

Original Research

THE INFLUENCE OF THE URBAN HEAT ISLAND ON *Abelia* × *grandiflora*
(ROVELLI EX ANDRÉ) REHDER TAXA

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Abstract

The effects of urban heat islands (UHIs) are an increasing challenge for urban environments, with many studies focusing on trees, yet there is a lack of explanations regarding how urbanization and UHIs affect shrub species. This study addresses that gap by investigating the cultivars ‘Little Richard’ and ‘Sunrise’ of the North American hybrid *Abelia* × *grandiflora* (Rovelli ex André) Rehder. The research was conducted using a cascading design approach at the Skyline mixed-use development within the UHI zone of the Savski Venac municipality in Belgrade, over the period 2023–2025. The effects of UHI on the temporal consistency of phenological pattern elements and flowering abundance were analysed through interactions between air temperature and flowering abundance using Spearman rank correlations and linear regression. The results indicate that flowering varied and correlated with daily maximum and minimum temperatures, as well as day length, which influences plant phenophases. The findings highlight Glossy *Abelia* as suitable for biodiversity conservation and ecosystem services under UHI conditions, implying the optimisation of urban management, restoration, planning, and design strategies.

Keywords: urban expansion, outdoor ornamental plants, air temperatures, resilience, ecosystem services.

INTRODUCTION

Urban heat islands (UHIs) are caused by urban structures, such as heat-absorbing materials, anthropogenic heat emissions, and increased infrared radiation, which result in higher air temperatures in urban areas compared to neighboring peri-urban and rural regions [1,2]. The UHI phenomenon is also closely linked to climate change and rapid urban development, leading to negative impacts on air quality due to pollutant accumulation, as well as rapid fluctuations in temperature and precipitation patterns, thereby increasing the risk of extreme weather events [3]. These interconnected effects highlight the need for

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comprehensive research aimed at mitigating the negative consequences of urban microclimates and preserving ecosystem services. To this end, the European Green Deal, the EU Biodiversity Strategy for 2030, and European guidelines on tree planting have been introduced, supporting biodiversity as well as the role of urban greenery, which also includes shrubs [4,5].

Therefore, this study analyses the impact of the UHI, within a challenging urban context, on the flowering of the shrub taxa *Abelia* × *grandiflora* (Rovelli ex André) Rehder (common name Glossy Abelia), cultivars ‘Little Richard’ and ‘Sunrise’. As the boundaries between *Abelia* R.Br. cultivars are often blurred and generally difficult to determine [6], cultivar identification was taken from the work contractors and confirmed through three consecutive years of monitoring. The cultivar ‘Little Richard’ is a compact plant with green leaves that acquire vivid bronze-red hues in autumn [7,8]. The cultivar ‘Sunrise’ is a cascading, finely textured plant with variegated green-yellow leaves that turn orange to deep red-burgundy in autumn. Its leaves remain variegated throughout the year, whereas other cultivars have green leaves during summer [7,8]. Both cultivars produce fragrant, ornamental white flowers in summer that attract pollinators, including bees and butterflies. They are also evergreen, although in colder climates they lose around 50% of their foliage in autumn, with the remaining leaves adopting a more intense red colour [6,8]. In light of the above, this study analyses the flowering of two *A. × grandiflora* cultivars, as introduced shrub taxa, under the complex influence of the UHI in a moderately continental climate characterised by hot summers without a pronounced dry period and minimal precipitation during the winter half of the year (RHMZ). The specific objectives are to determine the relationships between phenological patterns and flowering abundance with maximum and minimum air temperatures, as well as their contributions to aesthetics and ecosystem services. The purpose of the study is to optimise cultivation conditions through the prediction of phenological sustainability and flowering abundance, and to incorporate the benefits of ornamental shrub taxa into strategies for conserving urban dendroflora.

MATERIALS AND METHODS

The study area is part of a cascading design approach to the access of the Skyline mixed-use development within an urban heat island (UHI) zone in Belgrade, Serbia. Within the built planters, three individuals of *A. × grandiflora* ‘Little Richard’ and one individual of *A. × grandiflora* ‘Sunrise’ were identified. A description of the locations is presented in Table 1.

