

PHENOLOGICAL DEVELOPMENT OF OIL-BEARING ROSES DEPENDING ON GENOTYPE AND SELECTED METEOROLOGICAL FACTORS

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Abstract. Oil-producing rose cultivation in Bulgaria mainly includes the species *Rosa damascena* and *Rosa alba*, which are of important economic importance for the essential oil industry. The present study aimed to investigate the phenological development of both species depending on genotype and selected meteorological factors in the Rose Valley region (Kazanlak region) during the period 2023–2025. The experiment was set up using a block method with four replications and an experimental plot area of 25 m². The main phenological phases were monitored during the individual crop years: bud burst, leafing, budding, flowering, and second growth. The results showed that meteorological conditions, especially temperature fluctuations, had a significant impact on the onset and duration of the phenological phases. In 2025, the vegetation period began the earliest, but the subsequent low temperatures (down to –13°C) caused frost damage to the developed buds, leading to secondary bud burst and reduced flower yield. The duration of the phases varied between years, with shorter initial phases observed under higher temperatures. The leafing phase lasted between 25 and 29 days, while budding was delayed under cooler conditions. The flowering period ranged from 30 to 35 days and was strongly dependent on temperature and moisture conditions. The second growth phase extended until late autumn and was essential for the formation of generative organs for the following year. The obtained results emphasized the sensitivity of oil-bearing roses to climatic stress factors and the importance of meteorological conditions for their productivity.

Keywords: oil-bearing roses, phenology, growth stages, meteorological factors

INTRODUCTION

The production of oil-bearing roses in Bulgaria is one of the most traditional agricultural activities, concentrated mainly in the so-called “Rose Valley.” The primary purpose of this production is to yield high-quality rose oil, one of the most valuable essential oils in the world. *Rosa damascena* Mill. and *Rosa alba* L. are the main species cultivated in Bulgarian rose production. The first species is the primary raw material for the production of Bulgarian rose oil, whereas the second has recently gained increasing international attention due to the exceptionally fine quality of its essential oil (DEGRAFF, 2002).

Rose oil extraction is a resource-intensive process, requiring 3 to 5 tons of rose blooms to produce 1 kilogram of oil (SLAVOVA and STEFANOVA, 2018). The number of flowers produced varies significantly depending on the weather conditions throughout the year, especially precipitation and temperature. The synthesis and emission of aromatic compounds in essential oil plants are regulated by complex interactions between abiotic and endogenous

physiological mechanisms (SANGWAN et al., 2001). These processes are important to both science and practice.

Numerous factors, such as temperature (SAGAE et al., 2008), light (DUDAREVA et al., 2004), flower development phase (SHALIT et al., 2003), general weather conditions, and the physiological state of the plants (SANGWAN et al., 2001), affect the accumulation and composition of essential oil in rose flowers. Moreover, the time of harvest has a direct bearing on the dynamics of essential oil content. Harvesting must be done in the early morning because it has been discovered that the amount of oil in *Rosa damascena* flowers drastically decreases when collected after noon (DOBREVA and KOVACHEVA, 2010; KUMAR et al., 2013). Additionally, the geographic location and particular growing conditions affect the oil content (YILMAZ et al., 2011; RUSANOV et al., 2012).

Temperature and humidity have been shown to play an important role in the biosynthesis or accumulation of essential oils in stored herbs (SHARMA and KUMAR, 2016), just as temperature is important in maintaining post-harvest quality and extending the shelf life of fruits and vegetables (KAZAZ et al., 2009).

The high economic value of rose oil has contributed to an increase in the area occupied by oil-bearing roses in Bulgaria in recent years. At the same time, climate fluctuations present new challenges to production, influencing plant development and yield. In this context, the study of the phenological development of oil-bearing roses and its dependence on genotype and meteorological factors is of essential importance.

The current study seeks to investigate the effects of genotype and major meteorological factors (temperature and precipitation) on the phenological development of *Rosa damascena* and *Rosa alba*.

