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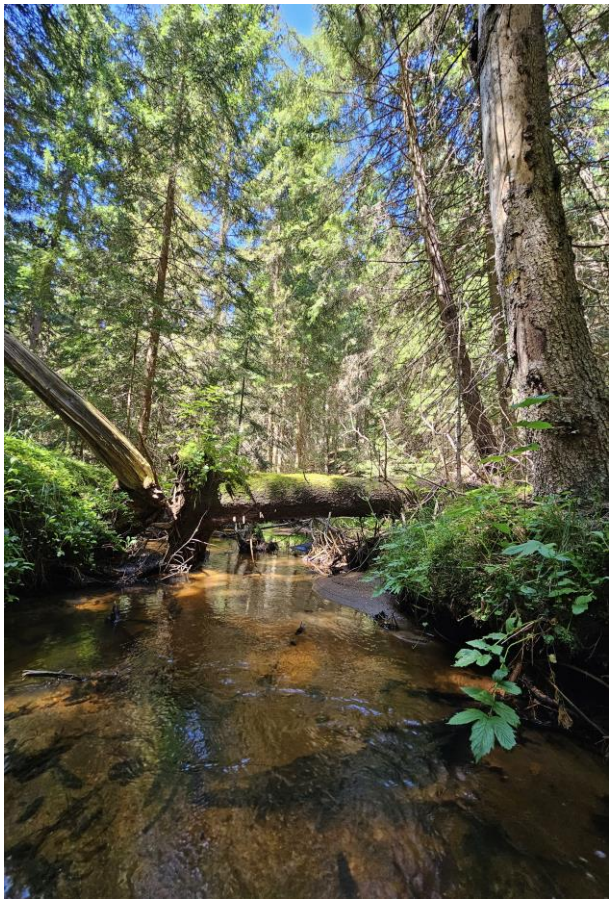

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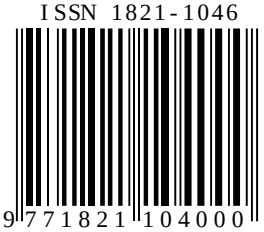

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Original scientific paper

THE MOST COMMON FUNGI ASSOCIATED WITH A DECLINE OF TURKEY OAK (*QUERCUS CERRIS* L.) IN URBAN CONDITIONS IN SERBIA

Aleksandar VEMIĆ[1], Zlatan RADULOVIĆ[1], Katarina MLADENOVIĆ[1], Ljubinko RAKONJAC[1]*

Abstract: *Turkey oak (Quercus cerris) is one of the most important tree species in park forests and parks in Serbia. Despite this, there has been no available information in domestic literature about the parasitic fungi that affect Turkey oak in urban areas. Research carried out between 2016 and 2023 identified 19 taxa of parasitic and saprotrophic fungi that colonize Turkey oak in urban conditions: one on the roots, two on the leaves, two on the bark, seven on the trunk, two on the branches, two on the fruits, two on the stumps, and one on both leaves and fruits. The most significant fungi found were Fomes fomentarius, Inonotus nidus-pici, and Fuscoporia torulosa, which cause heart rot and are typically found on individual trees. Most of the fungi identified occurred in succession. Following primary damage, the most frequently occurring fungus was Stereum hirsutum, while after mechanical injuries, Schizophullym commune was most frequently recorded. Alternaria spp. was found on old leaves and heavily damaged leaves. To protect the urban Turkey oak trees, measures should be focused on reducing tree density and preventing mechanical injuries. The findings from this research also contribute to understanding the ecological characteristics of these fungal taxa based on their frequent occurrence in urban conditions.*

Keywords: oak decline, causes, urban areas, first record.

