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Assessment of the impact of air temperature variations on the duration and abundance of flowering of *Abelia* × *grandiflora* ‘Little Richard’ in the context of urban planning and design

Djurdja Petrov[1*], Nevenka Galečić[1], Dejan Skočajić[1], Jelena Čukanović[2], Radenka Kolarov[2], Sara Đorđević[2], Mirjana Ocokoljić[1]

[1] University of Belgrade, Faculty of Forestry, Kneza Višeslava 1, 11030 Belgrade, SERBIA, [2] University of Novi Sad, Faculty of Agriculture, Trg Dositeja 8, 21000 Novi Sad, SERBIA, *djurdja.stojicic@sfb.bg.ac.rs

INTRODUCTION & AIM

According to urbanization projections [1], by 2030, 81% of the population will be urban. Intensive urbanization and anthropogenic pressure are changing land use and negatively affecting the environment. Urban Heat Islands (UHI) are highlighted as a key element of urban climate, increasing temperatures in cities [2]. Plant material within elements of Green Infrastructure (GI) can mitigate the negative impacts of air temperature variations in urban environments. For example, different types and compositions of GI elements have a stronger cooling effect (during summer) than simple structures lacking shrub vegetation or vertical layering [3]. The UHI effect, i.e. temperature variations, has the potential to either improve or disrupt ecological systems, while it remains unclear how the plasticity of Glossy Abelia, under conditions of localized climate change, may facilitate urban planning and design. Based on existing gaps in the literature, the aim of this study is to analyze the resilience of Abelia × grandiflora ‘Little Richard’ in a park as an element of GI under conditions of intensive urbanization in Belgrade (South-Eastern Balkans).

METHOD

Fig. 1. Study area: (a) Belgrade (Serbia) and (b) Glossy abelia at the entrance to “Lepi izgled” park, with a view towards the zone of intensive urbanisation (Belgrade Waterfront).

The study area is the “Lepi izgled” park, located within the municipality of Savski Venac, with an urbanization rate of 91.89% [4] and a tendency towards further intensive increase due to its immediate proximity to the Belgrade Waterfront development. The reported percentage does not include the remaining 8.11% of the area [4], which is currently undergoing rapid urbanization.

“Lepi izgled” park is situated within the Sava Amphitheatre (Fig. 1), and three individuals of *Abelia* × *grandiflora* ‘Little Richard’ are positioned at the park’s exit zone, which is designed as a cascading access to the mixed-use Skyline buildings, within an Urban Heat Island (UHI) zone in Belgrade (Serbia). The substrate is covered with geotextile and mulch, and corrugated pipes have been installed for regular irrigation and fertilisation. Therefore, results can be directly associated with the influence of air temperature. During three consecutive years (2023–2025), the following dates were recorded daily for each individual of Abelia × grandiflora ‘Little Richard’: BBCH 60 (the day when the first flower opened), beginning of flowering – BBCH 61 (the day when more than 10% of flowers were open), full flowering – BBCH 65 (the day when more than 50% of flowers were open), and end of flowering – BBCH 69 (the day when more than 80% of flowers had faded), according to the BBCH scale [5]. The recorded dates were subsequently converted into DOY (Day of Year) values using software. For the key phenophases, Growing Degree Days (GDD) were determined based on daily maximum (Tmax) and minimum (Tmin) air temperatures, applying improved formulae [6]. After establishing an appropriate series of active temperatures, they were accumulated from 1 January for each day up to the DOY corresponding to BBCH 61, BBCH 60, BBCH 65, and BBCH 69, separately for each year of the study. Phenological patterns and flowering abundance were analyzed using descriptive statistics, the Spearman rank test, the Mann–Kendall trend test in conjunction with Sen’s slope test, and regression analysis.

RESULTS & DISCUSSION

In the South-Eastern Balkans, flowering lasted from early summer to early winter, which differs from the reports of Casey [7] and the University of Delaware [8], who indicate that Glossy abelia flowers during summer. However, the results partially correspond with the Pl@ntNet database at GBIF [9] for the Northern Hemisphere, where flowering is recorded from June to November at altitudes up to 200 m.

