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Research article

ROSE 'CASINO' AS AN ELEMENT OF LANDSCAPE ARCHITECTURAL COMPOSITION IN THE COURTYARD OF THE CHURCH OF ST GEORGE IN BELGRADE UNDER CHANGING CLIMATE CONDITIONS

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ABSTRACT

The study analyses the in situ sustainability of the climbing rose 'Casino' in the courtyard of the Church of St George in Belgrade. The aim of the research was to assess the impact of changing climate conditions on its phenological flowering pattern. The evaluation assessed frost damage and timing of the phenological flowering phases - bud break, beginning of flowering, full bloom and end of flowering-as well as daily flowering abundance. The findings indicate that bud break timing was correlated with accumulated cold hours, which reached a sum level typical for early - flowering plants (to which the studied cultivar does not belong), as well as the accumulated heat sum for subsequent phenological phases. The flowering began 93 days earlier, and continued uninterrupted until the end of 2024 and into January 2025, with varying abundance. A comparative analysis determined the optimal daily maximum and minimum temperatures for peak flowering - 22.9°C (maximum) and 11.7°C (minimum) - and for abundant flowering - 20.8°C (maximum) and 9.8°C (minimum). Regression analysis confirmed a decline in flowering abundance when daily maximum and minimum air temperatures exceeded the optimal ranges. These findings have practical applications in urban landscape design, especially considering the projected global warming trends. Despite the resistance of the 'Casino' rose' to changing climate conditions, there is no certainty regarding the stability of the flowering phenophase in the coming years. In line with sustainable global trends, the 'Casino' cultivar is recommended for inclusion in Serbia's first rosarium and for future research programmes aimed at cultivar conservation and breeding improvements. Additionally, given its significance as a 30-year-old element of the landscape architectural composition, it is proposed for protection as a natural asset and as valuable source material for vegetative reproduction.

Key words:
climbing rose, flowering, seasonality, climate warming, sustainability, landscape design

Abbreviations:
DOY – day of the year; GDD – growing degree days

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INTRODUCTION

The spectrum of rose taxa is highly diverse, making it essential to identify cultivars most suitable for specific environmental conditions, cultural contexts, interests and preferences (Datta, 2018). Roses are extensively cultivated in various settings for different purposes, including economic, landscape architectural, agricultural, industrial, ecological, cultural and educational uses. However, the cultivation of roses, preservation of old cultivars and development of new varieties have become increasingly demanding (Leus et al., 2018) due to market changes and the necessity to adapt to climate change. Phenological studies of cultivated plants are therefore crucial (CAP Specific Objective, 2019) for understanding changes in phenology, as significant biological indicators influenced by climatic factors (Bertin, 2008). These changes affect bud dormancy (Kovaleski et al., 2018) and seasonal event variability (Chen et al., 2019), particularly in spring, but also during summer and autumn (Bertin, 2008). It is predicted that numerous taxa may face challenges to survive due to their intolerance to temperature fluctuations and other extreme climatic events, which adversely impact cultivation (CAP Specific Objective, 2019). While most research focuses on productivity, insufficient attention has been devoted to the conservation of old cultivars and their genetic resources, which are increasingly threatened by climate change, limiting future cultivation and ornamental value. Therefore, assessing the evolutionary potential of phenological events in response to climate change is crucial for understanding ecological indicators (Gauzere et al., 2019) and identifying taxa capable of adapting to rising temperatures and extended growing seasons (Crawford, 2008).

The biodiversity and origins of numerous cultivars of the genus *Rosa* L. (Krüssmann, 1974) account for the variations in their cultivation requirements and ornamental characteristics. Many adaptive roses that exhibit their full biological and ornamental potential are old garden varieties. However, modern roses, which have also reached considerable longevity and widespread distribution, are equally significant (Božanić Tanjga et al., 2022). Among them, climbing roses are particularly noteworthy, with the oldest cultivars originating from Asian species (*R. wichuraiana* Crép., *R. moschata* Herrm. and *R. multiflora* Thunb.), initially cultivated in regions with mild winters (Krüssmann, 1974). These ornamental cultivars are especially important for urban greening (Monder, 2018), as cities tend to warm faster compared to non-urbanized areas due to the urban heat island effect (Ocokoljić et al., 2023).