NAJČEŠĆE GLJIVE POVEZANE SA PROPADANJEM STABALA CERA (*QUERCUS CERRIS* L.) U URBANIM PODRUČJIMA SRBIJE

Sažetak: *Cer (Quercus cerris) predstavlja jednu od najvažnijih vrsta drveća u park šumama i parkovima Srbije. Do sada u domaćoj literaturi nije bilo podataka vezano za parazitski komples gljva koje kolonizuju cer u urbanim uslovima. Istraživanje izvršeno u periodu 2016-2023 je pokazalo 19 taksona parazitskih i saprofitskih gljiva; jedan na korenu, dva na listovima, dva na kori, sedam na deblu, dva на гранама, dva na plodovima, dva na panjevima i jedan na listovima i plodovima. Najvažnije gljive su bile Fomes fomentarius, Inonotus nidus-pici i Fuscoporia torulosa prouzrokovači centralne truleži, koje su konstatovane na pojedinačnim stablima. Većina konstatovanih gljiva se javljala u sukcesiji. Posle primarnih uzročnika oštećenja, najčešća je Stereum hirsutum, dok je posle mehaničkih oštećenja najčešće konstatovana Schizophyllum commune. Alternaria spp. je zabeležena na*

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starim listovima, kao i posle teških oštećenja listova. Mere zaštite cera treba da budu usmerene u smanjenju gustine i izbegavanju mehaničkog oštećenja stabala. Dobijeni rezultati takođe doprinose poznavanju ekoloških karakteristika taksona gljiva na osnovu njihove česte konstatacije u urbanim sredinama.

Ključne reči: propadanje hrastova, uzročnici, urbana područja, prvi nalaz.

1. INTRODUCTION

The *Quercus* genus comprises approximately 500 tree species in the northern hemisphere (Cvjetićanin et al., 2016). One particularly significant species in Europe and Asia Minor is the Turkey oak (*Quercus cerris* L.), which can be found in mixed forests in the Mediterranean basin and is commonly planted in parks due to its ability to withstand urban conditions (Cvjetićanin et al., 2016; de Rigo et al., 2016). Climate change is influencing the increasing importance of Turkey oak because of its enhanced adaptability to drier conditions and ability to recover after periods of drought. Its adaptability is somewhat lower in Southern Europe (Kasper et al., 2022; Mészáros et al., 2022; Šimková et al., 2023). Consequently, it is crucial to initiate research on the biotic factors contributing to the decline of these trees to enhance the likelihood of preserving as many trees as possible. Currently, there is limited detailed information available in domestic literature on the diseases affecting Turkey oak trees, particularly in urban areas where the trees are more exposed to air pollution and extremely high temperatures.

Fungi that harm Turkey oak can be found at all stages of its growth. To properly assess the impact of these fungi, it is important to know the stage of development of the tree's vegetative organs (Bercea, 2010). Additionally, in the case of Turkey oak, drought, and insect defoliation can contribute to the appearance of specific pathogens, such as *Biscogniauxia mediterranea* (De Not.) Kuntze (Capretti & Battisti, 2007; Vannini et al., 2009).

The health status of trees in urban areas reflects the development and quality of life in those areas (Solomou et al., 2019). Moreover, specific genera of fungi, such as *Alternaria* and *Cladosporium*, which appear on trees, can cause allergic reactions in humans (Kasprzyk et al., 2021). Experiences from various parts of Europe have demonstrated that fungal diseases are the most common cause of decay in Turkey oak trees (Georgieva et al., 2018).

In light of the above, a multi-year study was conducted in Serbia to investigate the diversity of fungi associated with symptoms of Turkey oak deterioration. The initial hypotheses were: i) there are not the same symptoms caused by different fungi on Turkey oak trees; ii) the causes of Turkey oak decay in urban areas are not different from those in rural areas.

2. MATERIAL AND METHODS

2.1 Field methods

Field research was conducted in all major cities of Serbia, with a focus on Belgrade. The research involved inspecting symptomatic trees and collecting

samples from these trees for laboratory analysis. The trees were inspected three times a year: in spring, summer, and autumn. Every part of the trees was visually inspected, and samples were taken for laboratory analysis in case of visible damage. Samples of tree parts or fruiting bodies of fungi were placed in paper bags and stored in a refrigerator until the analyses began.

