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Diversity of macromycetes in the Botanical Garden "Jevremovac" in Belgrade

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ABSTRACT: At locations in the outdoor area and in the greenhouse of the Botanical Garden "Jevremovac", a total of 124 macromycetes species were noted, among which 22 species were recorded for the first time in Serbia. Most of the species belong to the phylum Basidiomycota (113) and only 11 to the phylum Ascomycota. Saprobes are dominant with 81.5%, 45.2% being lignicolous and 36.3% are terricolous. Parasitic species are represented with 13.7% and mycorrhizal species with 4.8%. Inedible species are dominant (70 species), 34 species are edible, five are conditionally edible, eight are poisonous and one is hallucinogenic (*Psilocybe cubensis*). A significant number of representatives belong to the category of medicinal species. These species have been used for thousands of years in traditional medicine of Far Eastern nations. Current studies confirm and explain knowledge gained by experience and reveal new species which produce biologically active compounds with anti-microbial, antioxidative, genoprotective and anticancer properties. Among species collected in the Botanical Garden "Jevremovac", those medically significant are: *Armillaria mellea*, *Auricularia auricula.-judae*, *Laetiporus sulphureus*, *Pleurotus ostreatus, Schizophyllum commune, Trametes versicolor, Ganoderma applanatum, Flammulina velutipes* and *Inonotus hispidus.* Some of the found species, such as *T. versicolor* and *P. ostreatus*, also have the ability to degrade highly toxic phenolic compounds and can be used in ecologically and economically justifiable soil remediation.

Keywords: Botanical Garden "Jevremovac", diversity, macromycetes

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INTRODUCTION

Botanical gardens were established worldwide in order to collect, preserve and study plants autochthonous for specific areas, as well as to introduce them to other parts of the world. These artificial habitats with controlled conditions and diverse plants create favourable conditions for the development of fungi, and botanical gardens accordingly have an important role in their preservation. Studies of macromycetes in the Botanical Garden Soroksár (District of Budapest) began 40 years ago and 274 mushroom species, among which several are rare and protected species, were identified (Rimoczi 1998). Elsewhere, Folcz & Borcsok (2015) during two years of study noted 171 fungal species in the Botanical Garden of the University of West Hungary in Sopron. Besides outdoor areas, monitoring of macromycetes in greenhouses and cloches has also been performed, and Szczepkowski *et al.* (2014) noted 206 species in greenhouses in five European cities. Moreover, the fungi of urban areas, with special emphasis on rare and parasitic species, have been the subject of numerous investigations (Folcz & Borcsok 2015). Knowledge of the diversity of fungi has considerable significance, especially from the aspect of their role in biodegradation, i.e., degradation of plant residues and carbon cycles in nature, as well as in synthesis of various biologically active agents (Stajić 2015).

The goal of this study was to investigate the diversity of macromycetes in outdoor areas and the greenhouse of the Botanical Garden "Jevremovac" in Belgrade in order

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to determine whether specific environmental conditions and floristic content have effects on their development and record potential new hosts/substrates for autochthonous fungal species.

MATERIAL AND METHODS

Study area. The Botanical Garden "Jevremovac" in Belgrade (established in 1889) is a legacy of King Milan Obrenović and a protected cultural monument of Belgrade (Fig. 1A). Located at a longitude of 20° 28' 38" E, latitude of 44° 50' 31" N and altitude of slightly below 100 m (between 86.82 and 99.85 m), it covers an area of up to 5 ha and has a temperate continental climate and neutral to weakly alkaline soil (Jovanović-Juga 2005).

Outdoor area. The dendroflora of the outdoor area is composed of about 300 plant species. Besides a significant number of autochthonous species, some of which are endemorelicts, numerous allochthonous species, especially from Eastern Asia and North America, are also present (Jovanović-Juga 2005).