Each day over three consecutive years (2023–2025), at the individual level, phenological descriptors from the extended BBCH scale [9] were used for *A. × grandiflora* ‘Little Richard’ and ‘Sunrise’: 60 (day when the first flower opened), beginning of flowering – 61 (day when more than 10% of flowers were open), full flowering – 65 (day when more than 50% of flowers were open), and end of flowering – 69 (day when more than 80% of flowers had finished flowering). Recorded dates were automatically converted into DOY (day of year), where 1 January = DOY 1, 10 January = DOY 10, etc. Phenological patterns were analysed through graphical comparison of temporal overlap and statistically. Flowering duration was expressed as the number of days during which plants bore flowers, while flowering

abundance was assessed using the scale [10]: 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%).

Table 1 Description of the research area

Individual	Latitude ϕ	Longitude λ	Altitude H (m)	Taxa	Aspect	Slope*
1.	44°47'58.39"N	20°27'06.54"E	90	'Little Richard'	W	4.22°
2.	44°47'58.62"N	20°27'06.78"E	91	'Little Richard'	NW	4.60°
3.	44°47'58.52"N	20°27'06.91"E	91	'Little Richard'	NW	4.60°
4.	44°47'58.30"N	20°27'06.69"E	91	'Sunrise'	W	4.22°

*Slope angle: 3–5° (inclined terrain)

The effects of urban heat island influence on the temporal consistency of flowering abundance were analysed using interactions between air temperature and flowering abundance through Spearman rank (ρ) correlations and linear regression. The strength and direction of correlations were determined by the value and sign of the coefficient (–1 to 1) according to Gilbert [11]. Daily data on maximum and minimum air temperatures were obtained from the Republic Hydrometeorological Service of Serbia (RHMS) [12,13] from the Main Meteorological Station (MMS) Belgrade (44°47'54.44"N and 20°27'53.35"E; altitude 132 m), as it is located within an urban heat island zone at a distance of 1033.56 m from the study area. Data processing was performed at the population level, based on mean values for both cultivars and all individuals due to their established similarity, using XLSTAT 2022, PAST 4.11, and Google Earth Pro.

RESULTS AND DISCUSSION

In our study, within the phenological patterns, the absolute differences between the earliest and latest DOY values were 44 (BBCH 60), 25 (BBCH 61), 50 (BBCH 65), and 23 days for BBCH 69 (Figure 1). All key phenological phases occurred earliest in 2025, while the latest occurrences for the first two phases were recorded in 2023; full flowering and the end of flowering occurred latest in 2024, identified as the warmest year globally according to the Republic Hydrometeorological Service of Serbia. The patterns observed in our study differ from those reported by Casey [7] and the University of Delaware [8], according to which both cultivars flower during summer. In Belgrade (Serbia), flowering extended from early summer to early winter, with an average duration of 161.67 days over three consecutive years (140 days in 2023, 178 days in 2024, and 167 days in 2025). However, the results partially correspond with the GBIF database [14] for the Northern Hemisphere, where flowering phenological patterns are reported for the period June–November at altitudes up to 200 m. The phenological flowering patterns can be characterised by temporal consistency across the years in which observations were conducted (Figure 1).