2.2 Laboratory methods

The fungi were isolated and identified based on their morphological characteristics from the samples collected. When identifying fungi directly from plant material, we used temporary histological preparations following the procedure described by Muntanola Cvetković (1990). We followed the description by Ellis & Ellis (1985) to identify microfungi from histological preparations. The fungi were isolated using MEA (30 g/l Biolab, Hungary; 20 g/l Torlak, Serbia) and PDA (LAB M, UK) nutrient media. Pure culture identification was carried out using the keys provided by Nobles (1948, 1964) and Stalpers (1978).

3. RESULTS AND DISCUSSION

Based on the samples taken, 19 parasitic and saprophytic fungi taxa were identified on Turkey oak in urban areas of Serbia (see Table 1).

Table 1. *Identified fungi on Turkey oak in urban areas of Serbia*

Species	Tree part	Type of damage	Frequency	Significance
Alternaria spp.	Leaves, fruits	- Fruit rot	++	+
Armillaria mellea (Vahl) Kumm.	Root	Butt rot	+	+++
Botrytis cinerea Pers.	Fruits	Fruit rot	++	+++
Cladosporium spp.	Fruits	Fruit rot	++	+
Cytospora ambiens (Pers.) Sacc.	Bark	Bark necrosis	+	++
Diplodia spp.	Leaves	Spotting	+	++
Fomes fomentarius (L.) Fr.	Trunk	Heart rot	+	+++

Species	Tree part	Type of damage	Frequency	Significance
Gnomonia quercina Kleb.	Leaves	Leaf anthracnose	+	+++
Inonotus hispidus (Bull.) Karst.	Trunk	Heart rot	++	+++
Irpex lacteus Fr.	Stump	-	+	+
Inonotus nidus-pici Pilát	Trunk	Heart rot	+++	+++
Peniophora spp.	Branches	Sap rot	+	+
Peniophora quercina (Pers.) Cooke	Branches	Sap rot	++	+
Peziza spp.	Bark	-	+	+
Omphalotus olearius (DC.) Singer	Stump	-	++	+
Fuscoporia torulosa (Pers.) Wagn. & Fisch.	Trunk	Heart rot	+	+++
Schizophyllum commune Fr.	Trunk	Sap rot	+++	++
Stereum hirsutum (Willd.) Pers.	Trunk	Sap rot	+++	++
Trametes hirsuta (Wulf.) Pil.	Trunk	Sap rot	+++	++

Addendum to the table: + Fungus appears rarely or has no significant importance

++ Fungus occurs moderately often and is important

+++ Fungus appears often and has great importance

The largest number of taxa was found on the trunk (Table 1). It was also found that fungi from this group cause the most damage to trees (Table 1, Figure 1). Fungi from this group are categorized as those that directly cause damage to trees (*Fomes fomentarius, Inonotus hispidus, Inonotus nidus-pici* and *Fuscoporia torulosa*), and others that occur on damaged trees (Table 1, Figure 1).

The fungus *Schizophyllum commune* was found on both uninjured and injured trees (see Figure 1). Description of the damaged wooden substrate type and fungi occurrence is shown in Table 2.

Table 2. *The condition of the tree damage and the presence of fungi*

Damage type	**Fungus species**
Separated bark	*Schizophyllum commune* *Stereum hirsutum*
Widened radial fissures on the bark	
Windbreaks	
Stumps	*Fuscoporia torulosa** *Irpex lacteus* *Omphalotus olearius*