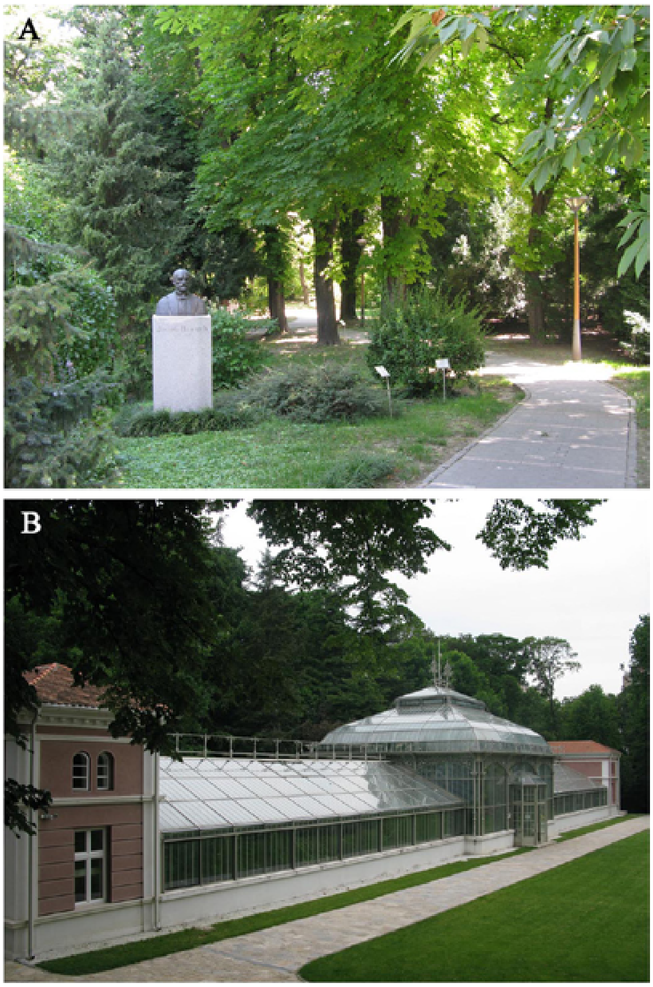

Fig. 1. Botanical Garden „Jevremovac", Faculty of Biology, University of Belgrade: **a)** entrance to the garden; **B)** greenhouse.

Greenhouse. The Victorian-style greenhouse of the Botanical Garden "Jevremovac" was built in 1892 and reconstructed in 2015. It is composed of a centrally placed high dome and two lower side wings, and extends over an area of 560 m^2 (Fig. 1B). The greenhouse is divided into three air regimes, where more than 1000 tropical, subtropical, Mediterranean and desert plant species from all over the world are grown (Bjelić-Mesaroš 2005).

Collection and identification of samples. Monitoring of fungi in outdoor areas and in the greenhouse of the Botanical Garden "Jevremovac" was performed from October 2014 to the end of March 2016, with different observation dynamics depending on climatic conditions. A total of about 90 targeted observations of outdoor land with herbaceous vegetation and trees, as well as land, trees and decorative logs in the greenhouse, were carried out (Table 1). Monitoring of outdoor areas with trained dogs was performed on February 2, 2016 with the aim of finding tubers.

Fruiting bodies were photographed in natural habitats and data on the substrate, neighbouring plants and collection dates were noted. Morphological features of collected fruiting bodies, such as shape, size, colour, odor, hymenophore and velum types, etc., were analysed. Spore slides were prepared in glycerin and fuchsin acid and observed under a light microscope (Zeiss Axio Imager M.1, with AxioVision Release 4.6 software). Some samples were isolated on a Malt agar medium, and macroscopic and microscopic characteristics of isolates were observed for precise identification. Identifications were done using relevant literature (Pace 1981; Phillips 1981; Breintebach & Kränzlin 1984-2000; Cappelli 1984; Příhoda *et al.* 1986-87; Cetto 1988, 1993; Dermak & Pilát 1988; Hrka 1988; Garnweidner 1990; Dëhncke 1993; Courtecuisse & Duhem 1994; Arzenšek *et al.* 2002; Davidović 2007; Božac 2008). Fungal classification and nomenclature are in compliance with Index Fungorum, and a list of species is presented in alphabetic order. Species were also classified in the ecological-trophic groups defined by Arnolds (1981) and designated by abbreviations: ST = saprotrophic terricolous, SL = saprotrophic lignicolous, P = parasitic (including both necrotrophic and biotrophic) and M = mycorrhizal.

Selected samples are maintained as exsiccates, and isolated cultures are preserved in the culture collection of the Institute of Botany (Faculty of Biology, University of Belgrade) for further use in mycological studies.

RESULTS AND DISCUSSION

Macromycetes diversity. During the studied period, a total of 124 fungal species were collected and identified, 93 species in outdoor areas and 31 species in the greenhouse, which represents the first register of species in the Botanical Garden "Jevremovac" (Table 1). According to the results

Table 1. List of macromycetes collected in the Botanical Garden "Jevremovac" in Belgrade.

