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Original scientific paper

CONDITION OF NORTHERN RED OAK TREES IN THE URBAN ENVIRONMENT OF BELGRADE (SERBIA)

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Abstract: *Forty-two trees of northern red oak (Quercus rubra L.) were examined in the area of the municipality of Savski Venac, Belgrade, to assess the condition of this allochthonous species in Serbia and its adaptability to urban environments. Physical measurements were taken and ratings of vitality and decorativeness were given. The analyzed trees are in very good condition based on their health status (80.95% of trees without visible indication of disease) and the mean values of ratings for vitality (4.45) and decorativeness (3.88). The obtained values of vitality and some physical measurements were greater than those stated in the literature, suggesting that the species has adapted well to the urban environment of Belgrade and it should be considered a suitable landscape tree species for planting in urban areas of Serbia.*

Keywords: *Quercus rubra* L., vitality, decorativeness, physical measurements, adaptability, Belgrade

STANJE STABALA CRVENOG HRASTA U GRADSKOJ SREDINI BEOGRADA (SRBIJA)

Sažetak: *Istraživanje je obuhvatilo 42 stabla crvenog hrasta (Quercus rubra L.) na teritoriji GO Savski venac u Beogradu, radi ispitivanja stanja ove alohtone vrste i njene prilagođenosti urbanoj sredini u Srbiji. Utvrđene su dimenzije stabala i procenjena je njihova vitalnost i dekorativnost. Zabeleženo je da su stabla vrlo dobre kondicije, na osnovu zdravstvenog stanja (80,95% stabala bez vidljivih simptoma oboljenja), kao i srednjih ocena vitalnosti (4,45) i dekorativnosti (3,88). Ustanovljene vrednosti za vitalnost i pojedine dimenzije stabala su bile veće od onih zabeleženih u relevantnoj literaturi, što navodi na zaključak da je ova vrsta drveća dobro prilagođena gradskoj sredini Beograda i da se može preporučiti za sadnju u urbanim područjima Srbije*.

Ključne reči: *Quercus rubra* L., vitalnost, dekorativnost, dimenzije, adaptibilnost, Beograd

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1. INTRODUCTION

One of the links between man and nature is represented by green areas and they play a key role in preserving the natural values of urban areas (Vukadinović et al., 2017). Urban green areas influence the regulation of the microclimate of city districts, reduce air pollution, filter floating particles, mitigate wind blows and soil erosion, influence the reduction of the negative effects of precipitation and reduce the noise level in cities (Prpić, 1992; Vuletić et al., 2010).

The capital of the Republic of Serbia, Belgrade, is located at 116.75 m elevation, at coordinates 44°49'14" north latitude and 20°27'44" east longitude. The urbanized area of the city is 359.92 km^2 (Grad Beograd, Sekretarijat za informisanje, 2022). The total area of green spaces in the city of Belgrade is 2,907.37 ha. Parks and squares make up 393.00 ha, greenery of residential areas 1,077.67 ha, green areas of roads 174.89 ha, urban forests 650.88 ha, coasts and shores and Great War Island 225.83 ha, protective areas 35.77 ha, and other categories of greenery 349.24 ha (Milanović, 2006). The significant microclimatic diversity of the city of Belgrade and its surroundings and other ecological factors have led to the formation of numerous plant communities that are typical for the region. The main forest communities in and around Belgrade and the most important dendroflora species were gradually enriched by man. In addition to native species of deciduous trees, there is also a large number of species brought from other climate areas. According to the literature (Maksimović et al., 1979), the most common autochthonous genera are linden, maple, ash, poplar, birch, hornbeam and others, while oaks are less represented. Among the introduced species, the most represented are acacia, honey locust, sophora, horse chestnut, catalpa, sycamore, etc. As for the domestic conifer species, Austrian pine and Norway spruce are the most common. Among the introduced species and varieties of conifers, the most represented are silver fir, cedar, yew, junipers, etc.