* The fungus causes tree cutting

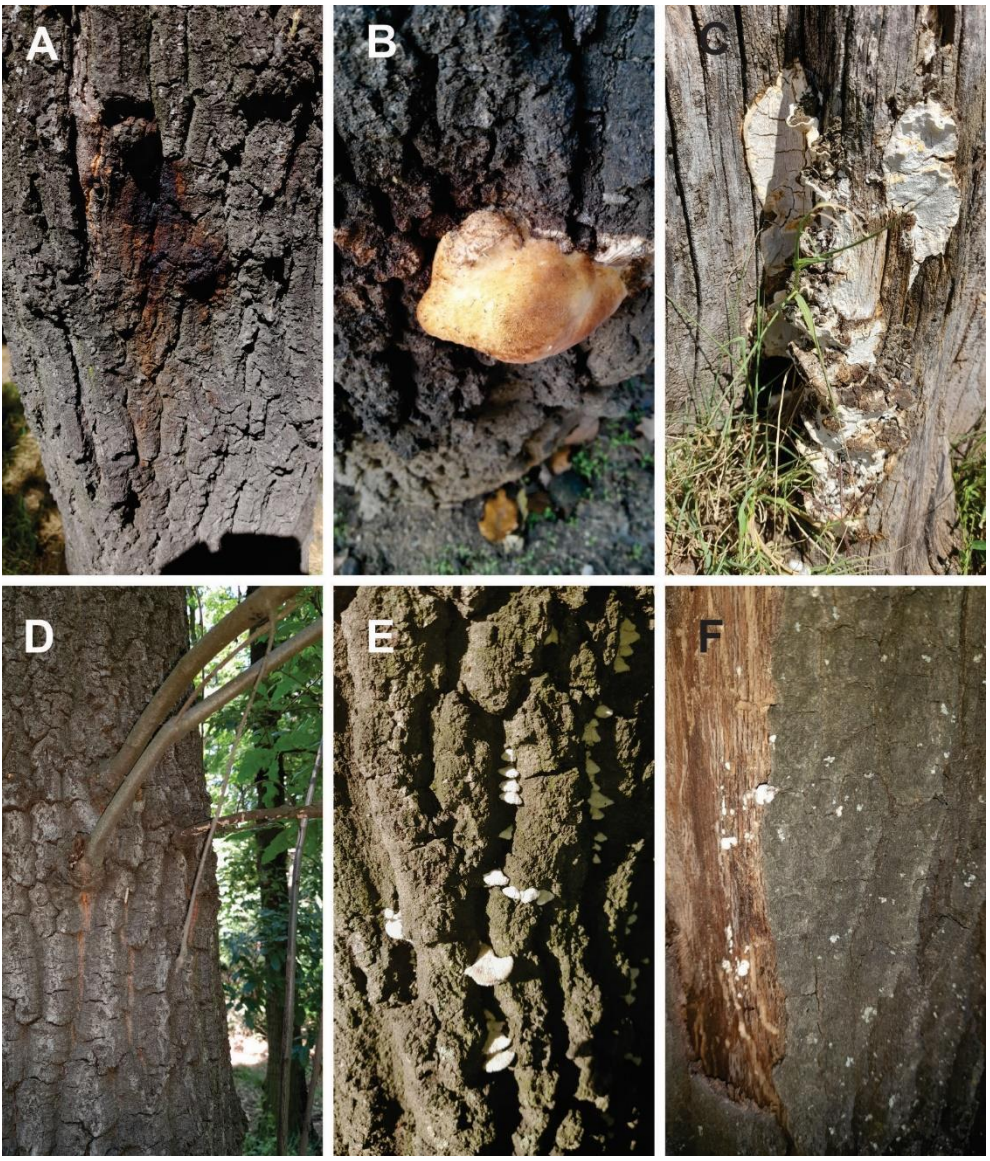

Figure 1. *The most common fungi on the trunk and stumps of Turkey oak trees in the cities of Serbia: A – Inonotus nidus-pici, B – Inonotus hispidus, C – Irpex lacteus, D – Peniophora spp., E-F – Schizophyllum commume*

Figure 2. *The most common fungi on the trunk, leaves, and stumps of Turkey oak trees in the cities of Serbia: A – Omphalotus olearius, B – Alternaria spp., C – Fuscoporia torulosa*

The number of fungal species found on Turkey oak in urban areas was lower compared to the number of fungi found in natural stands in Serbia (Karadžić et al., 2017). This could be due to the negative impact of urbanization on the presence of fungi (Meyer et al., 2021). In urban environments, there is a reduction in the diversity of fungi in the air, which is not the case with the fungi in the soil (Abrego et al., 2020). However, it is worth noting that most fungi found on Turkey oak in this study were facultative parasites, indicating that these species are actively dispersed through the air in urban conditions, unaffected by the environment. Additionally, the limited number of fungi found on the roots of Turkey oak does not necessarily mean a decrease in soil fungal diversity, as only the most common and noticeable fungi were examined for Turkey oak.