Species	Ecological trophic groups	Family	Order	Date and place of collection
Agaricus bitorquis (Quelet) Sacc.	ST	Agaricaceae	Agaricales	19.10.2015 OA
Agaricus campestris L.	ST	Agaricaceae	Agaricales	11.10.2015 OA
Agaricus cappellianus Hlaváček	ST	Agaricaceae	Agaricales	11.10.2015 OA
Agaricus dulcidulus Schulzer	M	Agaricaceae	Agaricales	19.10.2015 OA
Agaricus impudicus (Rea) Pilát*	ST	Agaricaceae	Agaricales	02.10.2014 OA
Agaricus moelleri Wasser	ST	Agaricaceae	Agaricales	22.09.2015 OA
Agaricus radicatus (Vittad.) Romagn.	ST	Agaricaceae	Agaricales	07.10.2015 OA
Agaricus semotus Fr.	ST	Agaricaceae	Agaricales	07.10.2015 OA
Agaricus xanhodermus Genev.	ST	Agaricaceae	Agaricales	11.10.2015 OA
Agrocybe vervacti (Fr.) Singer	ST	Agaricaceae	Agaricales	09.05.2015 OA
Amylostereum areolatum (Chaillet ex Fr.) Boidin	P	Amylosteraceae	Russulales	06.11.2014 OA
Amylostereum laevigatum (Fr.) Boidin	SL	Amylosteraceae	Russulales	06.11.2014 OA
Antrodia malicola (Berk. & M.A. Curtis) Donk*	SL	Fomitopsidaceae	Polyporales	11.10.2015 OA
Antrodia pulvinascens (Pilát) Niemelä*	SL	Fomitopsidaceae	Polyporales	11.01.2016 G
Antrodia xantha (Fr.) Ryvarden	SL	Fomitopsidaceae	Polyporales	14.12.2014 OA
Armillaria bulbosa (Barla) Kile & Watling	P	Physalacriaceae	Agaricales	30.10.2014 OA
Armillaria mellea (Vahl) P. Kumm.	P	Physalacriaceae	Agaricales	30.10.2014 OA
Auricularia auricula-judae (Bull.) Quél.	SL	Auriculariaceae	Auriculariales	22.09.2015 G
Calvatia gigantea (Batsch) Lloyd	M	Agaricaceae	Agaricales	22.09.2015 OA
Cheilymenia granulata (Bull.) J. Moravec*	ST	Pyronemataceae	Pezizales	06.02.2016 G
Chondrostereum purpureum (Pers.) Pouzar	P	Cyphellaceae	Agaricales	06.12.2015 OA
Conocybe pulchella (Velen.) Hauskn. & Svrček	ST	Bolbitaceae	Agaricales	24.11.2014 OA
Coprinellus disseminatus (Pers.) J.E. Lange	SL	Psathyrellaceae	Agaricales	02.10.2014 OA
Coprinellus domesticus (Bolton) Vilgalys, Hopple & Jacq. Johnson	ST	Psathyrellaceae	Agaricales	03.05.2015 G
Coprinellus impatiens (Fr.) J.E. Lange	ST	Psathyrellaceae	Agaricales	22.09.2015 G
Coprinellus micaceus (Bull.) Vilgalys, Hopple & Jacq. Johnson	ST	Psathyrellaceae	Agaricales	22.11.2014 OA
Coprinellus radians (Desm.) Vilgalys, Hopple & Jacq. Johnson	SL	Psathyrellaceae	Agaricales	17.03.2015 G
Coprinellus silvaticus (Peck) Gminder	SL	Psathyrellaceae	Agaricales	30.10.2014 OA
Coprinellus subimpatiens (Schaeff.) Readhead, Vilgalys & Moncalvo	ST	Psathyrellaceae	Agaricales	02.10.2015 OA
Coprinellus truncorum (Scop.) Redhead, Vilgalys & Moncalvo	SL	Psathyrellaceae	Agaricales	02.11.2014 OA
Coprinellus xanthothrix (Romagn.) Vilgalys, Hopple & Jacq. Johnson	SL	Psathyrellaceae	Agaricales	21.03.2015 G
Coprinopsis atramentaria (Bull.) Redhead, Vilgalys & Moncalvo	ST	Psathyrellaceae	Agaricales	17.04.2015 OA
Coprinopsis cinerea (M. Lange & A.H. Sm.) Readhead, Vilgalys & Moncalvo	ST	Psathyrellaceae	Agaricales	22.09.2015 OA
Coprinus comatus (O.F. Müll.) Pers.	ST	Agaricaceae	Agaricales	09.10.2014 OA
Coprinus romagnesii Locq.	ST	Agaricaceae	Agaricales	19.10.2014 OA
Crepidotus bresadolae Pilát*	SL	Inocybaceae	Agaricales	02.11.2014 OA
Crustomyces subabruptus (Bourdot & Galzin) Jülich*	SL	Cystostereaceae	Polyporales	14.12.2014 OA