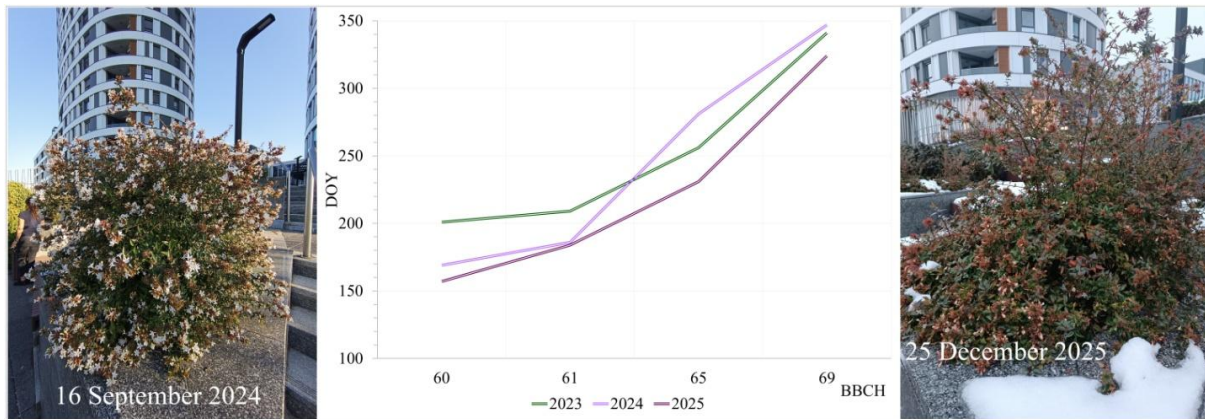


Figure 1 Phenological flowering patterns of Glossy Abelia in Belgrade based on in situ observations during the study years (2023–2025), and visual aspects at the full flowering stage (left) and at the beginning of the climatological winter (right).

The results indicate that flower formation varied throughout the study period and that it correlates with climatic parameters across the research years, while the day of year (DOY) was not a significant factor for the elements of the flowering phenophase. The validity of these conclusions is supported by the results of descriptive statistics (Table 2). This is further confirmed by the obtained values of the Spearman rank (ρ) coefficient, for the days when the first flower opened (60), the beginning of flowering (61), full flowering (65), and the end of flowering (69) of Glossy Abelia, which were not statistically significant.

Table 2 Descriptive statistics for BBCH 60 (first open flower), BBCH 61 (beginning of flowering), BBCH 65 (full flowering), and BBCH 69 (end of flowering) as key elements of the phenological flowering patterns of Glossy Abelia in Belgrade during the period 2023–2025.

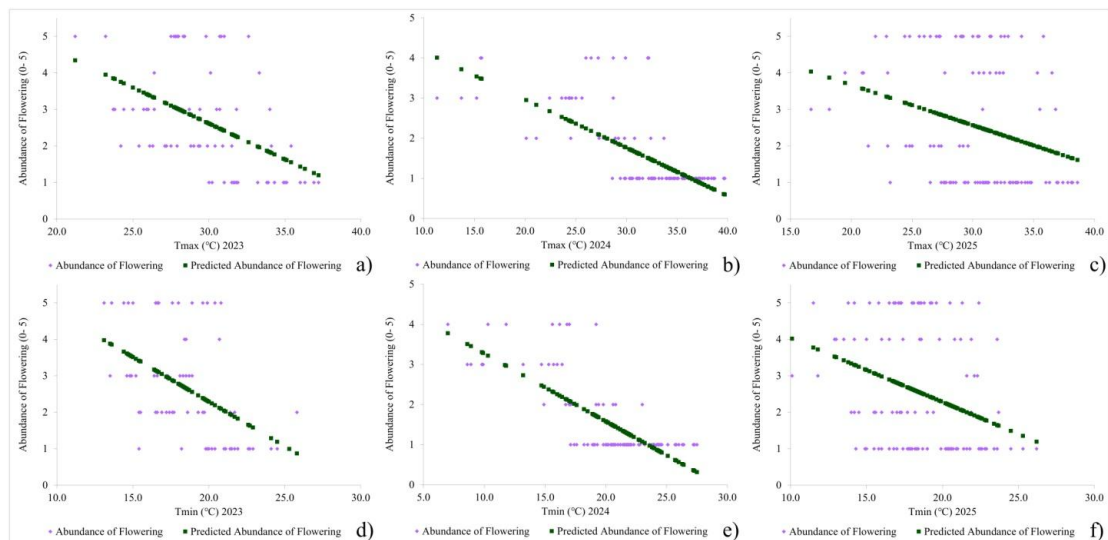
Parameters	60BBCH	61BBCH	65BBCH	69BBCH
Standard deviation	18.571	11.343	20.412	9.741
Variation coefficient	0.106	0.059	0.080	0.029
Variance	344.889	128.667	416.667	94.889
Standard err. of the variance	517.333	193.000	625.000	142.333