The primary factor influencing the development and flowering phenology of roses is air temperature (Desta et al., 2022). Włodarczyk et al. (2023) analyzed the flowering phenology of shrub rose cultivars and highlighted the significant impact of temperature and meteorological factors on individual phenophases and the overall flowering duration. These authors caution that, if warming trends continue, the flowering period will be significantly shortened. Some climbing rose cultivars have demonstrated frost resistance, which enhances their value in gardens and urban green spaces (Monder, 2022). Milder winters have also expanded the range of cultivars suitable for cultivation (Monder, 2021). Consequently, efforts in rose breeding focus on preserving, developing and propagating new cultivars that vary in flower size, colour, appearance, fragrance, length of the growing period and other characteristics (Leus et al., 2018).

However, successful cultivation requires not only expertise but also a refined sense of landscape aesthetics. According to Datta (2018), roses carry significant symbolic meanings and associations, including spiritual ones, often representing harmony and elevated emotions linked with the art of designing monastic gardens and church courtyards (Siewniak and Mitkowska, 1998). These spaces are characterized by unity of space and structures, surrounding lawns with lower decorative flowering plants to preserve views and create a place suitable for prayer and meditation (Majdacka-Strzeżek, 2008). In medieval gardens, special attention was given to resting areas and pergolas. Depictions from this era frequently illustrate the Virgin Mary with the child seated on a bench surrounded by flowers, with climbing roses in the background. The gardening traditions of other monastic orders in the West could not compare to those of the Carthusians. This tradition allowed each monk to cultivate their garden to their preference, either as a vegetable patch or a flower garden. According to Roth (1995), a modern Carthusian monk remarked that the state of a small garden adjacent to the monastic cell could reveal the personality of its resident: optimists planted roses, pessimists cultivated vegetables and realists allowed the grass to grow. The monks often used standard roses in symmetrical plantings to decorate their gardens. Additionally, early Renaissance villas incorporated medieval influences, including pergolas and rose gardens. In Serbian culture, as in many others, customs and beliefs have preserved elements of pagan heritage. The Church quickly embraced the cult of trees and plants, assigning symbolic meanings to these natural elements (Skočajić, 2004). Among these, the rose became primarily associated with the Virgin Mary.

Considering the above, as well as the Convention on Biological Diversity (CBD, 1992), this study aims to contribute to the preservation of the climbing rose biodiversity by analyzing: 1) the relationship between the phenological flowering patterns and air temperatures, 2) resistance to low temperatures, 3) the contribution of the 'Casino' rose to spatial aesthetics, emphasizing the importance of appropriate selection of plant material in landscape design,

particularly in monastic courtyards and 4) the potential for preserving the selected genotype through vegetative propagation. Additionally, this study seeks to provide deeper insights into climate change.

MATERIAL AND METHODS

The research was conducted in the courtyard of the Church of St George in Belgrade, located in the municipality of Čukarica, which holds a status of prior protection (Official Gazette of the City of Belgrade, 2005). The church, featuring a richly decorated facade with motifs reminiscent of the Moravian School influence, was constructed between 1924 and 1932. Designed by architect Vasilije Androsov, it adheres to the tradition of Serbian medieval ecclesiastical architecture (Church of St George in Belgrade – Čukarica, 2025). According to the Detailed Regulation Plan (Official Gazette of the City of Belgrade, 2005), it is planned to preserve the church complex, provide auxiliary facilities supporting its function, enhance the landscape design and improve the parking area. The protective measures also include maintaining the indivisibility of the cadastral parcel, urban and landscape architectural furnishing, maintenance and public accessibility of the courtyard in accordance with conservation and cultural heritage protection requirements.

A 30-year-old climbing rose 'Casino' (Figure 1) was identified as part of the vertical greening of a streetlight within the church complex. Georeferenced at 44°47'08.426"N, 20°25'06.06"E, it is situated at an altitude of 97 m, with a northern orientation (N aspect) and a terrain slope of 4.36° (gently sloping terrain). The soil type is Luvic Chernozem (WRB, 2015).