Species	Ecological trophic groups	Family	Order	Date and place of collection
Cyclocybe aegerita (V. Brig.) Vizzini	SL	Strophariaceae	Agaricales	13.12.2014 OA
Cylindrobasidium evolvens (Fr.) Jülich	SL	Physalacriaceae	Agaricales	18.12.2014 OA
Daldinia concentrica (Bolton) Ces. & De Not.	SL	Xylariaceae	Xylariales	03.05.2015 G
Daldinia vernicosa Ces. & De Not.	SL	Xylariaceae	Xylariales	11.01.2016 G
Entoloma infula (Fr.) Noordel.	ST	Entolomataceae	Agaricales	18.10.2015 OA
Fuscoporia ferruginosa (Schrad.) Murrill	SL	Hymenochaetaceae	Hymenochaetales	11.10.2015 OA
Flammulina fennae Bas*	SL	Physalacriaceae	Agaricales	13.10.2015 G
Flammulina velutipes (Curtis) Singer	SL	Physalacriaceae	Agaricales	18.12.2014 OA
Ganoderma adspersum (Schulzer) Donk	P	Ganodermataceae	Polyporales	01.10.2015 G
Ganoderma applanatum (Pers.) Pat.	P	Ganodermataceae	Polyporales	20.02.2016 OA
Ganoderma resinaceum Boud.	P	Ganodermataceae	Polyporales	02.10.2014 OA
Gleocystidiellum leucoxanthum (Bres.) Boidin*	SL	Stereaceae	Russulales	14.12.2014 OA
Granulobasidium vellereum (Ellis & Cragin) Jülich*	P	Cyphellaceae	Agaricales	19.10.2014 OA
Gymnopus dryophilus (Bull.) Murrill	ST	Omphalotaceae	Agaricales	28.10.2015 OA
Helicobasidium purpureum (Tul.) Pat.*	P	Helicobasidiaceae	Helicobasidiales	02.11.2014 OA
Helvella acetabulum L. Quél.	M	Helvellaceae	Pezizales	07.04.2015 OA
Homophron spadiceum (P.Kumm.) Örstadius & E. Larss.	ST	Psathyrellaceae	Agaricales	01.10.2015 OA
Hypsizygus tessulatus (Bull.) Singer	SL	Lyophyllaceae	Agaricales	12.11.2014 OA
Hypsizygus ulmarius (Bull.) Redhead	SL	Lyophyllaceae	Agaricales	11.01.2016 OA
Inonotus hispidus (Bull.) P. Karst.	P	Hymenochaetaceae	Hymenochaetales	01.10.2015 OA
Lacrymaria lacrymabunda (Bull.) Pat.	ST	Psathyrellaceae	Agaricales	11.10.2015 OA
Laetiporus sulphureus (Bull.) Murrill	P	Fomitopsidaceae	Polyporales	09.10.2014 OA
Lepista glaucocana (Bres.) Singer	ST	Tricholomataceae	Agaricales	05.10.2015 OA
Lepista nuda (Bull.) Cooke	ST	Tricholomataceae	Agaricales	17.03.2016 OA
Leucoagaricus leucothites (Vittad.) Wasser	ST	Agaricaceae	Agaricales	07.10.2015 OA
Leucoagaricus rubrotinctus (Peck) Singer*	ST	Agaricaceae	Agaricales	30.04.2015 G
Leucocoprinus birnbaumii (Corda) Singer*	ST	Agaricaceae	Agaricales	21.03.2015 G
Leucocoprinus brebissonii (Godey) Locq.*	ST	Agaricaceae	Agaricales	10.02.2016 G
Marasmius epodius Bres.*	ST	Marasmiaceae	Agaricales	11.10.2015 G
Marasmius rotula (Scop.) Fr.	SL	Marasmiaceae	Agaricales	31.03.2015 G
Melanoleuca melaleuca (Pers.) Murrill	ST	Tricholomataceae	Agaricales	19.10.2015 OA
Meripilus giganteus (Pers.) P. Karst.	SL	Meripilaceae	Polyporales	06.10.2014 OA
Mycena aetites (Fr.) Quél.	ST	Mycenaceae	Agaricales	18.10.2015 OA
Mycena latifolia (Peck) Mussat	ST	Mycenaceae	Agaricales	02.11.2014 OA
Mycena polygramma (Bull.) Gray	SL	Mycenaceae	Agaricales	19.10.2014 OA
Mycena stylobates (Pers.) P. Kumm.	ST	Mycenaceae	Agaricales	19.10.2015 OA
Mycoacia fuscoatra (Fr.) Donk*	SL	Meruliaceae	Polyporales	18.12.2014 OA
Nectria cinnabarina (Tode) Fr.	P	Nectriaceae	Hypocreales	20.12.2015 OA
Neonectria galligena (Bres.) Rossman & Samuels	P	Nectriaceae	Hypocreales	19.10.2015 OA
Odontia fibrosa (Berk. & M.A. Curtis) Kõljalg*	SL	Thelephoraceae	Thelephorales	16.01.2015 OA
Parasola hemerobia (Fr.)Redhead, Vilgalys & Hopple	ST	Psathyrellaceae	Agaricales	06.12.2015. G
Parasola leiocephala (P.D. Orton) Redhead, Vilgalys & Hopple	ST	Psathyrellaceae	Agaricales	31.03.2015 G
Parasola plicatilis (Curtis) Redhead, Vilgalys & Hopple	ST	Psathyrellaceae	Agaricales	30.10.2014 OA
Peniophorella pubera (Fr.) P. Karst.	SL	Rickenellaceae	Hymenochaetales	20.12.2015 OA