The average flowering duration was 161.67 days over the three consecutive years. All flowering phases occurred earliest in 2025, while the first two phases were latest in 2023; full flowering and the end of flowering were latest in 2024 (Fig. 2), which aligns with the mean monthly air temperatures (Fig. 3).

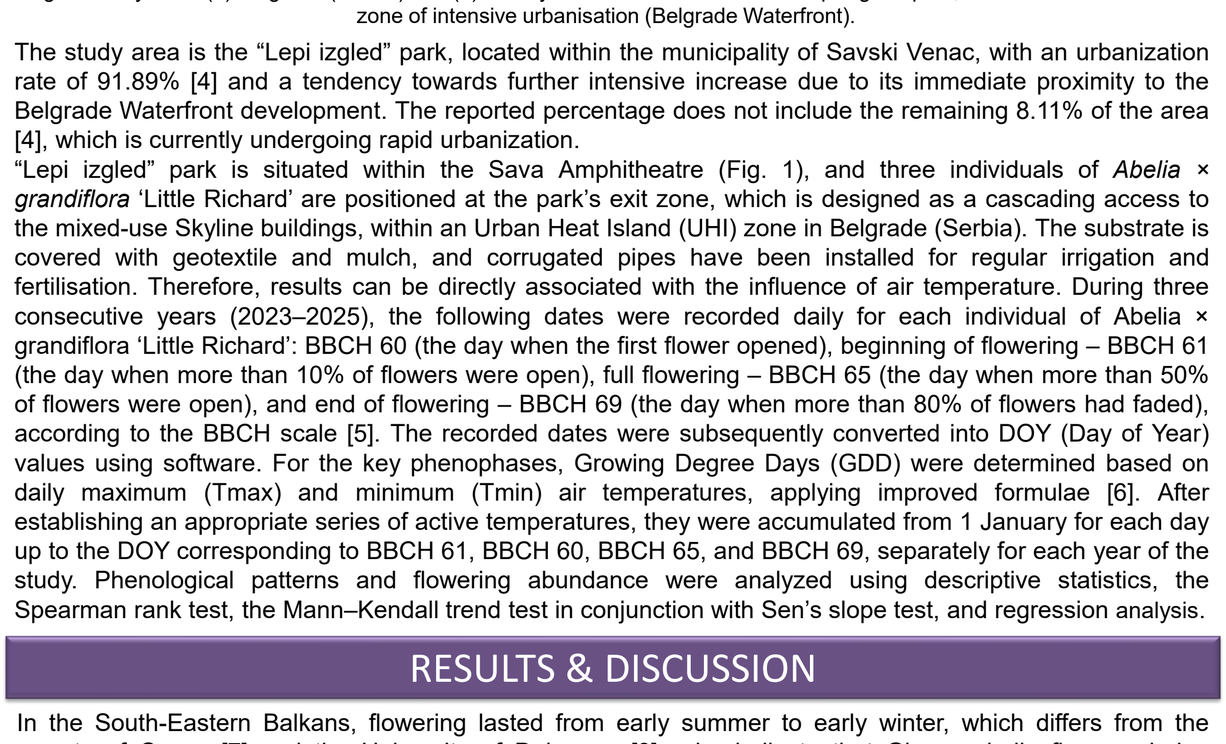


Fig. 2. Day of Year (DOY) of Glossy Abelia for key flowering phases in Belgrade during the study years (above), and phenological flowering patterns (GDD) of Glossy Abelia in Belgrade based on daily maximum and minimum air temperature (below) during 2023–2025, with visual aspects.