It is necessary to pay attention to *Inonotus nidus-pici*, which causes the most damage on Turkey oak in natural and urban areas (Karadžić & Milenković, 2015; Milenković et al., 2022). This fungus was recorded in Serbia on *Fraxinus angustifolia* and *Tilia platyphyllos* in urban areas, where infection spreads through wounds, probably due to climate change (Milenković et al., 2023). Most recorded fungi occur in the natural Turkey oak stands (Karadžić et al., 2017). Also, different fungi taxa have been found on previously damaged trees, causing white rot. Therefore, the first null hypothesis was rejected and the alternative hypothesis that different fungi on Turkey oak trees cause the same symptoms was accepted.

The findings are consistent with previous research (Ragazzi et al., 2003), which suggests fewer fungi on Turkey oak trees in urban areas than forests. The study also indicates that urban temperatures and conditions may contribute to the increased pathogenicity of endophytic fungi. The study identified the same fungal species in urban areas as in natural stands. As a result, the hypothesis that the causes of Turkey oak decline in urban areas are not different from those in natural areas has been rejected, and the alternative hypothesis has been accepted. Additionally, the study found no previously recorded individual species that rarely appear on Turkey oak trees (Vemić & Milenković, 2019). The researchers recommend monitoring rarely occurring fungi, such as the recently identified species *Trametes trogii* (Radulović et al., 2023), especially on other oak species to prevent the spread of infection, particularly in the context of globalization.

4. CONCLUSION

For the first time, this study detailed the diversity of the most common parasitic and saprophytic fungi on Turkey oak trees in urban conditions in Serbia. The results obtained are as follows:

- Nineteen taxa were identified, most of which were found for the first time on Turkey oak in urban areas in Serbia.
- The most important were the fungi found on the trunk. From this group, the most important were *Fomes fomentarius*, *Inonotus nidus-pici*, and *Fuscoporia torulosa*, causing white rot.
- The fungi *Schizophyllum commune* and *Stereum hirsutum* are often found on trees mechanically damaged by abiotic factors.

- The obtained results enable better planning of Turkey oak tree protection measures in the urban conditions of Serbia.

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THE MOST COMMON FUNGI ASSOCIATED WITH A DECLINE OF TURKEY OAK (*QUERCUS CERRIS* L.) IN URBAN CONDITIONS IN SERBIA

Aleksandar VEMIĆ, Zlatan RADULOVIĆ, Katarina MLADENOVIĆ, Ljubinko RAKONJAC

Summary

A multi-year study examined the mycoflora associated with symptoms in Turkey oak trees (*Quercus cerris*) in Serbian cities due to the need to preserve trees in urban areas. Nineteen fungi taxa were identified, and their distribution varied on different parts of the Turkey oak trees. The most significant number of taxa, including *Fomes fomentarius, Inonotus hispidus, Inonotus nidus-pici, Fuscoporia torulosa, Schizophyllum commune, Stereum hirsutum,* and *Trametes hirsuta*, was found on the trunk. Fewer taxa, such as *Alternaria spp., Diplodia spp.*, and *Gnomonia quercina*, were found on the leaves; *Cytospora ambiens* and *Peziza spp.* were found on the bark; *Alternaria spp., Botrytis cinerea,* and *Cladosporium spp.* were found on the fruits; *Peniophora spp.* and *Peniophora quercina* were found on the branches; and *Irpex lacteus* and *Omphalotus olearius* were found on the stumps. The smallest number of taxa was found on the root, specifically *Armillaria mellea*.

The most significant damage was caused by *Fomes fomentarius, Inonotus nidus-pici*, and *Fuscoporia torulosa*, which resulted in breaks and premature felling of the affected trees. Long-term monitoring revealed that these species were present on trees with no mechanical damage, indicating their role as the primary cause of damage. Conversely, *Schizophyllum commune* and *Stereum hirsutum* were found on damaged trees, and *Peniophora quercina* was observed on fallen branches.