Northern red oak (*Quercus rubra* L.) grows naturally in the eastern and central parts of the United States of America (Uzcategui et al., 2020). It was introduced to Europe in 1691 (Gubka & Špišák, 2010). To date, there are only small areas under northern red oak in Serbia (c. 60 ha), but there are significant stands of this species in the vicinity of Belgrade (Lazarević, 2020). Northern red oak has shown exceptional results in the xeromesophilic and xerothermophilic oak habitats. It is a species that tolerates aridity better than sessile oak (*Q. petraea* L.) and has fewer demands on soil fertility. In addition, it easily adapts to different climatic conditions and tolerates low temperatures well (Isajev et al., 2006). It has a large crown and crimson-coloured leaves, almost entirely marcescent on young trees in the winter, with a high decorative value in parks and public gardens and it is a common street tree (Brus, 2011). Northern red oak may be an alternative to native oaks, pedunculate oak (*Q. robur* L.) and sessile oak [*Q. petraea* (Mattushka) Liebl.], on sites that are marginal for the latter, or under expected climate change as a "drought tolerant species" (Ray et al., 2010).

In urban areas, there is an increasing need to assess the health status and mechanical parameters of standing trees, not only for the sanitary and aesthetic function of greenery but also for the safety of people and infrastructure. In this paper,

northern red oak trees growing in the area of Belgrade city were examined to assess their condition and adaptability to urban environments.

2. MATERIAL AND METHODS

2.1. Study area

The examined northern red oak trees are located in the area of the municipality of Savski Venac. The municipality is the traffic, tourist and business center of Belgrade and one of the oldest municipalities of the city. About 40,000 inhabitants live in this municipality, with twice as many people working there (Beogradska opština Savski venac, 2022). Its northernmost point is at 44°48'54", and its southernmost point is at 44°45'15" north latitude. Its westernmost point is at 20°25'29", and its easternmost point is at 20°28'26" eastern longitude. The extension of the municipality in the south-north direction is 6.91 km, and in the west-east direction is 5.20 km (Vojnogeografski institut, 1990). It covers an area of 15.8 km². The highest point of this municipality is located within the Royal Complex (210 m), while the lowest point is the confluence of Topčider river with the Sava river (75 m). The geological substrate consists of sediments of the Holocene age and the alluvial plain of the Sava river. This area is dominated by anthropogenic, modified soils. The climate is temperate and continental, with long hot summers and cold winters. It is characterized by a specific microclimate because residential areas and heavy traffic cause an increase in temperature as compared to the average. However, the municipality also has a high proportion of green areas, which has the opposite effect (Gradski zavod za zaštitu zdravlja Beograd, 2002). The flora of this municipality is quite rich. Among the deciduous trees, oak, birch, maple, cherry plum, apple tree and poplar can be distinguished, along with many conifers, such as pines, spruces, etc. (Wikipedia, 2022).

2.2. Data and methodology

Forty-two trees of northern red oak were examined in the study area (Figure 1). The trunk diameter (at breast height), tree height and crown diameter of the analyzed trees were measured, and their vitality and decorativeness were assessed. A diameter tape (Bandmass 10 m, Weiss, Germany) was used to measure the trunk diameter of the trees, and the tree height was measured with a height measuring instrument (Vertex 4, Haglöf, Sweden). The crown diameter was measured by projecting the edges of the crown to the ground and measuring the length along one axis using a measuring tape (Fast Winder Frame 30 m, Weiss, Germany). The vitality and decorativeness of the trees were assessed using the VTA method (Visual Tree Assessment) (Mattheck & Breloer, 1994), according to the rating scales in Table 1.

The obtained numerical data was processed employing descriptive statistical procedures. The descriptive statistical analysis included determining the following basic parameters: minimum value, maximum value, variation range, mean value, standard deviation and coefficient of variation. The analysis was performed using the Statgraphics Centurion software (ver. XVI.I; 2009, Statpoint Technologies, Inc., Warrenton, VA).