MATERIAL AND METHODS

The study took place in the Kazanlak region from 2022 to 2025 on a 2-hectare plot of land with two types of oil-bearing roses: *Rosa damascena* and *Rosa alba*.

Rosa damascena

The Kazanlak rose (*Rosa damascena* Mill.) is a perennial shrub reaching 1–2 m in height, forming well-branched stems with both vegetative and flowering shoots. Vegetative shoots can reach up to approximately 1 m, while flowering shoots are shorter (20–30 cm) and develop from axillary buds. The leaves are compound, pinnate, consisting of 5–7 leaflets with serrated margins. The flowers are arranged in panicle-type inflorescences, with 1 to 15, occasionally up to 30, buds formed on a single branch, which bloom successively. Each flower contains 25–35 petals, with the essential oil predominantly concentrated in the petals (92.8%). Three main varieties are distinguished—*macropetala*, *micropetala*, and *heteropetala*, the latter being the most widespread in Bulgaria.

Rosa alba

The white oil-bearing rose (*Rosa alba* L.) grows taller than the Kazanlak rose, reaching heights of up to 2.5 m. It has a more upright growth habit and is less branched. The species is characterized by broad leaves with coarsely serrated margins and uniformly developed, downward-curving prickles. The flowers are large, white, and arranged in groups of 5–7 on a flowering branch, with a comparatively weaker fragrance. The species is characterized by a higher flower yield but a lower essential oil content, which limits its economic importance. At the same time, it is more resistant to diseases, less demanding in terms of soil conditions, and more tolerant to low temperatures, while also producing a greater number of fruits rich in vitamin C.

Experimental field and cultivation technology

The cultivation of oil-bearing roses was carried out using an agrotechnical system that included 4–5 inter-row mechanized tillage operations and 2–3 intra-row manual treatments for weed control and soil loosening.

In February, pruning was performed to remove parts affected by *Agrilus*. At the end of February and the beginning of March, fertilization was carried out using distilled residues of lavender, lemon balm, yarrow, and rose distillation waste (pomace), applied at a rate of 20 tons per hectare. This was followed by spraying with Bordeaux mixture and sulfur.

During the vegetation period, the following were used: the fertilizer Horigrow N:P:K (20:20:20), the biostimulant Isabion, as well as insecticides and fungicides permitted for organic farming—Neem Azal and Omex Zynergy—to control rust and black leaf spot, as well as *Agrilus* and the St. Mark’s fly.

The experimental plot was grown under irrigated conditions. Irrigation stimulates the formation of more flower buds and greater vegetative growth.

After the rose harvest, contour pruning was carried out annually. In autumn, all cultivation practices were stopped.

Weather conditions

Kazanlak is located in a region with a transitional continental climate, characterized by a mild winter and a cool summer. Among the climatic elements, the most dynamic and those having a direct impact on the development of the oil-bearing rose are the annual precipitation and air temperature (NEDKOV et al., 2005).

The main results of the experimental work cover the period 2023–2025, with each year exhibiting specific climatic characteristics influencing the development of the oil-bearing rose, flower yield, and essential oil content, as illustrated by the monthly precipitation during the vegetation period (Table 1) and the mean daily air temperatures by months (Table 2).

Table 1

Monthly precipitation (mm) during the study period (2022–2025)												
Month	VII	VII	IX	X	XI	XII	I	II	III	IV	V	VI
2022-2023	42	45	85	92	79	106	61	73	90	80	120	115
2023-2024	60	62	106	104	62	92	61	68	73	73	90	54
2024-2025	41	60	79	82	87	90	58	45	70	51	70	63
Long-term average	40	51	100	80	115	90	70	80	73	72	110	51

The Kazanlak rose is a moisture-loving Mediterranean plant with a deep root system that keeps it hydrated during the summer. Winter precipitation is important for moisture retention, spring precipitation is essential for organ and oil formation, and summer precipitation is vital for the following harvest. In 2022–2023, precipitation was 988.2 mm – 56.8 mm above normal. Spring precipitation (120 and 115.4 mm) exceeded the long-term average, and summer precipitation was also above normal and provided sufficient moisture for the plants.

