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Original paper

Schizophyllum commune – the dominant cause of trees decay in alleys and parks in the City of Novi Sad (Serbia)

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Summary. As part of a study of the main causes of dying trees in alleys and parks in the City of Novi Sad, an investigation of the presence and diversity of macrofungi was undertaken over the period 2012-2014. The relatively poor genetic diversity of lignicolous (pathogenic or potentially pathogenic and saprotrophic) macrofungi with only 24 species representing this group (19 basidiomycets and 5 ascomycets) has been recorded. The poor qualitative composition of this important ecological group of fungi could be explained by the small number of plant species present in arbored walks and alleys, but also to the reduced number of fungi resistant to heavy air pollution caused by the close proximity of (1-5 m) fuel combustion engines. Although preliminary, these results point to the necessity of conservation and protection of the most beautiful features of the Novi Sad city - its alleys, avenues and parks - by undertaking measures of curing damaged trees and treating with fungicides in order to wipe out the epiphytia caused in more than 95% of cases by split-gill (*Schizophyllum commune*), found to be present on dead wood as well as damaged trees of: *Tilia cordata*, *T. platyphyllos T. argentea, Acer negundo*, *A. platanoides*, *Aesculus hyppocastaneum, Platanus acerifolia*, *Fraxinus ornus*, *Betula pendula*, *Robinia pseudoacacia, Celtis australis, C. occidentalis, Catalpa speciosa*, *Corylus avelana, Ficus carica, Pinus silvestris, Prunus* spp., *Salix alba, Carpinus betulus pyramidalis*, etc. Altogether, over the last decade, around 200 trees have collapsed or have been sanitary felled in alleys and parks of Novi Sad due to damage caused primarily by split-gill fungus. Thus, restoration of avenues along streets characterized by very polluted air generated by combustion engine fuel, accompanied by extreme temperatures, (from -30 °C to +45 °C), prolonged drought and heavy insolation of young plants is becoming an almost impossible mission. Analysis of trees along the streets of Novi Sad revealed that, in addition to visible suffocation of plants from heavy air pollution and wide asphalt surfaces located next to tree-trunks, illnesses caused by fungi are the dominant cause of tree decay. Because it has adapted to arid climates, and is resistant to air pollution, *Schizophyllum commune* turned out to be the most aggressive and successful ubiquitous fungal invader of trees in old alleys. This fungus is also an important factor threatening immune-compromised persons: there are recorded cases in the region of allergies, abscesses and inflammatory conditions caused by this basidiomycetous fungus among individuals of the human population.

Keywords: alleys, lignicolous fungi, Novi Sad, parks, *Schizophyllum commune,* split-gill.

INTRODUCTION

Schizophyllum commune Fries, is probably the most widespread macroscopic fungus, and is found on every continent except Antarctica. According to Raper and Hoffman (1974), it is not closely related to other species without lamellas, and most investigators categorized this species in the order of Shizophyllales, but according to the contemporary Index Fungorum (2018c), it belongs to the order Agaricales (family Schizophyllaceae, Agaricomycetidae, Agaricomycetes, Agaricomycotina, phylum Basidiomycota).

This sap-rot fungus is also recognized as a plant pathogen that causes wood rot on living trees; while many plant species, including fruit and ornamental trees, even *Opuntia* sp. have also been recorded as hosts (Takemoto et al. 2010; Vázquez-Mendoza 2013). Wood-rot disease caused by this fungus is promoted in temperate climate zones by drought, freezing temperatures and other weather conditions unfavorable for plants, since the fungus is well adapted to such adverse environmental conditions. It is expected that, depending on the plant species and locality, ongoing global warming is enhancing plant damage, which may predispose

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plants to fungal infection (Matavulj et al. 2005, 2013; Cviyanovicy et al. 2009).