Figure 1. *Locations of the analyzed northern red oak trees in Savski Venac municipality, Belgrade, Serbia*

Table 1. *Rating scales for vitality and decorativeness of trees.*

Grade	Vitality	Decorativeness
5	Excellent, healthy and strong trees, with no visible insect damage or indication of disease and no mechanical wounds.	Visually imposing and aesthetically valuable trees.
4	Trees in good condition, healthy, with only slight signs of injury, disease or physiological weakness.	Trees with a visually balanced form.
3	Trees with some mechanical, phyto-pathological or entomological damage.	Trees that have a clearly outlined crown in silhouette.
2	Trees with clearly visible mechanical damage from insects and/or diseases.	Trees of a disharmonious and disproportionate silhouette with insufficiently clearly delineated habitus.
1	Dead or nearly dead trees.	Trees without aesthetic value.

3. RESULTS

The results of descriptive statistics for the vitality, decorativeness and physical measurements of northern red oak trees, growing in the urban area of Belgrade, are shown in Table 2 and Figure 2.

According to the obtained physical measurements, the trunk diameter of the analyzed trees ranged from 7.50 cm to 85.00 cm, with a mean value of 45.00 cm and a coefficient of variation of 34.76%. In addition, the crown diameter ranged from 2.50 m to 17.50 m, with a mean value of 11.73 m and a coefficient of variation of 32.21%. Finally, the height of the analyzed trees ranged from 3.50 m to 22.50 m, with a mean value of 14.28 m and a coefficient of variation of 30.48% (Table 2). These results show that the physical measurements of the analyzed trees are highly variable, indicating that the sample consisted of trees with wide range of age.

Table 2. *Descriptive statistics for the vitality, decorativeness and physical measurements of northern red oak trees in the urban area of Belgrade.*

Property	Mean value	Standard deviation	Coefficient of variation (%)	Minimum value	Maximum value	Variation range
Trunk diameter (cm)	45.00	15.64	34.76	7.50	85.00	77.50
Crown diameter (m)	11.73	3.78	32.21	2.50	17.50	15.00
Tree height (m)	14.28	4.35	30.48	3.50	22.50	19.00
Vitality (1-5)	4.45	0.67	15.05	3.00	5.00	2.00
Decorativeness (1-5)	3.88	0.59	15.27	3.00	5.00	2.00

On the other hand, the vitality and decorativeness were much less variable features of the analyzed oak trees (coefficients of variation 15.05% and 15.27%, respectively). The vitality ranged from grade 3 to grade 5, with a mean value of 4.45, whereas the grades of decorativeness ranged from 3 to 5, with a mean value of 3.88 (Table 2). It was found that the analyzed trees are in very good condition based on their health status, considering that most of them (80.95%) had no visible indication of disease.

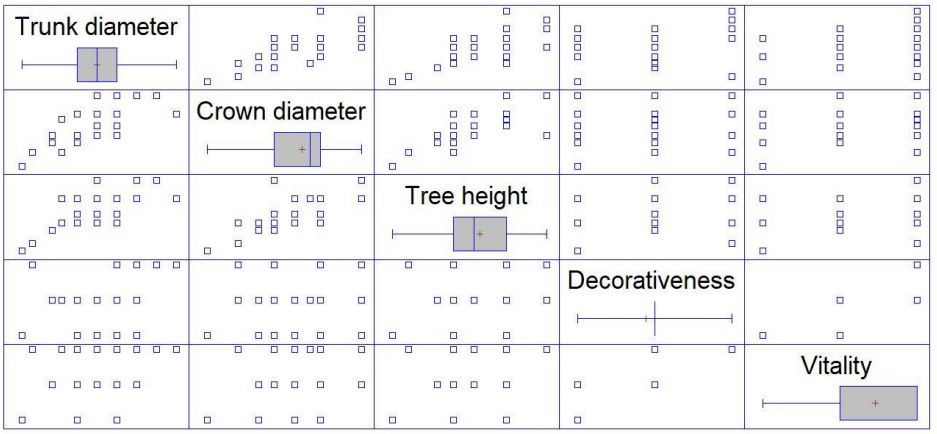

Figure 2. *Box-and-Whisker plot of basic parameters of vitality, decorativeness and physical measurements of northern red oak trees in the urban area of Belgrade. Legend: middle sign = mean, middle line = median, box = mean and standard deviation, whisker = variation range.*

