

EVALUATION OF THE UTILISATION POTENTIAL OF *FICUS CARICA* L. UNDER CONDITIONS OF CLIMATIC CHALLENGES: STATE AND PERSPECTIVES

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Abstract: The research was conducted to evaluate the practical potential and sustainability of *Ficus carica* L. in Belgrade, considering that climate change scenarios predict air temperatures as the primary stress factors. Through an integrative approach to the phenological fruiting patterns of figs over three consecutive years, the study confirmed the sustainability of the selected genotype and the potential for predictive understanding of phenological changes under climatic challenges. The results also provide insights into the fruit morphology of figs and the species' ecology, highlighting the necessity for in situ care measures. Particularly emphasized is the need for a 91.4% crown reduction at the end of the vegetation period, with a recommendation for the sustainable utilisation of the resulting biomass to extract bioactive compounds, followed by the use of the residues in the production of wood base panels (particleboards). The study promotes figs as a multipurpose plantation crop in Serbia.

Key words: Fig, Landscape architecture, Horticulture, Fruit growing, Wood industry, Sustainability, Climate change

1. INTRODUCTION

Due to climate challenges, many plant species have expanded and shifted their distribution as they have evolved and successfully acclimatised to new regions where they were previously unable to grow [1]. In Serbia, since the late 20th century, exotic species belonging to the Mediterranean floristic element have increasingly been utilised, benefiting from the conditions of a Mediterranean climate [2,3]. One such species is *Ficus carica* L., which has been recorded as part of the green infrastructure in Belgrade.

Ficus carica L. belongs to the family Moraceae Gaudich., with a native range extending from the eastern Mediterranean to Central Asia and Afghanistan [4]. According to fossil records, it has been cultivated for 11,000 years, with its domestication beginning in the early Neolithic period [5]. Fig is a highly valued fruit species, with fruits rich in vitamins, minerals, and bioactive compounds possessing a high antioxidant capacity [6] (Sandhu et al., 2023).

In landscape architecture practice, figs stand out as living sculptures when pruned in private gardens and open spaces and can also be used for vertical greening. They are particularly attractive as graceful solitary trees, contributing to landscape aesthetics throughout the year with their canopy texture and the distinctive architecture of smooth branches and trunks [2].

In recent times, interest in Fig cultivation has increased due to their taste, nutritional value, biological efficiency, and the economic and medicinal significance of their fruits. Given this, and considering the lack of morphological and phenological studies in Serbia, the aim of this research is to determine the morphological characteristics of Fig fruits, the phenological response of fruit ripening to climatic challenges, the potential for regeneration, and new ways of utilising biomass after pruning of Fig in Belgrade.

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2. EVALUATION OF THE UTILISATION VALUES OF *FICUS CARICA* L.

2.1. Study area

In the phenological monitoring network established in 2007 in the Belgrade area [7], a station was selected in 2022 for this research, located in the municipality of New Belgrade, on a flat and non-exposed terrain. The station is georeferenced with coordinates 44°48'20.20" N and 20°21'31.44" E, at an elevation of 101m. The subject of phenomonitoring at this station is *Ficus carica* L. (Fig), planted on Luvic Chernozems soil [8], in a private garden.

2.2. Acquisition of Data

The phenological data are the result of continuous monitoring conducted from 2022 to 2024. Observations were made visually, with dates recorded and then software-converted into days of the year (DOY). The coding of the fruit ripening phenological phase – RP (DOY when all fruits were ripe) was carried out using the extended BBCH scale [9].

The yield abundance was assessed using a scale from 0 to 5, where: 0 – no yield (0% of branches with fruit); 1 – very small yield (<20%); 2 – small yield (>20–<40%); 3 – moderate yield (>40–<60%); 4 – abundant yield (>60–<90%); 5 – maximum yield (>90%), according to Stilinović [10]. For the morphometric analysis of fruits at full ripening phase from the southern part of the canopy, 20 fruits were analysed each year of the study. The weight was determined using an analytical balance (precision ± 0.001 mg), while the length and width of the fruits were measured with high-precision (± 0.001 mm) electronic calipers.

Climate data for the reference period (1991-2020) and the research period (2022-2024) were obtained from the main meteorological station (MMS) in Surčin ($\phi 44^{\circ}47'54.44''\text{N}$ and $\lambda 20^{\circ}27'53.35''\text{E}$, elevation 99m), https://www.hidmet.gov.rs/ciril/meteorologija/klimatologija_godisnjaci.php and https://www.ogi_met.com/synopsc.phtml.en, accessed on January 6, 2025), located 5,725.1 meters from the phenostation.

2.3. Processing of Data

The study accumulated degree days (GDD) determined using the McMaster and Wilhelm [11] method, supplemented by Lalić et al. [12]. This integrated method involves using daily maximum and minimum air temperatures from the MMS Surčin for the years of the study and a temperature threshold of 5°C, as recommended by WMO [13] for conditions of a moderately continental climate.