Figure 1. Study area (a) and the climbing rose 'Casino' in March 2024 (b)

To determine the impact of air temperature on the phenological flowering pattern, daily in situ phenomonitoring was conducted throughout 2024, the warmest year globally. The BBCH scale (Meier, 1997) was used, recording the following: bud break (09 BBCH), beginning of flowering – 60 BBCH (about 10% of flowers open), full flowering – 65 BBCH (at least 50% of flowers open, first petal falling) and end of flowering – 69 BBCH (all petals fallen). The dates were automatically converted into Day of the Year (DOY) using software. To isolate the influence of air temperature on the phenological flowering pattern, irrigation and other maintenance measures were regularly applied. Meteorological data were obtained from the RHMZ (2025). The data were collected from the Main Meteorological Station (MMS) Surčin (φ44º47 54.44"N i λ20º27'53.35"E, altitude 99m), selected due to its altitude and the location of the study site on the edge of Banovo Brdo above the right bank of the Sava River and old Čukarica, with an open exposure towards Surčin. Accumulated cold hours were calculated using the Cosmulescu and Ionescu (2018) method, covering the period from 1 November 2023 to the date when the 09 BBCH phase was recorded in 2024:

$$CH_t = \sum_{i=1}^{t} H$$

if 0°C< T<7°C, then add 1, else 0.

Growing Degree Days (GDD) were calculated based on daily maximum and minimum air temperatures using the method proposed by Lalić et al. (2021) and a temperature threshold of 5°C following the WMO (2021)

recommendations for temperate continental climates. The relationship between air temperature and flowering abundance was analysed using correlation and linear regression. Flowering abundance was assessed using the Stilinović (1985) scale, which categorizes flowering abundance as follows: 0 – no flowers (0% of branches with flowers); 1 – very low (<20%); 2 – low (>20−<40%); 3 – moderate (>40−<60%); 4 – abundant (>60−<90%) and 5 – maximum (>90%). A digital Vernier caliper (500 mm, ETIM class code: EC000157, accuracy 0.01 mm) was used to measure two diameters of 40 fully open flowers from the southern, sun-exposed part of the canopy and 40 flowers from new plants obtained through propagation in a greenhouse.

Additionally, in June 2024, during routine pruning as part of regular maintenance, 40 semi-hardwood cuttings were collected (green at the tip and partially woody at the base—heel cuttings), (Avdić, 2021). The 14 cm-long cuttings were inserted into a 5 cm-long section of an *Aloe vera* (L.) Burm.f. leaf and then planted together with the leaf in plastic pots filled with a 1:1 mixture of sand and peat, identified as an optimal rooting substrate for semi-hardwood cuttings (Avdić et al., 2017).

Quantitative data analysis included descriptive statistics, the Spearman Rank test and linear regression. Data processing was performed using statistical software packages XLSTAT 2020, Past 4.11 and ArcGIS 10.8/ArcMap 10.8.

RESULTS AND DISCUSSION

Phenological Flowering Pattern

The accumulated cold hours up to the 09 BBCH phase amounted to 749 hours (DOY: 17). To our knowledge, this is the first recorded determination of cold hours for the 'Casino' cultivar. In the same year, manna ash required 1,061 hours for the corresponding phase (Ocokoljić et al., 2024), while in the previous year, *Chaenomeles* × *superba* 'Pink Lady' required 623 hours (Petrov et al., 2023), indicating that early-flowering species generally require fewer cold hours. Our findings confirm that each taxon has specific cold hour requirements that determine flowering time, shaped by long-term climatic adaptations of genotypes across different regions (Ruiz et al., 2007). For the 60 BBCH phase (beginning of flowering), the accumulated heat sum required was 62.4°C (DOY: 35), while for the 65 BBCH phase (full flowering), it was 402.7°C (DOY: 89). The 69 BBCH phase (end of flowering) was not recorded by 31 December 2024 (Figure 2). These results confirm that the flowering phases are determined not by the days of the year (as the cultivar 'Casino' is not among early-flowering taxa) but rather by the accumulated heat sums, as indicated by research on woody flowering ornamental taxa (Ocokoljić et al., 2023; Čukanović et al., 2024; Petrov et al., 2024). As early as 1735, Réaumur observed that plant development is proportional to the accumulated air temperature rather than the temperature values during the phenophases. Currently, the 'Casino' cultivar is not widely studied. However, its ornamental value and adaptability make it a promising candidate for future research aimed at optimizing cultivar conservation and breeding programs. The preservation of old cultivars in green spaces depends primarily on their ability to adapt to changing climatic conditions.