Species	**Ecological trophic groups**	**Family**	**Order**	**Date and place of collection**
Peziza domiciliana Cooke	ST	Pezizaceae	Pezizales	07.04.2015 OA
Phlebia radiata Fr.	SL	Meruliaceae	Polyporales	20.12.2015 OA
Phleogena faginea (Fr.) Link	SL	Phleogenaceae	Atractiellales	26.04.2015 G
Phloeomana alba (Bres.) Redhead	SL	Porotheleaceae_	Agaricales	11.10.2015 OA
Pleurotus dryinus (Pers.) P. Kumm.	SL	Pleurotaceae	Agaricales	20.02.2016 OA
Pleurotus ostreatus (Jacq.) P. Kumm.	SL	Pleurotaceae	Agaricales	13.01.2015 OA
Pluteus cervinus (Schaeff.) P. Kumm.	SL	Pluteaceae	Agaricales	13.12.2014 OA
Pluteus phlebophorus (Ditmar) P. Kumm.	SL	Pluteaceae	Agaricales	20.02.2016 G
Pluteus podospileus Sacc. & Cub.	SL	Pluteaceae	Agaricales	19.10.2014 OA
Pluteus romellii (Britzelm.) Sacc.	SL	Pluteaceae	Agaricales	11.10.2015 G
Polyporus squamosus (Huds.) Fr.	P	Polyporaceae	Polyporales	27.09.2015 OA
Postia stiptica (Pers.) Jülich	SL	Fomitopsidaceae	Polyporales	20.12.2015 G
Protostropharia semiglobata (Batsch) Redhead, Moncalvo & Vilgalys	S	Strophariaceae	Agaricales	02.11.2014 OA
Psathyrella candolleana (Fr.) Maire	ST	Psathyrellaceae	Agaricales	07.10.2015 OA
Psathyrella multipedata (Peck) A.H. Sm.	ST	Psathyrellaceae	Agaricales	18.10.2015 G
Psathyrella piluliformis (Bull.) P.D. Orton	SL	Psathyrellaceae	Agaricales	18.10.2015 OA
Psathyrella pygmaea (Bull.) Singer	ST	Psathyrellaceae	Agaricales	19.10.2015 G
Psathyrella rostellata Örstadius*	SL	Psathyrellaceae	Agaricales	29.11.2015 G
Psathyrella spadiceogrisea (Schaeff.) Maire	ST	Psathyrellaceae	Agaricales	20.12.2015 OA
Psilocybe cubensis (Earle) Singer*	ST	Hymenogastraceae	Agaricales	31.03.2014 G
Radulomyces molaris (Chaillet ex Fr.) M.P. Christ.	SL	Pterulaceae	Agaricales	18.12.2014 OA
Sarcodontia spumea (Sowerby) Spirin	SL	Meruliaceae	Polyporales	30.10.2014 OA
Schizophyllum amplum (Lév.) Nakasone	SL	Schizophyllaceae	Agaricales	11.10.2015 OA
Schizophyllum commune Fr.	SL	Schizophyllaceae	Agaricales	17.03.2015 G
Schizophyllum radiatum Fr.*	SL	Schizophyllaceae	Agaricales	23.02.2016 G
Schizopora paradoxa (Schrad.) Donk	SL	Schizoporaceae	Hymenochaetales	11.10.2015 OA
Scleroderma cepa Pers.	M	Sclerodermataceae	Boletales	30.09.2014 OA
Scleroderma verrucosum (Bull.) Pers.	M	Sclerodermataceae	Boletales	03.11.2014 OA
Sistotrema coroniferum (Höhn. & Litsch.) Donk*	SL	Hydnaceae	Cantharellales	22.01.2015 OA
Steccherinum ochraceum (Pers.) Gray	P	Meruliaceae	Polyporales	21.03.2015 OA
Stereum gausapatum (Fr.) Fr.	SL	Stereaceae	Russulales	29.11.2014 OA
Stereum subtomentosum Pouzar	SL	Stereaceae	Russulales	11.10.2015 OA
Stropharia coronilla W. Saunders & W.G. Sm.	ST	Strophariaceae	Agaricales	05.05.2015 OA
Subulicystidium longisporum (Pat.) Parmasto*	SL	Hydnodontaceae	Trechisporales	02.11.2014 OA
Trametes trogii Berk.	SL	Polyporaceae	Polyporales	06.11.2014 OA
Trametes versicolor (L.) Lloyd	SL	Polyporaceae	Polyporales	06.11.2014 OA
Trechispora stellulata (Bourdot & Galzin) Liberta*	SL	Hydnodontaceae	Trechisporales	20.12.2015 OA
Tremella mesenterica Retz.	P	Tremellaceae	Tremellales	14.12.2014 OA
Tubaria sp.	SL	Tubariaceae	Agaricales	22.09.2015 OA
Tuber brumale Vittad.	M	Tuberaceae	Pezizales	06.02.2016 OA
Xylaria digitata (L.) Grev.	SL	Xylariaceae	Xylariales	18.06.2015 G
Xylaria longipes Nitschke	SL	Xylariaceae	Xylariales	17.05.2015 G
Xylaria polymorpha (Pers.) Grev.	SL	Xylariaceae	Xylariales	18.06.2015 G

ST = saprotrophic terricole; SL = saprotrophic lignicole; P = parasitic (including both necrotrophic and biotrophic); M = mycorrhizal; OA = outdoor area; G = greenhouse; * = first record for Serbia.