Schyzophyllum commune is popular as an edible fungus in Nigeria, in some regions of Mexico and the peninsula of Malaysia (Adejoye et al. 2006; Takemoto et al. 2010). However, in our climate it is inedible due to its small size and the leathery consistency of the basidiocarps, and has since proven to be super accumulator of Fe and Zn (Karaman and Matavuly 2005; Javid et al. 2010; Milovac et al. 2017). Mushroom basidiocarps can often be found on the bark of dead trees, or even on dead branches or living trees soon after their vitality has been reduced. Some scholars consider *Sch. commune* as a wound parasite or even as a saprobic (saprotroph), while others recognize it as a plant pathogen, causing "Schizophyllum rot" in living trees. The mushroom produced white rot on test substrates in vitro, which is similar to the decline observed in earlier stages in the corneal part of the lignocellulosic material (Takemoto et al. 2010).

Although *Sch. commune* hydro-distilled extracts may be considered as promising sources of phenolic and antibiotic (antioxidant, antibacterial, antifungal, antitumor) natural products (Karaman et al. 2012; Arun et al. 2015; Glumac et al. 2015, 2017; Yao et al. 2016), this fungus is also the most famous cause of human infections among the macroscopic Basidomycota. In the world, there are cases where this fungus has been shown to be a cause of allergic sinusitis, pulmonary disease, ulcerative palate lesions, meningitis and abscesses (Premamalini et al. 2011). In northern Sudan, in the southwestern parts of the USA and in northern India, fungal infections of the paranasal sinuses have been reported (Swain et al. 2011). It was reported to cause allergic bronchopulmonary mycosis (Kamei et al. 1994) in a healthy female and was repeatedly isolated from the sputum of a patient with chronic lung disease (Ciferri et al. 1956). Other reports of *Sch. commune* infection include cases of meningitis (Chavez-Batista et al. 1955), sinusitis (Kern and Uecker 1986; Rosenthal 1992; Buzina et al. 2002), ulcerative lesions of the hard palate (Restrepo 1973), and possible onychomycosis (Kligman 1950) in both immuno-competent and immunosuppressed hosts. Although it is sometimes difficult to evaluate the significance of isolation of *Sch. commune* from clinical specimens (Kligman 1950; Greer 1977), there have been a number of well-documented reports, especially involving the nasal mucosa, hard palate, and lung (Catalano et al. 1990; Rosenthal 1992; Buzina et al. 2003). To date, all confirmed cases of *Sch. commune* infection have been based on isolates which form characteristic fruiting bodies in culture. Additional features which enable identification of an isolate as *Sch. commune* include narrow hyphal pegs or spicules (Catalano et al. 1990) present on some hyphae. Greer (1977) reported that these pegs could also be observed on hyphae growing in tissue. In Japan, it has recently been identified as the cause of MIB (Mucoid impaction of the bronchi) and ABPM (Allergic bronchopulmonary mycosis). Identification *Sch. commune* using pathological patterns or smears is difficult. This mushroom appears in the longitudinal form of aggregated hypha in swabs, and it is difficult to differentiate morphologically from filamentous mushrooms such as *Aspergillus* sp. (Ishiguro et al. 2007). Human infections caused by *Sch. commune* in Serbia were reported recently by Bulajic et al. (2006), Arsic Arsenijevic et al. (2010), Pekic et al. (2010), and Perić et al. (2011).

Lithuanian scientists identified an environmental issue with *Sch. commune* at the beginning of the 21st century, that appeared on the trunks of trees alongside streets. This fungus, however, like other saprotrophs, can also lead to a parasitic lifestyle (Snieškiene and Juronis 2001). Trimming branches contributed to an increased percentage of diseased trees of the species *Tilia cordata* and *T. platyphyllos*, as well as the species *Quercus rubra* (Snieškiene et al. 2007). In addition to parasitization of these species, similar changes were observed in the species *Aesculus hyppocastaneum* (Snieskiene et al. 2011). Also, results were published suggesting an impact on the health status of species of the genera *Acer*, *Juglans*, *Fagus*, *Quercus*, *Phellodendron*, *Populus*, *Robinia* (Žiogas et al. 2007).