According to OLBCR (2013), the 'Casino' cultivar has two flowering periods, in June–July and September–October. However, in Belgrade in 2024, flowering began 93 days earlier and continued uninterrupted through August, with an extension of 61 days until the end of 2024, continuing into January 2025. Understanding these phenological changes (Figure 2) requires comparison with climatic data, as the timing and duration of key phenological events reflect local climate conditions (Penzar and Penzar, 2000), particularly in cases of earlier or postponed onset and extended growing season (Büntgen et al., 2022), as observed in this study.

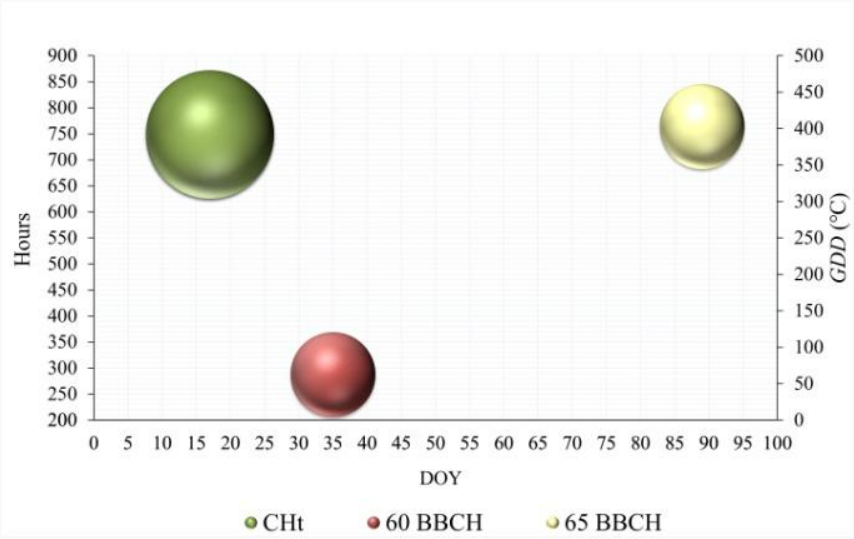

Figure 2. Phenological observations of the 'Casino' rose in 2024: Days of the Year (DOY) and accumulated cold hours (CHt) for the bud break phase (09 BBCH) and accumulated heat sums (GDD) for the beginning of flowering (60 BBCH) and full flowering (65 BBCH)

During 366 days of phenological monitoring, as well as through interviews with the responsible personnel, it was confirmed that all maintenance measures, including regular irrigation, were consistently carried out. These findings indicate that the observed phenological responses and flowering abundance were influenced by air temperature (Figure 3).