In 2023-2024, winter precipitation (December-February) and flowering period precipitation (May-June - 220.6 mm) are below the multi-year average (240.0 mm), whereas summer precipitation (July-August - 122.2 mm) exceeds the thirty-year average (90.5 mm). The annual total precipitation is 905.1 mm, i.e. 26.3 mm less than those recorded for a multi-year period.

In 2024–2025, precipitation was 745.5 mm – significantly less than in previous years and about 24% below the norm during the growing season. After the rose harvest, the precipitation was sufficient, but, from January to May, there was insufficient precipitation (239.3 mm compared to a

norm of 405.2 mm), which had a negative impact on production and quality. The Kazanlak rose is resistant to temperatures as low as -20°C.

After sap flow begins, the Kazanlak rose freezes at -5 to -10°C. Frosts occur in autumn-winter and winter-spring (YANKULOV, 2010). Winter dormancy is not necessary for the formation of flower buds, but spring temperature fluctuations are important (about 4°C to over 16°C), which support the development and accumulation of essential oil. Deviations from this regime reduce the number of flowers and yields.

Table 2

Mean monthly air temperature (°C) during the study period (2022–2025)												
Month	VII	VII	IX	X	XI	XII	I	II	III	IV	V	VI
2022-2023	26.0	26.5	20.0	14.4	10.2	4.5	1.5	6.4	9.6	14.0	16.0	24.2
2023-2024	28.0	28.3	21.7	15.0	13.4	4.6	4.4	9.4	13.4	19.0	22.5	25.3
2024-2025	27.2	28.0	22.3	16.4	14.2	5.1	4.1	8.7	10.2	8.6	16.9	23.7
Long-term average	24.5	24.5	17.4	14.3	8.5	2.0	0.5	2.2	5.1	10.0	16.5	20.8

During the winter months of the period, the average temperatures are higher than the multi-year averages: December – 4.5; 4.6; 5.1°C, January – 1.5; 4.4; 4.1°C and February – 6.4; 9.4; 8.7°C for 2022–2023, 2023–2024 and 2024–2025. No frosts have been observed on the rose bushes (Table 2).

The region's typical gradual increase in temperatures from March to April and the stabilisation of temperatures during flowering in May–June are the defining characteristics of the spring months during this period. April 2025 is an exception, as sudden and protracted cold snaps caused frostbite of some of the formed flower buds, resulting in a decrease in the yield of pink flowers in this last experimental year.

The most favorable conditions are in 2023 - with pronounced temperature fluctuations, cooler average temperatures (May 16.0°C, June 24.2°C) and frequent rainfall, leading to the highest yields and mass bud bloom.

RESULTS AND DISCUSSIONS

During the vegetation period, oil-bearing roses annually pass through the following main phenological stages: bud break, leaf development, bud formation, flowering, and second growth (MEIER et al., 2009; RUSANOV et al., 2011).

The timing of the main phenological stages of *Rosa damascena* and *Rosa alba* (2023–2025) is presented in Table 3, while Figure 1 illustrates their duration (days).

Bud break

During the experimental period, in 2025, vegetation in both oil-bearing rose species began earlier compared to 2023 and 2024. In *Rosa damascena*, bud break was recorded on 15 February, while in *Rosa alba* it occurred two days later. As a result of a temperature drop ranging from -5 to -13°C during the period 18 February–2 March, the developed buds were damaged by frost. Following an increase in temperature above 5°C, a second bud break was observed on 11 March in both species, which led to a reduction in flower yield during the 2025 growing season. During the 2023 growing season, the first phenological phase lasted 12 days; in 2024, 10 days; and in 2025, 8–9 days for both oil-bearing rose species.