In comparison with the literature data, the mean value of trunk diameter of the analyzed northern red oak trees was greater than the mean value reported for pedunculate oak (35.20 cm) (Pretzsch et al., 2015), but less than the mean values recorded for water oak (*Q. nigra* L.) (61.50 cm) (Dahlhausen et al., 2016) and white oak (*Q. alba* L.) (69.90 cm) (Sonti et al., 2019) in similar environments. The mean value of crown diameter of the analyzed trees was greater than that stated by Pretzsch et al. (2015) for pedunculate oak (3.60 m), and by Dahlhausen et al. (2016) for water oak (7.10 m). In contrast, the mean value of tree height obtained in this study was less than that given by Dahlhausen et al. (2016) for water oak (15.90 m).

It is necessary to assess the vitality of park species and determine biotic and abiotic factors that directly or indirectly threaten their condition so that adequate care and protection measures can be applied (Mladenović et al., 2020). The vitality of the sampled trees of northern red oak was greater than the values reported by Bühler et al. (2007) for four oak species (*Q. palustris* Münchh., *Q. petraea*, *Q. robur* and *Q. rubra*) (3.40 on a scale of 0–5, i.e., 2.83 on a scale of 1–5), and by Östberg et al. (2021) for pedunculate oak (66 on a scale of 0–100, i.e., 3.27 on a scale of 1–5). Still, these results were probably influenced by the fact that the majority of the sampled trees are located in the Royal Complex, where the environment conditions are more favorable than those in the city core.

For the establishment of functional green areas in urban environments, healthy planting stock and properly selected plant species are needed, along with appropriate tending and protection measures including substitution of sensitive species with more resistant ones (Mladenović et al., 2018). Based on the obtained results in this study and their comparison with literature data, it can be argued that northern red oak has adapted well to the urban environment of Belgrade, exhibiting very good health condition and adequate physical characteristics. Therefore, this plant species can be recommended for planting in the urban areas of Serbia as a landscape tree.

4. CONCLUSION

Based on the obtained data on vitality, decorativeness and physical measurements of northern red oak trees in the urban area of Belgrade, the following conclusions can be drawn:

- physical measurements of northern red oak trees in Belgrade (trunk diameter, tree height and crown diameter) are highly variable, indicating that the sampled trees are of a wide range of age;
- vitality and decorativeness are moderately variable traits of the northern red oak trees in the area;
- the analyzed trees are in very good condition based on their health status (80.95% of trees with no visible indication of disease) and mean values of ratings for vitality (4.45) and decorativeness (3.88);
- the obtained values for the vitality and some physical measurements (crown diameter and, in some cases, trunk diameter) of the sampled trees were greater than those stated in the literature for the same or related species in similar environments.

Finally, it can be concluded that northern red oak has adapted well to the urban environment of Belgrade and it should be considered a suitable landscape tree species for planting in urban areas of Serbia.

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Summary

In urban areas, there is an increasing need to assess the health status and mechanical parameters of standing trees, not only for the sanitary and aesthetic function of greenery but also for the safety of people and infrastructure. In the present paper, northern red oak trees (*Quercus rubra* L.) were examined in the urban area of Belgrade city to assess the condition of this allochthonous species in Serbia and its adaptability to urban environments.

Forty-two trees of northern red oak were examined in the area of the municipality of Savski Venac (Figure 1). The trunk diameter (at breast height), tree height and crown diameter of the sampled trees were measured using adequate tools and instruments (Weiss Bandmass 10 m; Haglöf Vertex 4; Weiss Fast Winder Frame 30 m). The vitality and decorativeness of the trees were assessed according to the VTA method (Visual Tree Assessment) (Mattheck & Breloer, 1994) using the rating scales given in Table 1. The obtained data was processed employing descriptive statistical procedures.