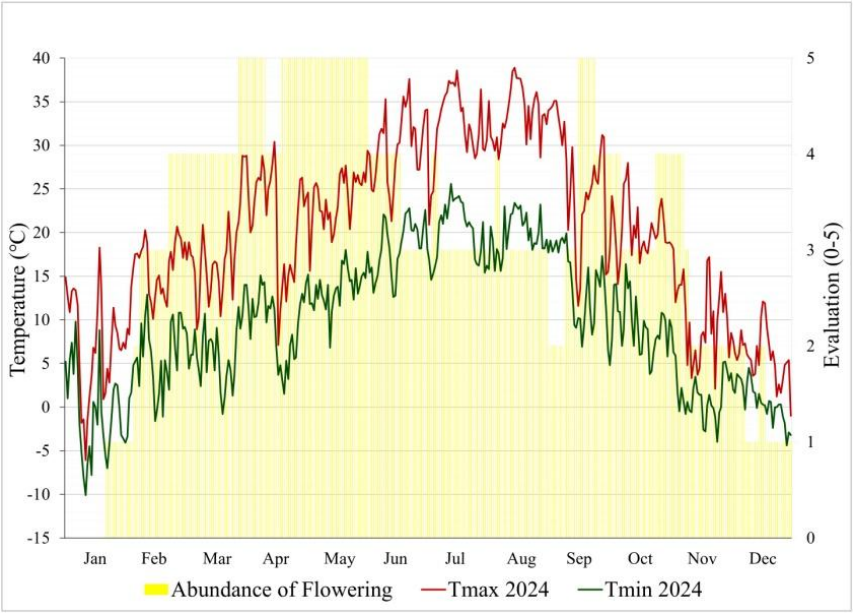

Figure 3. Graphical representation of flowering abundance of the 'Casino' cultivar and daily minimum and maximum air temperatures in 2024, based on data from MMS Surčin

The average annual flowering abundance rating for the 'Casino' cultivar was moderate (value of 3.2). Data analysis (Figure 3) identified optimal daily maximum and minimum temperatures for flowering: for maximum flowering, the optimal temperatures were 22.9°C (max) and 11.7°C (min), while for abundant flowering, the optimal values were 20.8°C (max) and 9.8°C (min). Spearman's correlation coefficients, calculated for the 366 days of 2024, revealed a very strong positive correlation (0.92708) between daily maximum and minimum air temperatures and a weak positive correlation between maximum temperatures and flowering abundance (0.37539), as well as minimum

temperatures and flowering abundance (0.35786), with a probability of $p<0.05$. These findings indicate that increases in maximum temperatures led to increases in daily minimum temperatures, while rises in both variables had a weak but positive effect on flowering abundance. The obtained results were influenced by the year-round dataset, as well as the early onset, continuous and extended flowering period. The spring of 2024 was the warmest on record in Surčin, characterized by the lowest number of frost and ice days (RHMZ, 2025). This period was preceded by warm January, February and March, during which the mean maximum temperatures were 2.6–8.1°C higher, and mean minimum temperatures were 1.5–6.2°C higher compared to the 1991–2020 climate normals (Table 1). The only month in 2024 with lower mean maximum and minimum air temperatures than the reference period was November (Table 1).

Table 1. Mean monthly maximum and minimum air temperatures (°C) and their deviations from the normal values of the reference period (1991–2020), based on data from MMS Surčin

Parameter **Month**	**Tmean max 2024**	**Tmean max 1991-2020**	**Deviation of Tmean max in 2024 from the normal (1991–2020)**	**Tmean min 2024**	**Tmean min 1991-2020**	**Deviation of Tmean min in 2024 from the normal (1991–2020)**
I	7.1	4.5	2.6	-0.8	-2.3	1.5
II	15.5	7.4	8.1	5.2	-1.0	6.2
III	17.2	12.9	4.3	6.3	2.6	3.7
IV	21.6	18.4	3.2	9.3	7.1	2.2
V	23.7	23.2	0.5	13.6	11.8	1.8
VI	29.9	26.9	3.0	18.4	15.4	3.0
VII	32.2	29.0	3.2	20.1	16.8	3.3
VIII	33.6	29.3	4.3	19.8	16.9	2.9
IX	25.9	24.1	1.8	14.1	12.6	1.5
X	20.3	18.5	1.8	9.3	7.9	1.4
XI	10.4	11.9	-1.5	1.4	3.6	-2.2
XII	5.9	5.5	0.4	0.7	-0.9	1.6

Legend: Tmean max- average monthly maximum temperature; Tmean min- average monthly minimum temperature

In November, minimum temperatures ranging from -0.1°C to -4.0°C, including several consecutive days at these levels, did not interrupt flowering. However, in December, five consecutive days with minimum temperatures reaching -4.4°C, including one ice day with a maximum temperature of -1.0°C, stopped flowering, although monthly average maximum and minimum temperatures were higher than normal values (Table 1). Flower buds and open flowers remained intact, with no signs of frost damage.