Leaf development

Leaf development begins with the appearance of the first leaf on the flowering shoot and continues until the formation of the last leaf (4 or 5).

During the period 2023–2025, the leaf development phase lasted 28 days in the first year, 25 days in the second, and 29 days in the third growing season. In 2023, leaf development began on 21 March and 24 March; in 2024, on 29 March–1 April; and in 2025, on 13 April–16 April for *Rosa damascena* and *Rosa alba*, respectively.

Table 3

Phenological Development Stages of *Rosa damascena* Mill. and *Rosa alba* L. (2023–2025)

Development stages	<i>Rosa damascena</i> Mill.			<i>Rosa alba</i> L.		
	2023	2024	2025	2023	2024	2025
Bud break	9.03	22.02	15.02-1st bud break 22.02-frost damage 11.03-2nd bud break	12.03	26.02	17.02-1st bud break 22.02-frost damage 11.03-2nd bud break
Leaf development	21.03	03.03	19.03	24.03	06.03	20.03
Bud formation	18.04	29.03	13.04	19.04	01.04	16.04
Flowering	16.05	02.05	18.05	18.05	05.05	20.05
Second growth (second flush)	18.06	06.06	15.06	21.06	10.06	20.06

Bud formation

Bud formation is characterized by the appearance of the first flower buds in the inflorescence. During this phase, the synthesis of essential oil begins. In the first growing season (2023), this phase in *Rosa damascena* began on 18 April and lasted 28 days, while in *Rosa alba* it occurred one day later and lasted 29 days. In the 2024 growing season, bud formation occurred approximately 11 days earlier, whereas in 2025 it was delayed by about 25 days compared to 2023.

Flowering

Flowering is characterized by the opening of the petals of the first flower buds and continues until all flowers have fully opened.

During the experimental years, the duration of the flowering phase varied from 30 days in 2025 to 35 days in 2023. In *Rosa damascena*, flowering began on 16 May, and in *Rosa alba* on 18 May during the first growing season; on 2 May and 5 May in 2024; and on 18 May and 20 May in 2025, respectively. The duration of flowering is determined by temperature and moisture conditions during each growing season.

Second growth

After the rose harvest, buds located in the leaf axils of the flowering shoots begin to develop, forming the so-called second growth—i.e., the initiation of new flowering shoots.

The second growth phase begins, depending on the year and the rose species, from the first to the third ten-day period of June and continues until the onset of winter, when the mean daily temperature drops below 4°C and vegetation ceases.

Under the conditions of the experiment (2023–2025), this phase lasted until mid-December in the 2023 and 2024 growing seasons, and until the end of December in 2025. The duration of second growth in *Rosa damascena* and *Rosa alba* was similar, ranging from 28 to 36 days depending on the growing season.