The results show that the trunk diameter of the analyzed trees has a range of values 7.50–85.00 cm and a mean value of 45.00 cm; the crown diameter ranged from 2.50 m to 17.50 m, with a mean value of 11.73 m, and the tree height ranged from 3.50 m to 22.50 m, with a mean value of 14.28 m, indicating a wide range of age of the sampled trees. On the other hand, the vitality and decorativeness were much less variable features. The mean value of vitality is 4.45 and the mean value of decorativeness is 3.88 (Table 2). In addition, the analyzed trees are in very good condition based on their health status (80.95% of trees are with no visible indication of disease). In comparison with literature data (Bühler et al., 2007; Dahlhausen et al., 2016; Östberg et al., 2021; Pretzsch et al., 2015), the obtained values for the vitality and physical measurements (crown diameter and, in some cases, trunk diameter) of the sampled trees were greater than those stated for the same species or other oak species [*Q. robur* L., *Q. alba* L., *Q. palustris* Münchh., *Q. petraea* (Mattushka) Liebl.] in similar environments.

Based on the obtained results in this study, it can be concluded that northern red oak has adapted well to the urban environment of Belgrade and it should be considered a suitable landscape tree species for planting in urban areas of Serbia.

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Rezime

U gradskim sredinama je sve izraženija potreba za procenom zdravstvenog stanja i mehaničkih parametara dubećih stabala, ne samo zbog higijensko-sanitarne i estetske funkcije zelenila, već i zbog bezbednosti ljudi i infrastrukture. U radu su ispitana stabla crvenog hrasta (*Quercus rubra* L.) na području grada Beograda, radi procene stanja ove alohtone vrste i njene prilagođenosti urbanoj sredini u Srbiji.

Istraživanje je obuhvatilo 42 stabla koja se nalaze na teritoriji GO Savski venac (slika 1). Prsni prečnik, visina stabala i širina krošnje mereni su odgovarajućim alatima i uređajima (Weiss Bandmass 10 m; Haglöf Vertex 4; Weiss Fast Winder Frame 30 m), dok su vitalnost i dekorativnost stabala procenjeni prema VTA metodi (Mattheck & Breloer, 1994) na petostepenoj skali (tabela 1). Dobijene numeričke vrednosti su obrađene u skladu sa deskriptivnim statističkim metodama.

Rezultati istraživanja pokazuju da prsni prečnik ispitanih stabala ima raspon vrednosti 7,50–85,00 cm i srednju vrednost 45,00 cm; širina krošnje je varirala od 2,50 m do 17,50 m, sa srednjom vrednošću 11,73 m, dok je visina stabala varirala od 3,50 m do 22,50 m, sa srednjom vrednošću 14,28 m, što ukazuje na to da su uzorkovana stabla vrlo različitih starosti. S druge strane, vitalnost i dekorativnost su znatno manje varijabilne odlike ispitanih stabala. Srednja vrednost vitalnosti stabala je 4,45, a dekorativnosti 3,38 (tabela 2). U prilog tvrdnji da su ova stabla veoma dobre kondicije svedoči i njihovo zdravstveno stanje (80,95% stabala je bez vidljivih fitopatoloških promena). U poređenju sa literaturnim podacima (Bühler et al., 2007; Dahlhausen et al., 2016; Östberg et al., 2021; Pretzsch et al., 2015), utvrđene vrednosti za vitalnost stabala i njihove dimenzije (širina krošnje i, u nekim slučajevima, prsni prečnik debla) bile su veće od onih navedenih za ovu vrstu hrasta ili druge hrastove [*Q. robur* L., *Q. alba* L., *Q. palustris* Münchh., *Q. petraea* (Mattushka) Liebl.] u sličnim uslovima.

Na osnovu rezultata ovog rada, moguće je doneti zaključak da je crveni hrast dobro prilagođena vrsta gradskoj sredini Beograda i da se može preporučiti za sadnju u urbanim područjima Srbije.