Figure 3 illustrates a decline in flowering abundance during heatwave periods, characterized by high maximum and minimum air temperatures, with five such events recorded during the summer (particularly intense in mid-July and mid-August, according to RHMZ). To assess the impact of daily maximum and minimum air temperatures on flowering abundance, a regression analysis was conducted from the period when flowering abundance reached a rating of 4 until the first half of September (Figure 4).

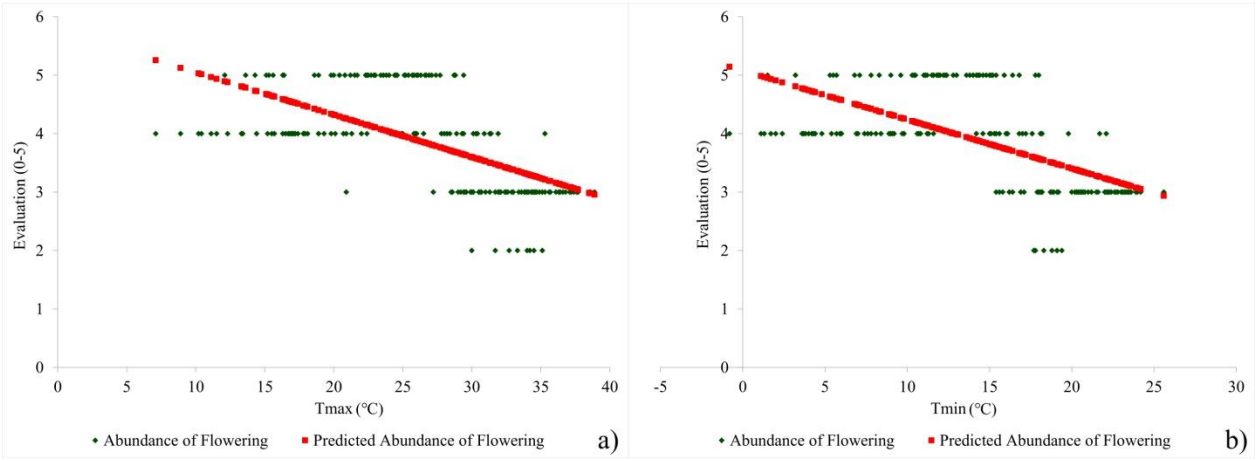

Figure 4. Scatter plots and prediction of the impact of: a) daily maximum and b) daily minimum air temperatures on the flowering abundance of the 'Casino' rose

A declining trend is observed for both variables (Figures 4a and b) after approximation of the selected data, i.e. fitting the curve or determining the regression line. As daily maximum and minimum air temperatures exceed the optimal range, flowering abundance decreases. This conclusion is statistically significant at the $p<0.0001$ level, as confirmed by the results of the regression ANOVA analysis (Table 2).

Table 2. ANOVA results for the impact of daily maximum and minimum air temperatures on the flowering abundance of the 'Casino' rose during the period from 22 February 2024 to 9 September 2024

Parameter	df	SS	MS	F	Significance F
Tmax					
Regression	1	56.49535	56.49535	110.9074	0.0000
Residual	198	100.8567	0.509392		
Total	199	157.355			
Tmin					
Regression	1	52.16151	52.16151	98.18079	0.0000
Residual	198	105.1935	0.53128		
Total	199	157.355			

The regression analysis for flowering abundance indicates that air temperatures in 2024 were statistically the most significant factors influencing the number of flowers and overall flowering abundance. These findings, in line with the observations of Tabaei-Aghdaei and Rezaee (2003), indicate the importance of such research for development and conservation of cultivars with greater potential for extended flowering duration and increased flowering abundance.

The established values for the 'Casino' rose in terms of flowering duration and abundance are important for landscape design in both private and public green spaces. The significance of these findings is further emphasized when compared with previous studies, which often omit certain essential characteristics of climbing roses, including the phenological flowering pattern (which can be continuous, intermittent, or single-season) and flowering abundance (Frazik Adamczyk, 2004; Monder, 2006). No prior research has indicated that the 'Casino' cultivar is capable of continuous flowering, a characteristic observed in this study.