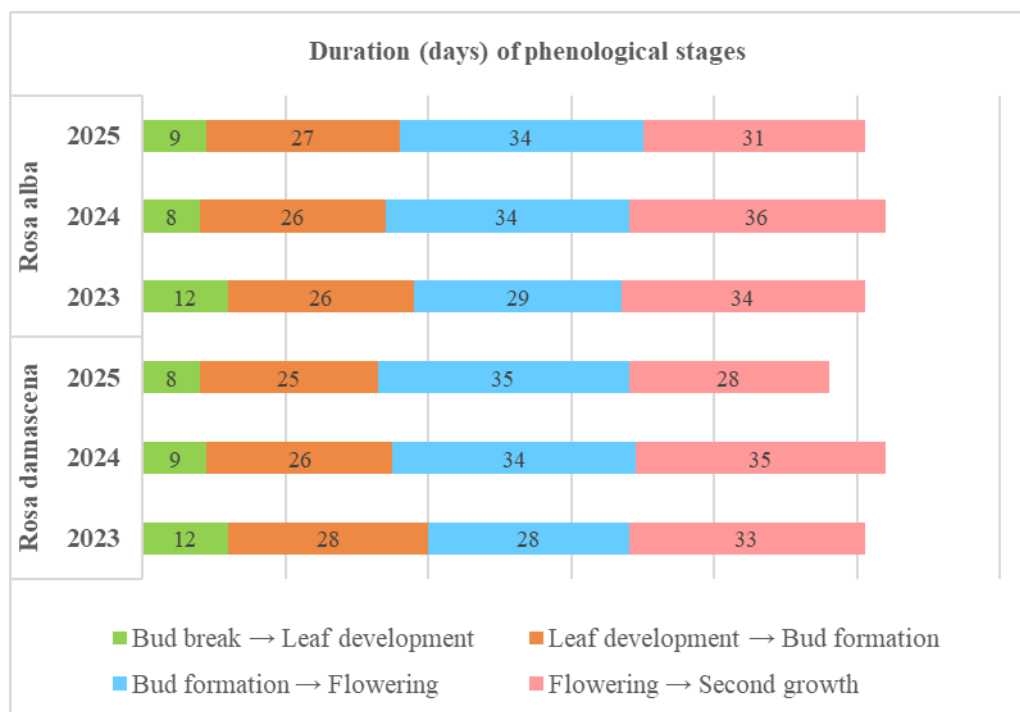


Figure 1: Duration (days) of phenological stages in *Rosa damascena* Mill. and *Rosa alba* L. (2023–2025)

Correlation analysis

The correlation matrix illustrates the relationships between the main climatic factors and the duration of phenological phases for *Rosa damascena* and *Rosa alba* (Table 4).

Table 4

Correlation matrix: climate-phenology for *Rosa damascena* and *Rosa alba*¹

Variable	<i>Rosa damascena</i>			<i>Rosa alba</i>		
	Temperature (°C)	Precipitation (mm)	Phase duration (days)	Temperature (°C)	Precipitation (mm)	Phase duration (days)
Temperature (°C)	1.00	-0.34	-0.83**	1.00	-0.34	-0.81**
Precipitation (mm)	-0.34	1.00	0.34*	-0.34	1.00	0.38*
Phase duration (days)	-0.83**	0.34*	1.00	-0.81**	0.38*	1.00

¹significance: * $p < 0.05$; ** $p < 0.01$;

A separate correlation analysis performed for *Rosa damascena* and *Rosa alba* revealed highly consistent results. A strong negative correlation between air temperature and the duration of phenological phases was noted for both species (*Rosa damascena*: $r = -0.83$; *Rosa alba*: $r = -0.81$), indicating that higher temperatures significantly accelerate plant development and shorten phenological stages. Precipitation showed a weak positive correlation

(*Rosa damascena*: $r = 0.34$; *Rosa alba*: $r = 0.38$), suggesting a limited tendency to prolong developmental phases under higher moisture availability. However, this effect is considerably less pronounced compared to temperature.

These results verify that temperature is the dominant factor influencing phenological development, while precipitation plays a secondary and modifying role and species-specific variations are insignificant in the conditions under investigation.

CONCLUSIONS

The study highlights the high sensitivity of oil-bearing roses (*Rosa damascena* Mill. and *Rosa alba* L.) to climate variability and emphasizes the importance of temperature as a key factor determining their development and adaptation to changing environmental conditions.

The results showed that higher temperatures accelerate the onset of phenological stages and shorten their duration, while lower temperatures and frost events cause delays and damage to developing buds, consequently reducing flower yield.

In *Rosa damascena*, all growth and developmental stages occur 2 to 5 days earlier compared to *Rosa alba*. The greatest variability was observed in the flowering phase, which ranged from 30 to 35 days and was strongly dependent on temperature and moisture conditions.

Correlation analysis further supports this, showing that temperature is the dominant factor controlling phenological development, while precipitation has a weaker and secondary effect.

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