The simmilar problem was recorded during the last decade in Novi Sad, especially in alleys and parks with conditions inadequate for plants but favorable for the fungus which seems to be well adapted to such adverse environmental conditions. The aim of this research was to investigate the recent status of planted trees in different environmental conditions of parks and high-frequency traffic alleys and streets in Novi Sad city and eventually anticipate further development of the phenomenon of survival of horticultural plants in worsened environmental conditions in the future.

MATERIAL AND METHODS

Streets with the most frequent traffic of the Novi Sad city were analyzed over the spring and summer seasons from 2012 to 2014, from the Boulevard of Liberation (Bulevar oslobodjenja) to the Danube River (1 - Mihailo Pupin Boulevard, 2 - Maksim Gorki street, 3 - Radnička street, and 4 - Tsar Lazar Boulevard). In addition to these streets, the health conditions of trees in the Danube park (DP) and the University campus park (UP) was monitored, with the intention to determine the species of trees affected by *Sch. commune* (Figure 1).

Individual visual inspection of the trees was used to determine their health condition. The presence of pests and overall health status was assessed, ranging from healthy young trees, at-risk trees with partially damaged trunks and peak branches, to diseased trees and dead trees. Visual inspection involved identification of damage on the trees in terms of their vitality and changes to the treetop and possibly the tree-trunk itself.

Fungi were identified on the basis of both morphologi-

Figure 1. Localities (streets and parks) in Novi Sad investigated on *Schizophyllum commune* incidence. (**1** - Mihailo Pupin Boulevard; **2** - Maksim Gorki street; **3** - Radnička street; **4** - Tsar Lazar Boulevard; **DP** - Danube park; **UP** - University campus park)

cal and anatomical properties of fruit bodies, as well as according to specific chemical reactions using modern keys (Webster 1980; Phillips 1981; Hermann 1990; Uzelac 2009).

RESULTS

Out of a total of 833 analyzed trees in four streets in the wider center of Novi Sad, 213 trees were infected, as indicated by the presence of fungal fruiting bodies (26%); 386 trees were healthy without any visible infection (46%); 101 trees were considered to be young (12%); 69 trees were found to be at risk (8%); 53 trees were dead and recommended for removal (6%); 6 trees were recently removed (1%); and 5 trees were trimmed (1%). Less than half of the observed trees were relatively healthy, without any visible signs of invasion by the parasite.

Out of 27 species of identifiable lignicolous mushrooms in the spring and summer period within Novi Sad woods and parks, 22 species belonged to the Basidiomycotina division and 5 to the Ascomycotina division. Basidiomycets were represented by 12 species belonging to the order Polyporales (plus 1 species belonging to Aphyllophorales, earlier known as Polyporales), 5(6?) species belonging to Agaricales, 2 species of Russulales, one species of Auriculariales and one species of Schizophyllales (Agaricales?).

The general health condition of trees in the University Park, with respect to the presence of *Sch. commune* species, was found to be much more satisfactory when compared to the health condition of tree trunks in the four analyzed city streets. There are a large number of trees in this park, but representatives of the species *Populus euramericana* and *Platanus* spp. are predominant. It is important to point out that mainly populations of *Platanus* species had preserved vitality, with no trees with recorded sporocarps of lignicolous fungi on them. This could be influenced by the location of the park on the alluvium of the river Danube and the relatively shallow groundwater that protects these trees from summer droughts, but from the extreme low temperatures too. Unlike *Platanus* spp., the existence of other types of lignicolous macro-fungi were recorded on the stumps of species of *Populus* genus (*P. alba, P. euramericana, P. nigra)* (Table 1).

In the Danube park, which has official status as a Nature monument, the presence of other lignicolous fungal species, not found in University park and alleys of the studied streets, were recorded. Heavy infestation of *Sch. commune* on various species of trees in Novi Sad city alleys and parks in the course from spring 2013 to the winter 2014, listed in Table 2, is also partially documented in Figure 2.

Table 1. Generic composition of macrofungi found on trees and parks of the city of Novi Sad.