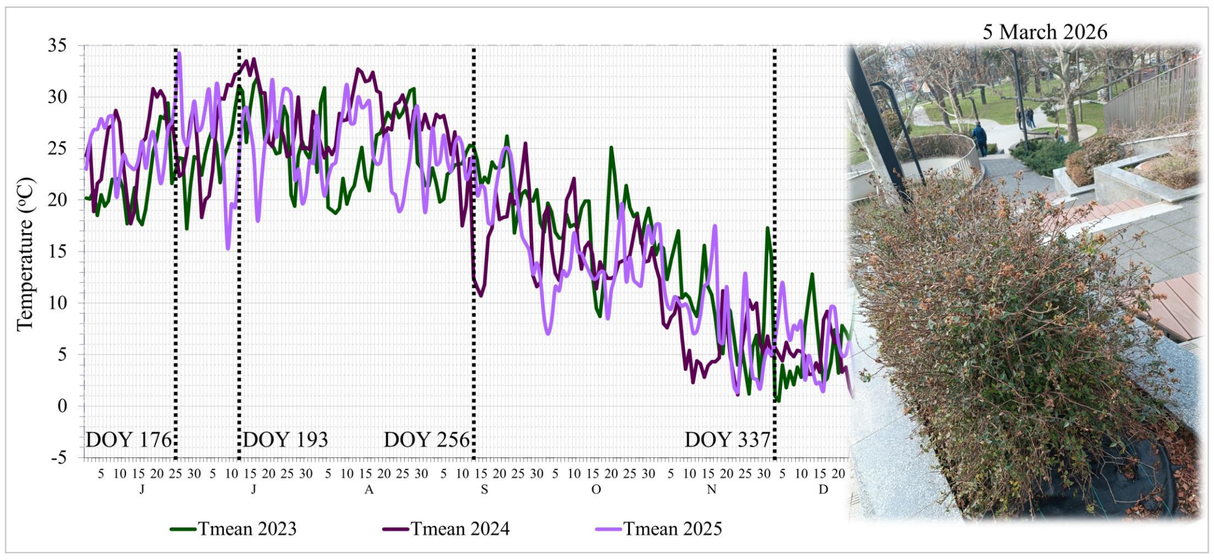


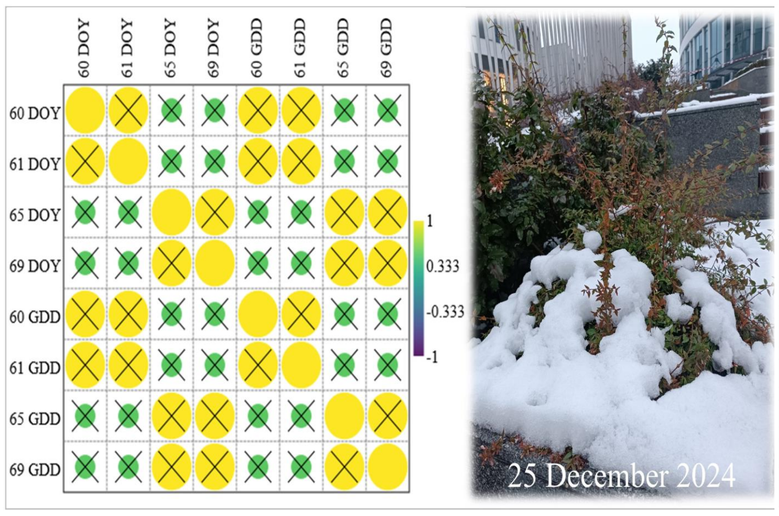
Fig. 3. Graphical representation of mean daily air temperatures for the study years, showing the average DOY values for BBCH 60, BBCH 61, BBCH 65, and BBCH 69 phases, based on data from the Belgrade Main Meteorological Station (MMS) and the present study.

The absolute differences in phenological patterns between the earliest and latest GDD values were 715.22 °C (BBCH 60), 334.07 °C (BBCH 61), 1,179.08 °C (BBCH 65), and 400.66 °C (BBCH 69) (Fig. 2). For all key phenological phases, the lowest accumulated GDD occurred in 2025, while the highest values for the first two phases were recorded in 2023. Full flowering and the end of flowering reached their highest GDD values in 2024, which was the globally warmest year. The determined values correlate with the maximum and minimum daily air temperatures in the study years, independent of DOY [10].

The Spearman rank correlation coefficient (ρ) values for DOY and GDD, recorded for the first flower opening (BBCH 60), beginning of flowering (BBCH 61), full flowering (BBCH 65), and end of flowering (BBCH 69) of Glossy Abelia, indicate that there are no statistically significant differences between years (Fig. 4). These results suggest that the days of the year (DOY) are not significant for the phenological flowering patterns.