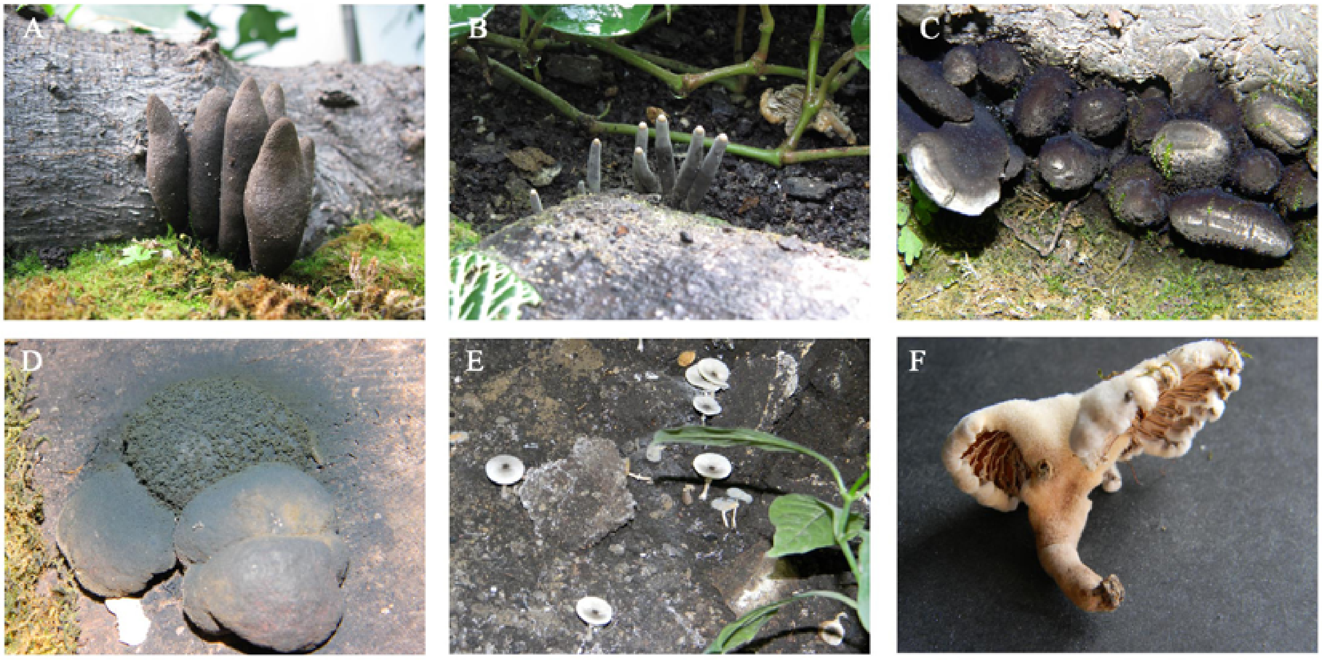

Fig. 2. Stromata and fruiting bodies: **A)** *Xylaria digitata*; **B)** *X. longipes;* **C)** *X. polymorpha*; **D)** *Daldinia concentrica*; **E)** *Leucocoprinus brebissonii* and **F)** *Schizophyllum radiatum*.

of taxonomic analysis, 91.1% of representatives belong to the phylum Basidiomycota and only 8.9% to Ascomycota, of which six species were collected in the greenhouse (*Cheilymenia granulata*, *Daldinia concentrica*, *D. vernicosa*, *Xylaria digitata*, *X. longipes* and *X. polymorpha*) and four in outdoor areas (*Nectria cinnabarina*, *Neonectria galligena*, *Peziza domiciliana* and *Tuber brumale*) (Table 1). In total, 15 orders were identified, along with 77 species belonging to Agaricales (36 genera) and 17 species to Polyporales (12 genera), while other orders are represented with 1-5 species.

The continuous presence of stromata with perithecia in species from the family Xylariaceae (*X. digitata, X. longipes, X. polymorpha* and *D. concentrica*) was noted in the greenhouse, which is not the case in nature (Fig. 2A-D). Fruiting bodies of the terricolous species *Leucocoprinus brebissonii* were noted in all three air regimes of the greenhouse throughout most of the whole observation period (Fig. 2E). This phenomenon can be attributed to higher humidity and temperature in the greenhouse, which is favourable for the development of saprotrophic species. The common species *Schizophyllum commune* was noted in the outdoor area, and *Schizophyllum radiatum*, a species characteristic of regions with a tropical climate, was present on decorative logs in the greenhouse, a first record for Serbia (Fig. 2F).

Saprotrophic species are dominant with a proportion of 81.5%, 45.2% being lignicolous and 36.3% terricolous; parasitic species are represented with 13.7% and mycorhizal species with 4.8% (Fig. 3). Although lignicolous species are the most numerous, limiting factors for their

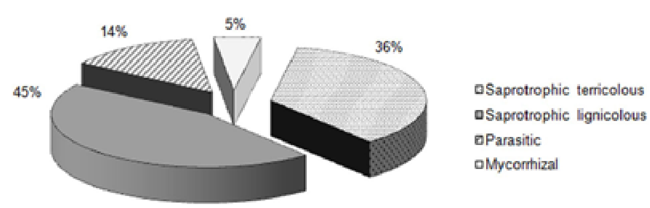

Fig. 3. Proportion of ecological trophic groups of macromycetes.

development include the removal of plant residues (only insignificant amounts are left) and plant treatments with fungicides, which is a common procedure in protected areas. According to the BioRAS database (1998) and numerous publications (Ivančević 2002; Hadžić 2005; Cvijanović *et al.* 2009; Vukojević & Hadžić 2013), 22 species (17.7%) were not noted until now in Serbia, and the obtained results therefore represent a significant contribution to knowledge about diversity of the country's macromycetes (Figs. 4, 5). Although the identified species cannot be found in the list of rare and endangered species in Serbia (SGRS 2010-2011), this should be accepted only in part because a revision of that list is necessary.