Fungal species	Taxonomic position Order and Familia	Locality	Plant host species
Schizophyllum commune Fries 1815	Agaricales (Schizophyllales), Schizophyllaceae	Parks, Alleys Streets	
Funalia trogii Berk 1850	Polyporales, Polyporaceae	U Park	*Populus euramericana* stump, *Populus alba* branch
Lentinus strigosus Fr.	Polyporales, Polyporaceae	U Park	*Tilia* sp., *Populus euramericana* tree trunks
Laetiporus sulphurens (Bull.) Murrill	Polyporales, Polyporaceae	U Park	*Populus euramericana*, *Salix alba* tree trunks
Agrocybe aegerita (V. Brig.) Singer	Agaricales, Strophariaceae	U Park	*Populus euramericana*, *Populus nigra* stumps
Fomes fomentarius (L.) J.J. Kickx 1867	Polyporales Polyporaceae	U Park, Alley	*Populus* spp.; *Salix alba* tree trunk
Stereum hirsutum (Willd.) Pers. 1800	Russulales, Polyporaceae (Stereaceae)	U Park, Alley	*Tilia* spp. tree trunk; *Salix alba* stump
Stereum rugosum Pers. 1794	Russulales, Polyporaceae (Stereaceae)	D Park, Alley	*Tilia* sp. tree trunk
Coriolus versicolor (L.) Quél. 1886 *Trametes vrsicolor* (L.) Pilát.	Aphyllophorales, Coriolaceae	U Park, Alley	*Salix alba* tree trunk; Lime branch;
Trametes hirsuta (Wulfen) Pilát, (1939)	Polyporales, Polyporaceae	D Park	*Tilia* sp. tree trunk
Flammulina velutipes (M.A. Curtis) Singer, 1951	Agaricales, Tricholomataceae	U Park	*Salix alba* tree trunk
Trametes gibbosa (Pers.) Fr., (1836) *Pseudotrametes gibbosa* (Pers.) Bondartsev & Singer 1944	Polyporales, Polyporaceae	U Park, Alley	*Populus euramericana*, *Aesculus hypocastaneum* stumps
Ganoderma applanatum (Pers.) Pat.	Polyporales, Ganodermataceae	U Park	*Salix alba* tree trunk
Ganoderma resinaceum Boud.	Polyporales, Ganodermataceae	U Park	*Salix alba* stump
Ganoderma lucidum (Curtis) P. Karst	Polyporales, Ganodermataceae	U Park	*Salix alba* tree trunk
Ganoderma adspersum (Schulzer) Donk	Polyporales, Ganodermataceae	U Park	*Tilia* sp. tree trunk
Polyporus squamosus Huds.) Quélet (1886)	Polyporales, Polyporaceae	U Park	*Salix alba* tree trunk
Piptoporus betulinus (Bull. ex Fr.) P. Karst.	Polyporales, Fomitopsidaceae	U Park	*Betula* sp. tree trunk
Panellus stipticus (Bull.) P. Karst. (1879)	Agaricales, Mycenaceae	U Park	*Salix alba* stump
Pholliota squarosa (Oeder) Kumm. (1871)	Agaricales, Strophariaceae	U Park	*Populus* sp. stump
Meripilus giganteus (Pers.) P. Karst. 1882	Agaricales, Meripilaceae	U Park	*Ae. hypocastaneum* stump
Auricularia auricula-judae (Bull.) J. Schröt.	Auriculariales, Auriculariaceae	U Park	*Sambucus nigra* fallen dry branch
Rhytisma acerinum Schwein., (1832)	Rhytismatales, Rhytismataceae	U Park	*Platanus* sp. leaves
Bulgaria imquinans (Pers.) Fr. (1822)	Helotiales, Bulgariaceae	D Park	*Quercus* sp. fallen branch
Nectria cinnabarina (Tode: Fr.) Fr. 1849	Hypocreales, Hypocreaceae, (Nectriaceae)	D Park	*Tilia* sp. dry fallen branch
Xylaria hypoxylon (L.) Grev.(1824)	Xylariales, Xylariaceae	D Park	*Ae. hypocastaneum* stump
Xylaria polymorpha (Pers.) Grev., (1824)	Xylariales, Xylariaceae	U Park	*Ae. hypocastaneum* stump