The study employed descriptive statistics, the non-parametric Mann-Kendall trend test, and the Spearman Rank correlation test, with a significance level of $p < 0.05$. Data processing was carried out using the software packages XLSTAT 2020 and Past 4.11.

3. RESULTS AND DISCUSSION

The primary response of the Fig to climatic challenges is a longer growing season during the study years, with an extension of the autumn phenophases. The ripening phase (RP) was observed from 307 DOY (2023 and 2024) to 315 DOY (2022). The value of the GDD at the last RP, with fruits ripening successively from July, was 3,380.6 (2022), 3,439.0 (2023), and 3,845.6 (2024). The results of the Mann-Kendall trend test indicate the insignificance of the DOY for the final fruit ripening, but the significance of increasing GDD values ($S = 5$, $p = 0.042$). The Spearman Rank coefficient (ρ) for the final fruit ripening is -0.94281, although it is not significant since the p-value is not lower than 0.05.

Comparative analysis of the tests reveals that the accumulated heat sums for the last fruit ripening correlate with the increase in average daily air temperatures (Figure 1). Statistical processing of the air temperatures determined that the average annual air temperatures were: 15.1°C (2024), 14.2°C (2023), 13.8°C (2022), and the reference period of 12.5°C. An increase in average annual temperatures of 2.6°C (2024), 1.7°C (2023), and 1.3°C (2022) was observed compared to the 1991-2020 baseline.

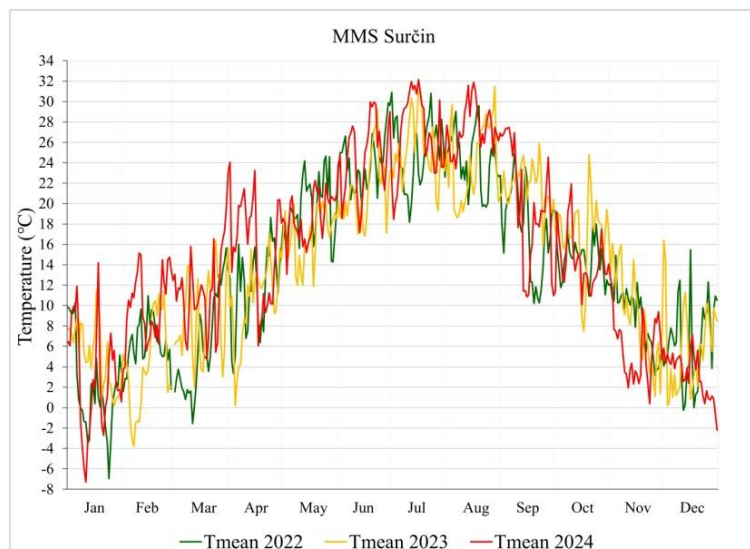


Figure 1 – Graphical representation of average daily temperatures for the research years, based on data from MMS Surčin

The observed temperature values and the rise in air temperature contributed to abundant yields, which averaged 4.83 across the three years of the study. Additionally, the average weight of individual fruits during the three-year period was 28.85g, with a length of 46.27mm and a width of 41.36mm. The investigated biometric characteristics of fruits in the last full ripening phase, during the years of research, are shown in Figure 2. Table 1 shows the parameters of descriptive statistics with a clear standing out of the standard deviation (8.51) and the coefficient of variation (29.50) of the fruit weight, which indicate greater variability. The standard deviation and other parameters of deviation from the mean values of the length and width of individual fruits indicate that there were no significant deviations. Our results for the morphological parameters of the fruits are consistent with those of Şimşek [14] and Mahmoudi et al. [15], who reported fruit lengths of 30-60mm and widths of 40-60mm. However, the weight of individual fruits in our study is lower than their findings (30-60g). The summer period with evident increased temperatures, according to the data obtained on the fruit phenology, indicates that the species has adapted very well to the conditions of the changed humid continental climate in Serbia.

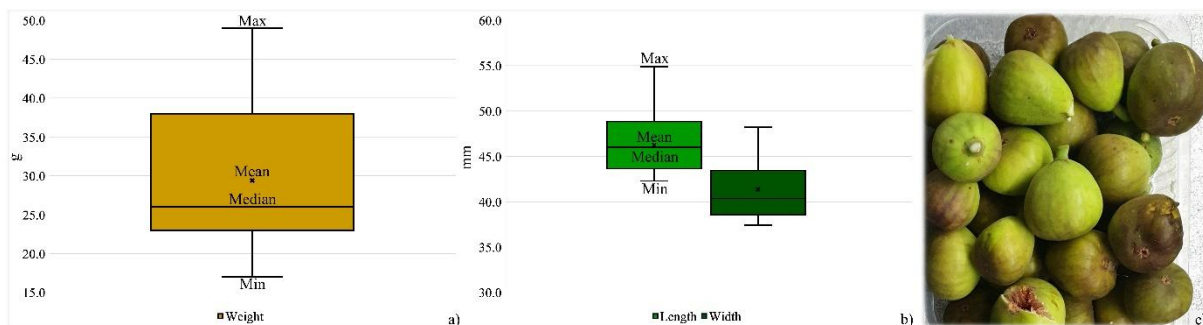


Figure 2 – Biometric characteristics of fig fruits at the last full ripening phase (November) for three consecutive years of research for (a) weight, (b) length and width and (c) visual aspect of fruits from 2024

