
Phenylethanol	3.47	2.89	3.25	3.65	2.52	3.11	3.66	2.31	2.87	3.09	2.26	2.71

CONCLUSIONS

During the test period, the yields of rose flower and essential oil changed under the influence of both the applied organic fertilization and the climatic conditions. Fertilization with bone meal contributed to an increase in the average yields of rose flower by up to 15%. As a result of the same treatment, a maximum content of essential oil in the rose flower of 0.053% was also recorded.The application of bone meal and vermicompost increases the % of monoterpene alcohols in the oil, which respectively increases the quality of the raw material.The results obtained allow bone meal to be recommended for the needs of organic and sustainable rose production.

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