DISCUSSION

Climate change has had a major impact on the health status and survival of woody plant species. According to some estimates, southern Europe is expected to experience an increase in air temperature of around 2-3 °C during the summer over the next decades. It is also expected to have decreased summer precipitation by 5-15%. The Balkan Peninsula is included in this drought endangered area. Also, from the beginning to mid of February 2012, in Novi Sad the lowest temperatures were recorded during the last two decades, which lasted several days below -30 °C (Smailagić et al 2012), and killed the most of fig trees that were successfully cultivated in the course of more than 40 years in the University campus park.

All of these changes will likely result in a decrease in

Table 2. The *Schizophyllum commune* incidence on various species of trees in Novi Sad alleys and parks.

Tree species	English name	Fungal supstrate	Locality
Betula pendula	Silver birch, warty birch	Tree trunk	U Park
Tilia cordata	Small-leaved lime	Tree trunk, branch	U Park, Alley
Tilia platyphyllos	Large-leaved lime	Tree trunk, branch	U Park, Alley
Tilia argentea (T. tomentosa)	Silver lime	Tree trunk, branch	U Park, Alley
Acer platanoides	Norway maple	Tree trunk, branch	U Park, Alley
Acer negundo	Box elder, boxelder maple	Tree trunk, branch	D Park, Alley
Acer pseudoplatanus	Sycamore maple	Tree trunk	U Park
Corylus avelana	Common hazel	Tree trunk	U Park
Aesculus hypocastaneum	Horse-chestnut tree	Tree trunk, fallen branch	U Park, Alley
Salix alba	White (golden) willow	Tree trunk	U Park
Robinia pseudoacacia	Black locust	Tree trunk	U Park
Fraxinus ornus	South European flowering ash	Tree trunk	U Park, Alley
Prunus sp.	Plum	Tree trunk, branch	U Park
Catalpa speciosa	northern (western) catalpa, hardy catalpa, cigar tree	Tree trunk	Alleys
Carpinus betulus pyramidalis	European hornbeam, pyramidal form	Tree trunk	U Park, Alley
Platanus acerifolia	London plane, hybrid plane	Tree stump	U Park
Celtis australis	European nettle tree, Mediterranean hackberry	Tree stump	U Park, Alleys
Celtis occidentalis	American nettle tree, common hackberry	Tree stump	U Park, Alleys
Ficus carica	Fig, Common fig	Tree stump	U Park
Pinus silvestris	Scots pine	Tree stump	U Park

the vitality of woody plant species and their gradual decline, mainly for the following reasons: reduction of soil moisture, the occurrence of climatic extremes, reduction of the vegetation period, reduction of resistance to harmful biotic factors, the occurrence of epiphytosis of pathogenic fungi and insects, all of which lead to the wide scale decay of trees in parks and alleys.

In urban sites like cities, there are additional aggravating factors such as tree grafting into asphalt and other types of impermeable surfaces, air pollution by exhaust gases from motor vehicles, inadequate maintenance which involves pruning over the course of the vegetation season, the absence of wound healing during pruning, the inadequate removal of diseased or damaged parts of trees, etc. (Snieškienė and Juronis 2007; Takemoto et al. 2010; Matavulj et al. 2013).

On the basis of our obtained results, the necessity of preserving and protecting the most beautiful features of the city of Novi Sad in the form of measures for treating damaged trees and reviving trees, as well as replacing dead trees with young plantings of the same or some other species of tree. The present study revealed a wide distribution of *Sch. commune* fungus in the horticultural plantations of Novi Sad, suggesting that this species is the most aggressive macroscopic basidiomycet that attacks different species of trees. Because it was recorded in streets with frequent traffic, it can be said that this species has adapted to a high level of air pollution, in accordance with earlier reported findings by Krbić et al. (2010), Škrbić et al. (2012), Matavulj et al. (2013), and Milovac et al. (2017).