Climbing roses have traditionally been used in the design of confined spaces for vertical greening (Gustavsson, 1999), as well as in representative locations, historic gardens and monastic courtyards (Gustavsson, 1999; Monder, 2018). When designing a garden adjacent to a sacred site, greenery is one of the main compositional elements. Under the modified temperate continental climate, the 'Casino' cultivar is recommended for its suitability to these conditions. This cultivar is well-suited for spaces that encourage meditation, reflection and prayer (Repelewicz and Tubielewicz, 2019). Additionally, gardens surrounding sacred buildings contribute significantly to the aesthetic quality of the urban landscape.

The selected 'Casino' rose as source material for propagation

The rooting success of semi-hardwood cuttings taken from a 30-year-old plant was 100%. From June through the end of 2024, the rooted plants reached an average growth of 32 cm, and by December, each plant produced one fully open flower. The mean diameter of the first fully open flowers on the newly propagated plants was 370.20 mm, representing a 24.53% reduction compared to the mean value of two measured diameters of fully open flowers on the parent plant during the full flowering phenophase (65 BBCH) (Figure 5).

Figure 5. Visual aspects of the climbing rose 'Casino': part of the plant's habitus in the courtyard of the Church of St George (a), flowers of the parent plant in stage of full flowering in April (b), and flowers of the newly propagated plant on 28 December 2024 (c)

To our knowledge, this is the first documented instance of using *Aloe vera* (L.) Burm.f. leaves instead of rooting hormones to promote the rooting of rose cuttings. Our findings confirm that *Aloe vera* (L.) Burm.f. possesses nutritive properties and acts as a growth and development stimulant, which aligns with the findings of Aktar et al. (2008) and Kumari et al. (2023), who conducted experiments with taxa from the family *Orchidaceae* Juss. The observed interactions between *Aloe vera* (L.) Burm.f. and the tissues of semi-hardwood cuttings provide new insights into more efficient and sustainable production of old rose cultivars. These observations contribute to the conservation and enhancement of the woody ornamental plant *diversity*, including the rose cultivars studied in this research. The 'Casino' cultivar, a climbing rose with a spectacular habit and yellow flowers, was bred and cultivated in 1963 (OLBCR, 2013). In line with global sustainability initiatives, we recommend this cultivar for establishment of Serbia's first rosarium and for larger-scale projects of global significance, as emphasized by Čurčić et al. (2024).

CONCLUSION

In recent years, mild winters have resulted in continuous flowering of the 'Casino' cultivar for 12 months, with varying abundance during the study period. This characteristic enhances its value as a climbing rose. The findings have practical applications in landscape design and plant selection, especially in relation to the phenological flowering pattern, flowering abundance and flower colour and size. In particular, in church courtyard compositions, a contemplative relationship with natural elements may contribute to heightened spiritual experience. Currently, the 'Casino' cultivar is relatively under-researched. However, given its ornamental appeal and adaptability, its further inclusion in research programmes aimed at optimising cultivar conservation and breeding improvements would be beneficial. The maintenance of old cultivars in green spaces primarily depends on their ability to adapt to changing climatic conditions. Based on the study results and projected global warming trends, the 'Casino' rose is expected to demonstrate high tolerance in urban environments.

It is proposed that the identified rose be designated as a natural asset, due to its significance in the landscape architectural composition of the Church of St George courtyard in Belgrade. Additionally, at 30 years of age, it holds potential as source material for vegetative propagation.

Authors' Contribution: Conceptualization: M.O. and Dj.P.; Methodology: M.O.; Software: D.S., M.O. and J.Č.; Validation: D.S., M.O. and Dj.P.; Formal Analysis: J.Č., R.K. and S.Đ.; Investigation: D.S. and N.G.; Resources: D.S. and N.G.; Data Curation: J.Č., Dj.P., R.K. and S.Đ.; Writing – Original Draft Preparation: M.O.; Writing – Review & Editing: D.S., J.Č., Dj.P., N.G., R.K., S.Đ. and M.O.; Visualization: D.S. and N.G.; Supervision: M.O. All authors have read and agreed to the published version of the manuscript.

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