Lignicolous species were also dominant on decayed lignocellulosic residues in the Zasavica Nature Reserve (Serbia) (Cvijanović *et al.* 2009), and the majority of them were noted in the Botanical Garden "Jevremovac". Significant data on the diversity of macromycetes in Serbia were recorded by members of Serbian Mycological

Fig. 4. Species recorded for the first time in Serbia: A) *Agaricus impudicus*; B) *Antrodia malicola*; C) *Antrodia pulvinascens*; D) *Cheilymenia granulata*; E) *Crepidotus bresadolae*; F) *Crustomyces subabruptus*; G) *Flammulina fennae*; H) *Gleocystidiellum leucoxanthum*; I) *Granulobasidium vellereum*; J) *Helicobasidium purpureum*; K) *Leucoagaricus rubrotinctus*; L) *Leucocoprinus birnbaumii.*

Society in its organ, The World of Mushrooms. Thus, Ivančević (2002) presented a list of about 600 species from Serbia and Montenegro, which were found by reviewing the mycological literature until 1993, but the author emphasised that the number is higher because numerous records were not published. During 12 years of monitoring macromycetes on Ada Ciganlija Island in Belgrade, about 250 species, predominantly saprotrophic lignicolous species from the Basidiomycota, were collected and identified (Hadžić 2005). Despite its close geographic

Table 2. Allochthonous plants as hosts/substrates for macromycetes.

Fungal species	Plant	Origin of the plant
Coprinellus silvaticus	*Fagus moesiaca* (K.Malý) Czeczott	Balkan Peninsula
Ganoderma applanatum	*Corylus colurnoides* C.K.Schneid.	North China, Korea, Japan
	Diospyros virginiana L.	East of North America
Hypsizygus tessulatus	*Aesculus hippocastanum* L.	Balkan Peninsula (FYR of Macedonia, Bulgaria, Greece);
Hypsizygus ulmarius	*Ulmus minor* Mill.	Central Europe to Urals, North Africa, Asia Minor
	Celtis occidentalis	Eastern and Central America
Inonotus hispidus	*Sophora japonica* L.	China, Korea, Japan
Polyporus squamosus	*Koelreuteria paniculata* Laxm.	North China, Korea, Japan
Sarcodontia spumea	*Acer campestre* L.	Europe, Western Asia
Tuber brumale	*Corylus colurna* L.	Balkan Peninsula, Romania, Asia Minor

proximity to Ada Ciganlija, 22 species new for Serbia were found in the Botanical Garden "Jevremovac", and it can be concluded that the studied area has an important role in the protection of fungal diversity, as was emphasised elsewhere by Lacheva & Radoukova (2014) after mycological analysis of the Chivira Protected Area in the Sredna Gora Mountains of Bulgaria.

Some allochthonous plant species were hosts or substrates for the development of lignicolous species whose fruiting bodies on these plants were noted for the first time in Serbia (Table 2). This was the case with *Celtis occidentalis* and *Diospyros virginiana* (originating from North America), where *Hypsizygus ulmarius* and *Ganoderma applanatum* were found; as well as with *Corylus colurnoides, Sophora japonica* and *Koelreuteria paniculata* (originating from North China, Korea and Japan), where macromycetes were also noted in the Botanical Garden "Jevremovac".

Significance of macromycetes. Analysis of the collected species showed that only 34 species are considered edible, five are conditionally edible and eight are poisonous, while 70 species are inedible, primarily due to the woody consistency of their fruiting bodies. Among edible species, *Agaricus campestris*, *Calvatia gigantea*, *Cyclocybe aegerita*, *Flammulina velutipes* and *Pleurotus ostreatus* are considered to be delicious culinary species, and *Tuber brumale* is especially prized. In the case of poisonous species, four species are from the genus *Agaricus* (*A. moelleri*, *A. radicatus*, *A. semotus* and *A. xanthodermus*), two from the genus *Leucocoprinus* (*L. birnbaumii* and *L. brebissonii*) and one from the genus *Entoloma* (*E. infula*) and genus *Scleroderma* (*S. cepa*), but they are not deadly poisonous (Table 1; Fig. 6).

Some representatives belong to the category of medicinal species. There is a large body of published data on long-term use of fungi in traditional medicine, and the benefit of possessing a healing property is confirmed by modern science. Thus, *Armillaria mellea* has been traditionally used against vertigo and epilepsy, and it is now known that its extracts possess significant antioxidative properties (Stajić *et al.* 2013). Extracts of *Auricularia auricula-judae*, *Meripilus giganteus*, *Laetiporus sulphureus* and *Pleurotus ostreatus* basidiocarps are also good antioxidative agents due to a high proportion of the phenols, gallic, caffeic and protocatechuic acids. Numerous mushroom species have a cytotoxic potential. Thus, the polysaccharide schizophyllan isolated from *Schizophyllum commune* showed antitumor activity based on immunomodulatory properties; the polysaccharide POPS-1 from *P. ostreatus* has high cytotoxic activity against cervical cancer cells; *Ganoderma applanatum* terpenes and terpenoids act against melanoma cells; and extracts of *Coprinus comatus* act against breast and prostate cancer cells (Lo & Wasser 2011; Schneider *et al.* 2011; Patel & Goyal 2012; Yahayaa *et al.* 2014). Proteins from *Flammulina velutipes* have cytotoxic activity against melanoma, hepatoma and leukaemia cells, while the proteoglucans Krestin and PSP from *Trametes versicolor* act against various cancer cell lines (El Enshasy & Hatti-Kaul 2013; Knežević *et al.* 2015; Stajić 2015).