Table 1 – Descriptive statistics for morphometric characteristics of fig fruits at the last full ripening phase in the period 2022-2024

Parameter	Weight (g)	Length (mm)	Width (mm)
Min	17	42.3	37.4
Max	49	54.9	48.2
Mean	28.85	46.265	41.36
Std. error	1.902996	0.7017375	0.7660356
Variance	72.42789	9.848711	11.73621
Stand. dev	8.510458	3.138266	3.425815
Median	27	46	40.35
25 prcntil	23.625	43.65	38.55
75 prcntil	35.8	48.85	43.45
Skewness	0.8927501	1.02886	0.8740811
Kurtosis	0.2496846	1.342582	-0.321490
Coeff. var	29.49899	6.783239	8.282919

As for low temperatures during winter, this part of the research and the results refers to the adaptability of the studied genotype which was confirmed by its existence *in situ* from 2007 to the present. During the winter of 2016/2017, due to low temperatures (Figure 3), the plant froze to the ground [7]. At the same time, during that period the specimen was not protected during the winter months. The lowest temperature that winter was recorded on January 8, 2017, and was -16.2°C , which falls into the category of severe frosts according to the Republic Hydrometeorological Institute of Serbia (RHMZ). That same winter, there were 9 additional days with severe frosts. On January 7, the maximum temperature was -9.9°C , with a total of 25 freezing days ($T_{\text{max}} < 0^{\circ}\text{C}$) and 58 frosty days ($T_{\text{min}} < 0^{\circ}\text{C}$), emphasizing that consecutive frosty days occurred between December 28, 2016, and January 31, 2017.

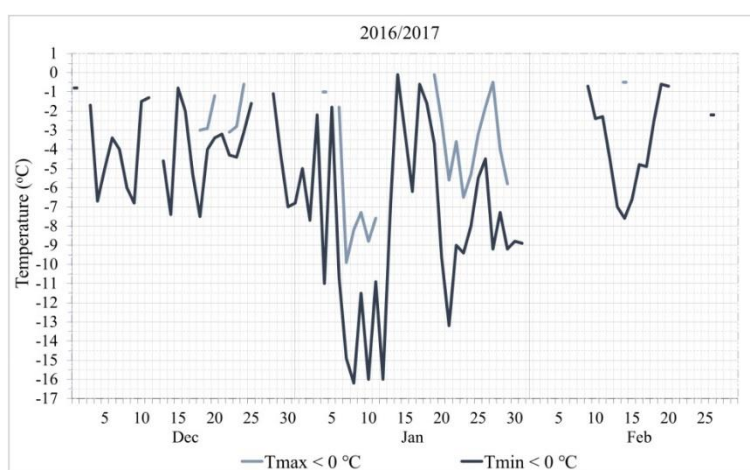


Figure 3 – Daily course of maximum and minimum air temperatures below 0°C for the winter of 2016/2017, based on data from MMS Surčin

In 2017, the observed Fig regenerated and already bore an abundant crop that year. Since then, the garden owners have pruned the plant every year at the end of November and wrapped it in agrofilm. After removing the film at the beginning of spring 2024, the Fig quickly regenerated, reaching a height of 2.92m and a canopy diameter of 4.65m (Figure 4a). In November 2024, it was pruned to a height of

1.7m, which is also the canopy diameter of the pruned plant (Figure 4b). The canopy reduction in this phase alone amounted to 91.4%, and during the growing season, additional pruning was done to promote fruiting.



Figure 4 – Fig during the growing season (a) and after in situ care measures (b) in 2024

Considering the volume of removed biomass (branches and leaves) and the findings of Boukhalfa et al. [16] that Fig leaf and branch extracts contain compounds that can reduce plasma lipid concentrations and significantly contribute to the overall antioxidant properties, the studied species is highlighted as important not only in landscape architecture, fruit growing, and pharmaceuticals but also in the wood industry. After the extraction of phenols, flavonoids, and anthocyanins, we recommend the sustainable use of biomass as the basic lignocellulosic raw material for the production of boards (particleboards). Additionally, it can be used as bedding for animal husbandry, mulch in horticulture, liquid fuel production, and for new technologies in development.

4. CONCLUSION

The research confirmed the sustainability strategies of the Fig under conditions of extreme heat stress, which were recorded from 2022 to 2024, and its rapid regeneration after freezing. The identified utility potential at the phenological station Novi Beograd provides a solid foundation for selective work with Fig under moderately continental climate conditions, classified as C(f)wa according to Köppen in Serbia. The analysed genotype enables the development of a sustainable ornamental variety that can be used for aesthetic and functional landscape enhancement, therapeutic and preventive nutrition, and for the first time, is highlighted as a species of the future for multi-purpose plantation cultivation, given its rapid regeneration after climatic challenges.

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