Also, it can be concluded that in the studied area this parasitic species mainly infects host tree species of *Tilia* (linden), *Acer* (maple) and *Aesculus* (chestnut), generally on dead dry, broken or trimmed branches of wounded but still alive trees. The present study also suggests that this parasitic species is well adapted to extreme air pollution, and evident climate change in the form of severe winters and summer droughts that were not characteristic of the climate of this region some decades ago. Similar results were recorded recently in Lithuania (Snieskiene et al. 2011; Snieškienė et al. 2011) and Bosnia (Matavulj et al. 2013; Milovac et al. 2017) where the condition of *Aesculus hyppocastaneum*, caused by infection of fungal pathogens, has worsened, and includes *Sch. commune.*

In a more positive note, streets where the avenue is made up of species of the genus *Celtis* certainly stand out. Unlike linden, *Celtis* species, European (*C. australis*) and American (*C. occidentalis*) hackberry proved to be much more resistant to this kind of mushroom. Although the nettle tree is aesthetically endangered in terms of crushing branches due to pruning and strong winds, as well as recent

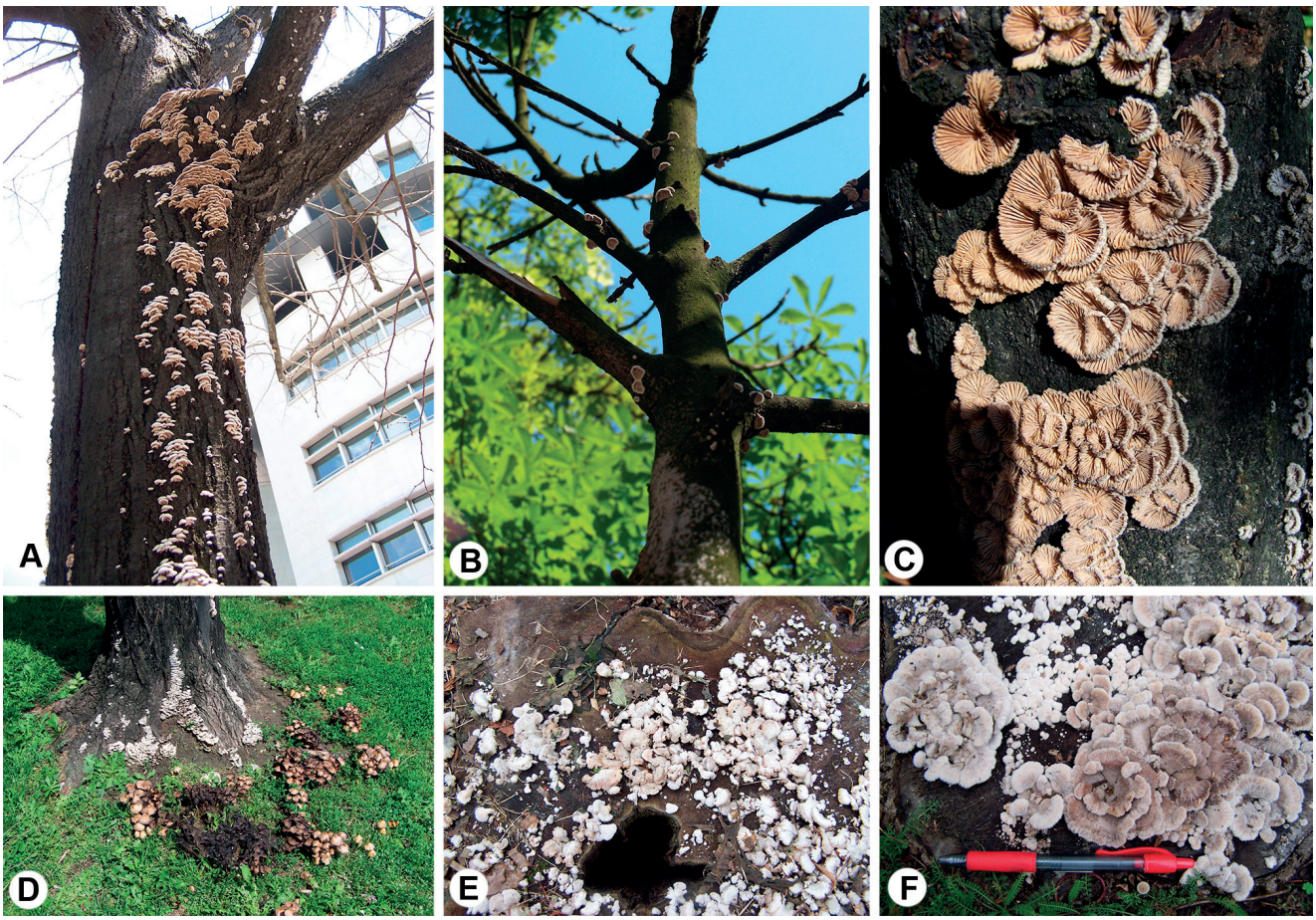

Figure 2. Heavy infestation of *Schizophyllum commune* on various species of trees in Novi Sad city. (**A** - Dead Tree of *Tilia* sp. with visible longitudinal cracks occurred due to freezing during the previous winter 2012; **B** - Dry branches of young tree of *Aesculus hypocastaneum*; **C** - Branches of *Tilia* sp displayed from below; **D** - Base of *Tilia* sp. tree with secondary infestation of underground root parts; **E** - *Aesculus hypocastaneum* stump; **F** - The old stump of *Pinus silvestris*).

construction work due to the reconstruction of Radnička street, *Celtis* species resisted parasitism by this and other lignicolous mushrooms.

By analyzing the health conditions of trees in the Danube park and University Park, we attempted to determine the extent to which *Sch. commune* has become an aggressive species and universal parasite with cosmopolitan distribution in our climatic conditions. Unlike the Danube Park, which is located in an unfavorable heavy traffic location in terms of anthropogenic impact, the University Park is in a somewhat better position, but characterized by a smaller biodiversity of species. The main difference between these two parks is that a large number of individual trees in the