The highly regarded edible mushroom *P. ostreatus* also has antihypercholesterolemic effects owing to the synthesis of lovastatin; terpenes and terpenoids from *Ganoderma applanatum* are antihypertensive; and extracts of *Agaricus campestris*, *Lepista nuda* and *Coprinus comatus* basidiocarps have an antihyperglycemic capacity (Lo & Wasser 2011; Schneider *et al.* 2011; Patel & Goyal 2012). Efficient antiviral agents are the peptide pleurostrin, isolated from *P. ostreatus*, phenolic compounds from *Inonotus hispidus*; and proteins of *F. velutipes*, while *G. applanatum* terpenoids, psaliotin from the slightly poisonous species *Agaricus xanthodermus* and extracts of *Calvatia gigantean* and *L. nuda* possess an antibacterial

Fig. 5. Species recorded for the first time in Serbia: A) *Leucocoprinus brebissonii*; B) *Marasmius epodius*; C) *Mycoacia fuscoatra*; D) *Odontia fibrosa*; E) *Psathyrella rostellata*; F) *Psilocybe cubensis*; G) *Schizophyllum radiatum*; H) *Sistotrema coroniferum*; I) *Trechispora stellulata*; J) *Subulicystidium longisporum.*

potential (El Enshasy & Hatti-Kaul 2013; Yahayaa *et al.* 2014; Stajić 2015).

Lignicolous species also have a potential for soil remediation due to their well developed ligninolytic enzyme system and high rate of mycelial growth (Manoharachary *et al.* 2005). Eggen & Majcherczyk (1998) and Winquist *et al.* (2014) noted high efficiency of *Pleurotus ostreatus* and *Trametes versicolor* in the degradation of polycyclic aromatic hydrocarbons. Phthalates are also highly toxic environmental pollutants, ones which can be completely degraded by *T. versicolor* and *Daldinia concentrica* after 6 days of incubation (Lee *et al.* 2004). Besides the mentioned abilities, *T. versicolor* has a significant potential for the mineralisation of parabens due to the production of active laccase isoforms (Mizuno *et al.* 2009). Generally, some fungal species possess the capacity to degrade phenolic pollutants in non-toxic or weakly toxic compounds, which can then be further mineralised by bacteria. Intensive studies with the goal of selecting the most efficient degrader(s) and obtaining recombinant systems with a higher potential of xenobiotic

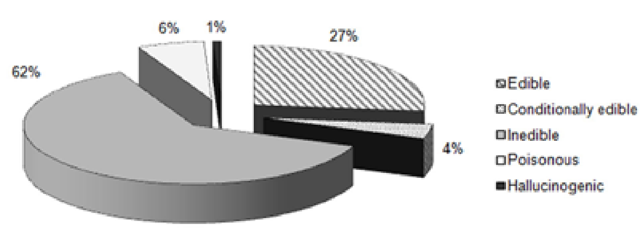

Fig. 6. Proportion of macromycetes according to edibility.

depolymerisation are currently being carried out because bioremediation is an ecologically and economically justifiable process.

CONCLUSION

As the the first monitoring of macromycetes in the Botanical Garden "Jevremovac", the present study increases our knowledge about the biodiversity of that area and about the mycobiota in urban environments and protected micro-locations in general. Cultures of many of the recorded species will be used in further mycological studies, i.e., in testing of their biological potential.

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Botanica SERBICA

REZIME

Diverzitet makromiceta u botaničkoj bašti “Jevremovac” u Beogradu

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Na otvorenom prostoru i u stakleniku Botaničke bašte “Jevremovac” zabeležene su 124 vrste makromiceta od čega su 22 vrste prvi put nađene u Srbiji. Najveći broj vrsta pripada razdelu Basidiomycota (113) a samo 11 razdelu Ascomycota. Dominantni su saprobi sa 81,5%, i to 45,2% saprobne lignikolne i 36,3% saprobne terikolne vrste, paraziti su zastupljeni sa 13,7%, a mikorizne vrste sa 4,8%. Najveći broj pripada kategoriji nejestivih (70 vrsta), jestive su 34 vrste, 5 je uslovno jestivih, 8 otrovnih i jedna halucinogena (*Psilocybe cubensis*). Značajan broj predstavnika pripada kategoriji lekovitih tj. medicinski značajnih vrsta. Poznato je dugogodišnje korišćenje gljiva u tradicionalnoj medicini Dalekoistočnih naroda. Savremena istraživanja potvrđuju i objašnjavaju iskustvena znanja i otkrivaju nove vrste koje produkuju biološki aktivne supstance koje imaju antimikrobna, antioksidativna, antikancerogena i genoprotektivna svojstva. Među sakupljenim vrstama u Botaničkoj bašti “Jevremovac” medicinski značajne su: *Armillaria mellea*, *Auricularia auricula-judae*, *Laetiporus sulphureus*, *Pleurotus ostreatus, Schizophylum commune, Trametes versicolor, Ganoderma applanatum, Flammulina velutipes* i *Inonotus hispidus*. Neke od zabeleženih vrsta, kao što su *Trametes versicolor* i *Pleurotus ostreatus*, imaju i sposobnost razgradnje visoko-toksičnih fenolnih jedinjenja zbog čega se mogu koristiti u remedijaciji zemljišta što je ekološki i ekonomski prihvatljiviji proces.

Ključne reči: Botanička bašta „Jevremovac“, diverzitet, makromicete.