Given that, to the authors' knowledge, this is the first study addressing flowering abundance and temperature ranges, values for the five-level scale ratings were separated into two periods: up to 30 September (i.e. until the end of the growing season) and from 1 October (end of the growing season) to the end of flowering. Ranges of daily temperatures corresponding to flowering abundance ratings were determined in accordance with Lalić *et al.* [15], who emphasized that at different geographical latitudes the length of the growing season is closely related to temperature and duration of sunlight, and Zaytseva *et al.* [16], who highlighted that under given climatic conditions and day-length regimes in Europe, both temperature and photoperiod must be considered. A comparative analysis identified the ranges of daily maximum and minimum temperatures for the flowering abundance of Glossy Abelia (Table 3).

Table 3 Ranges of daily maximum (T_{max}) and minimum (T_{min}) air temperatures (based on RHMS data) corresponding to flowering abundance ratings (1–5) of Glossy Abelia (own in situ recorded data)

Flowering Abundance	T _{max} (°C)	T _{min} (°C)	T _{max} (°C)	T _{min} (°C)
	Up to 30 September		From 1st October to the end of flowering	
2023				
1	30.0–37.2	15.4–25.3	3.6–22.7	0.0–10.9
2	24.2–35.4	15.4–24.8	7.6–23.0	3.5–9.3
3	23.7–34.0	13.5–18.9	16.2–26.9	5.3–14.4
4	26.4–33.3	18.4–20.7	14.0–30.2	5.3–19.6
5	21.2–32.6	13.1–20.8	22.2–28.1	9.7–16.0
2024				
1	39.7–28.6	17.1–27.5	1.1–9.7	-1.0–4.9
2	20.1–33.7	14.9–23.0	3.9–13.5	0.2–5.2
3	16.4–28.7	11.3–8.6	4.8–19.7	-0.1–9.4
4	15.6–32.2	7.0–15.6	3.9–25.9	-1.0–16.3
5	-	-	9.1–29.2	0.4–17.6
2025				
1	23.2–38.6	14.3–26.2	2.2–16.1	-0.5–8.9
2	21.4–35.4	14.0–23.7	4.7–25.9	1.9–14.0
3	21.4–35.4	14.0–23.7	8.2–25.6	5.6–15.3
4	19.5–36.5	12.9–23.6	-	-
5	22.0–35.8	11.5–22.4	-	-

Spearman correlation coefficients, with a significance level of $p < 0.05$, confirmed strong positive correlations between T_{max} and T_{min} for all three years (0.918 in 2023, 0.938 in 2024, and 0.921 in 2025), and significant moderate negative correlations of T_{max} and T_{min} with flowering abundance only for 2024 (-0.599 for T_{max} and -0.633 for T_{min}). Therefore, regression analyses were performed based on daily maximum and minimum air temperatures, separated by periods, to determine their influence on flowering abundance (Figures 2 and 3).

**Figure 2** Scatterplots and predicted effects of daily maximum (a, b, c) and minimum (d, e, f) air temperatures on flowering abundance up to the end of the growing season (30 September)