The number of pathogens on the leaves was not high enough to threaten the health of the trees. *Alternaria spp.* was commonly found on leaves before they fell and on leaves that were damaged by different biotic and abiotic factors. *Botrytis cinerea* was the primary fungus affecting the fruits, causing gray mold in the cupule and nut. Other fungi were also frequently seen, but their significance was not determined.

It is essential to control the number of Turkey oak trees in park forests and parks to prevent mechanical damage, which can lead to the growth of various fungi. All the different types of fungi found should be considered when developing forest protection plans to minimize the spread of their inoculum and reduce damage to Turkey oak trees in urban areas.

The study recorded many fungi for the first time on Turkey oak trees in urban areas in Serbia. These findings provide valuable insights into the ecology of the identified fungi in urban conditions based on their presence on Turkey oak trees.

NAJČEŠĆE GLJIVE POVEZANE SA PROPADANJEM STABALA CERA (*QUERCUS CERRIS* L.) U URBANIM PODRUČJIMA SRBIJE

Aleksandar VEMIĆ, Zlatan RADULOVIĆ, Katarina MLADENOVIĆ, Ljubinko RAKONJAC

Rezime

Usled potrebe očuvanja stabala u urbanim područjima, izvršeno je višegodišnje istraživanje mikoflore povezane sa simptomima na stablima cera (*Quercus cerris*) u gradovima Srbije. Utvrđeno je devetnaest taksona gljiva, čija distribucija je različita na različitim delovima stabala cera. Najveći broj taksona: *Fomes fomentarius*, *Inonotus hispidus*, *Inonotus nidus-pici*, *Fuscoporia torulosa*, *Schizophyllum commune*, *Stereum hirsutum*, *Trametes hirsuta* je konstatovan na deblu. Manji broj taksona: *Alternaria* spp., *Diplodia* spp. i *Gnomonia quercina* su konstatovane na listovima, na kori: *Cytospora ambiens* i *Peziza* spp., plodovima: *Alternaria* spp., *Botrytis cinerea* i *Cladosporium* spp., granama: *Peniophora* spp. i *Peniophora quercina*, panjevima: *Irpex lacteus* i *Omphalotus olearius*. Najmanji broj taksona je konstatovan na korenu (*Armillaria mellea*).

Najveća oštećenja su zabeležena od *Fomes fomentarius*, *Inonotus nidus-pici* i *Fuscoporia torulosa*, koja su dovodila do lomova i prevremene seče zahvaćenih stabala. Takođe, višegodišnji monitoring je pokazao da su ove vrste konstatovane na pojedinačnim stablima na kojima nije bilo mehaničkih oštećenja, ukazujući na njihov značaj kao glavnih uzročnika oštećenja. Sa druge strane, *Schizophyllum commune* i *Stereum hirsutum* su konstatovane na oštećenim stablima, a *Peniophora quercina* na opalim granama.

Patogeni listova nisu zabeleženi u većoj brojnosti koja bi ugrozila vitalnost stabala. Najčešće je konstatovana *Alternaria* spp., na listovima pred opadanjem, kao i na listovima oštećenim usled različitih abiotičkih i biotičkih uzročnika. Na plodovima je bila najznačajnija *Botrytis cinerea* koja je izazivala sivu plesan kupula i orašica. Ostale gljive su takođe često konstatovane ali njihov značaj nije utvrđen.

Mere zaštite treba da budu usmerene u regulisanju gustine stabala cera u park šumama i parkovima, iz razloga smanjenja mehaničkog oštećenja koje pogoduje razvoju velikog broja konstatovanih gljiva. Sve konstatovane vrste gljiva treba uključiti u šire strategije zaštite šuma u cilju ograničenja prenosa njihovog inokuluma, kako bi se umanjile štete na ceru u urbanim uslovima.

Većina zabeleženih gljiva u ovoj studiji je prvi put konstatovana na ceru u urbanim uslovima Srbije. Dobijeni rezultati omogućavaju bolje poznavanje ekologije konstatovanih gljiva bazirano na njihovim nalazima na ceru u urbanim uslovima.

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