Based on daily maximum and minimum air temperatures, regression ANOVA analyses were performed to determine their influence on flowering abundance, with statistical significance assessed at $p < 0.05$. The results of the regression analysis indicate that daily maximum and minimum air temperatures, depending on the period, were factors influencing flowering abundance.

Since, to the authors’ knowledge, this is the first study on flowering abundance and the effect of air temperatures, two periods were analyzed: from the beginning of flowering to the end of the vegetative season (30 September), and from 1 October to the end of flowering. A comparative analysis of flowering abundance and daily maximum and minimum air temperatures showed that long sunny days with high temperatures reduced flowering abundance.



Parameter	df	SS	MS	F	Significance F
Tmax 2023 (up to 30 September)					
Regression	1	35.77679	35.77679	21.77369	0.0000
Residual	71	116.6616	1.643121		
Tmin 2023 (up to 30 September)					
Regression	1	36.80095	36.80095	22.59535	0.0000
Residual	71	115.6374	1.628696		
Tmax 2023 (up to 1st October)					
Regression	1	125.8756	125.8756	135.6849	0.0000
Residual	69	64.01168	0.927706		
Tmin 2023 (up to 1st October)					
Regression	1	125.866	125.866	135.6542	0.0000
Residual	69	64.02128	0.927845		
Tmax 2024 (up to 30 September)					
Regression	1	50.05076	50.05076	97.28432	0.0000
Residual	104	53.50584	0.514479		
Tmin 2024 (up to 30 September)					
Regression	1	59.42218	59.42218	140.0246	0.0000
Residual	104	44.13443	0.424369		
Tmax 2024 (up to 1st October)					
Regression	1	62.34134	62.34134	76.76515	0.0000
Residual	84	68.2168	0.812105		
Tmin 2024 (up to 1st October)					
Regression	1	39.00113	39.00113	35.78202	0.0000
Residual	84	91.55701	1.089964		
Tmax 2025 (up to 30 September)					
Regression	1	30.09541	30.09541	11.57323	0.0009
Residual	115	299.0499	2.600434		
Tmin 2025 (up to 30 September)					
Regression	1	36.04853	36.04853	14.14407	0.0003
Residual	115	293.0968	2.548668		
Tmax 2025 (up to 1st October)					
Regression	1	9.869894	9.869894	31.35267	0.0000
Residual	76	23.92498	0.314802		
Tmin 2025 (up to 1st October)					
Regression	1	15.86918	15.86918	67.28096	0.0000
Residual	76	17.92569	0.235864		

Fig. 4. Graphical representation of Spearman correlation coefficients for DOY and GDD: BBCH 60, BBCH 61, BBCH 65, and BBCH 69 as key elements of Glossy Abelia flowering phenology in Belgrade during 2023–2025, with Glossy Abelia under snow cover still displaying open flowers; ANOVA results (at $p < 0.05$) for the effect of daily maximum and minimum air temperatures on the flowering abundance of Glossy Abelia during 2023–2025 (right).

CONCLUSION

This study provides a framework for modelling the potential effects of temperature changes on the dynamics and abundance of flowering at the local level. The research highlights key events in flowering patterns to emphasize the influence of air temperatures on shifts in the urban phenology of Glossy Abelia, aiming to support the operationalization of urban park planning and design. The results confirm the significance of this species and facilitate the planning and design of parks as elements of Green Infrastructure (GI), where *Abelia* × *grandiflora* ‘Little Richard’ could be incorporated in areas with a high degree of urbanization. ‘Little Richard’ allows for achieving vibrant color effects, particularly during summer, autumn, and winter. The study contributes to expanding knowledge on the interactions of ‘Little Richard’ with temperature and environmental variations, as well as its impact on ecosystem services. The findings suggest that Glossy Abelia cultivars should be considered when selecting taxa for GI in Urban Heat Island (UHI) areas, both for new plantings and restoration projects, as they can accelerate ecological succession and enhance additional ecosystem services by attracting bees, butterflies, and birds in zones of intensive urbanization.

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