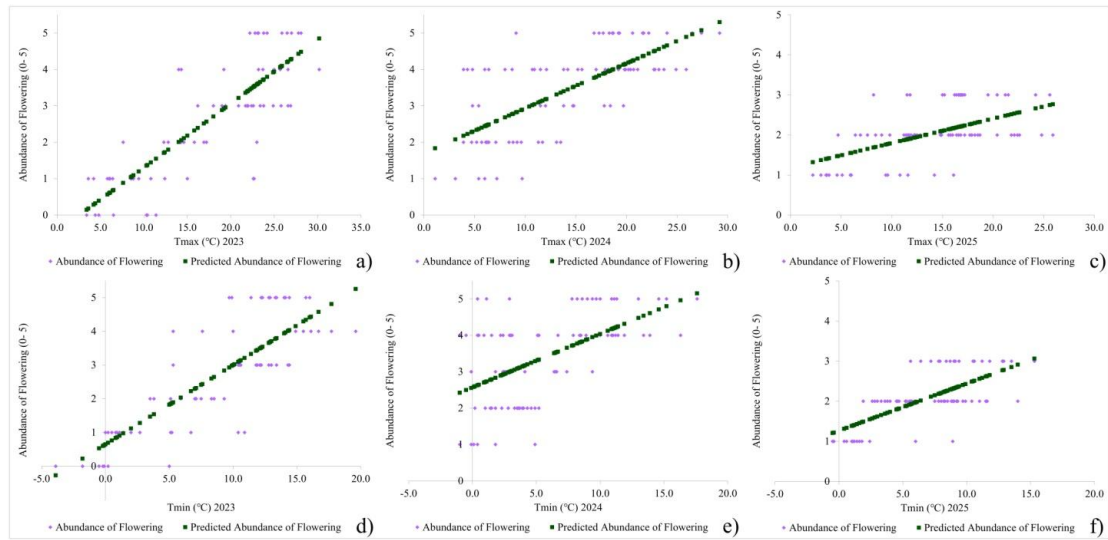


Figure 3 Scatterplots and predicted effects of daily maximum (a, b, c) and minimum (d, e, f) air temperatures on flowering abundance 1 October to the end of flowering.

Variable trends are noticeable after approximating the extracted data and determining the regression lines. The statistical significance of the conclusions, at $p < 0.05$, is confirmed by the results of regression ANOVA. Up to 30th September, for Tmax the values were $F = 12.533$, $p < 0.0005$ (2023); $F = 97.284$, $p < 0.0000$ (2024); and $F = 11.573$, $p < 0.0009$ (2025), while for Tmin they were $F = 22.595$, $p < 0.0000$ (2023); $F = 140.025$, $p < 0.0000$ (2024); and $F = 14.144$, $p < 0.0002$ (2025). From 1st October to the end of flowering, for Tmax the values were $F = 135.865$, $p < 0.0000$ (2023); $F = 76.765$, $p < 0.0000$ (2024); and $F = 31.353$, $p < 0.0000$ (2025), while for Tmin they were $F = 135.654$, $p < 0.0000$ (2023); $F = 35.782$, $p < 0.0000$ (2024); and $F = 67.281$, $p < 0.0000$ (2025).

The results of the regression analysis for flowering abundance indicate that daily maximum and minimum air temperatures, analysed by periods, were key factors influencing flowering abundance, along with day length, which affects phenophases of temperate zone plants [17]. Furthermore, the relationship between flowering and air temperatures suggests that long sunny days with high temperatures—particularly when plants are grown in stone planters that absorb heat [1], led to a reduction in flowering abundance. Conversely, shorter day lengths combined with rising temperatures contributed to increased flowering abundance. These findings are important for supplementing the list of suitable plants for landscape design in urban heat island (UHI) zones and rapidly developing urban areas, such as the municipality of Savski Venac, with an urbanisation rate of 91.89% [18], which attract organisms crucial for ecosystem services, including bees, butterflies, and birds, many of which have been displaced over the last decade due to anthropogenic pressures [2].

CONCLUSION

The findings of this intensive, pioneering case study conducted in Belgrade during 2023, 2024, and 2025 stand out for their contribution to knowledge on the acclimatization and sustainability of Glossy Abelia taxa in urban heat island (UHI) zones. The analysed taxa are recommended for achieving structural “layering” across all open urban spaces to support biodiversity conservation and ecological sustainability. The study highlights key events in

flowering patterns to emphasise the influence of air temperatures on shifts in urban phenology of Glossy Abelia, providing a basis for operationalizing urban planning and design. Continued phenological monitoring is necessary to further clarify the causes and consequences of shifts in flowering phenophases and abundance, as well as questions related to the spatial and temporal organisation of ecological communities.

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