University Park are London hybrid plane, that have proved to be much more resistant to *Sch. commune*. However, species of willow, birch and acacia are susceptible to risk. Also, in this park we recorded species of lignicolous mushrooms on poplar stumps (Table 1). *Celtis* spp. proved to be more resistant to *Sch. commune* infection, along with a *Platanus acerifolia* hybrid, as is the case in other parts of the city.

CONCLUSIONS

Although preliminary, our present study suggests the necessity of conservation and protection of the most beautiful features of the city of Novi Sad - its alleys and avenues - by means of undertaking measures for curing damaged trees and treating infected trees with fungicides in order to eliminate the epiphytia caused by Split-gill fungus. According to results of our analyses, over the study period, 213 trees were sick and 53 trees were proposed for complete removal due to poor general condition and signs of disease in the form of heavy *Sch. commune* basidiocarps presence, loss of leaves and drying branches. The percentage of trees at risk indicates the possibility of further spread by *Sch. commune*, while the number of young trees indicates that certain mea-

sures in the city are being undertaken to restore alleys, but that these measures do not appear to be the right solution for combating the given species of mushrooms, if other necessary measures are not applied such as regular watering, removal of dead branches, and expansion of soil space around bigger trees.

The extreme low and high temperatures (from -30 °C to + 45 °C) as a result of climate change that have affected our temperate climate over the past few decades have had a strong impact on vegetation conditions. In addition to extreme high and low temperatures, concrete and asphalt greatly influence the health conditions of alley trees, reducing the flow of water and air to the root system, as well as adding mechanical pressure to the root system of the trees. Parasitism by the fungus *Sch. commune* was noted on more than 85% of species of plants in the studied area, suggesting the ubiquitous distribution and aggressiveness of this species, which is also more and more threatening to immune-compromised and even healthy human individuals.

Besides the species of *Sch. commune*, in the area of Novi Sad, 26 other species of lignicolous mushrooms were recorded on trees, branches and stumps of woody plant species.

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