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Fungal diversity as influenced by soil characteristics

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Abstract

The purpose of this study was to determine the influence of soil properties on the biodiversity of soil fungi. An analysis of the fungal diversity of eight different soil types with different soil texture, organic matter, carbonate content, pH, cation exchange capacity and different land uses identified a total of 38 different species grouped in 24 genera. Among all soil fungi identified, the most common were organic matter decomposers. The species most frequently identified were *Aspergillus* spp., *Alternaria* sp., *Fusarium* spp., *Mortierella* sp. and *Penicillium* spp. The greatest similarities between fungal communities were seen in arable land with a low or moderate cation exchange capacity and organic matter content, while the least similarities were found between forest *Cambisol* (*CM*) and garden soils. The Shannon-Wiener diversity index indicated the highest diversity in *Chernozem* (*CH*), *Fluvisol* (*FL*) and *Arenosol* (*AR*) all used as arable land or garden soil, while the lowest diversity was recorded in a *Gleysol* (*GL*) under a meadow, caused by poor aeration and a poor water regime. Canonical correlation analysis (CCA) showed the relationship of soil fungi with all soil environmental factors analysed and indicated that certain soil fungi were positively related to organic matter, sand and clay content.

Key words: biodiversity, land use, soil fungi.

Introduction

Soils are one of the largest biodiversity reservoirs, and biological diversity in the soil is several times greater than on the surface. The biochemical activity of microorganisms affects the pedogenetic process and thus participates in the creation and maintenance of soil fertility. Fungi play a key role in ecosystem function, primarily due to the decomposition of plant residues (Bridge, Spooner, 2001). Quantitative and qualitative improvement of organic matter (OM) in the soil is mainly found in agroecosystems that contain many fungi communities, but the mechanisms that lead to this improvement are not fully understood (Six et al., 2006). Critical stages of lignin decomposition are almost completely carried out by soil fungi, while the cleavage of complex biomolecules in the soil, such as cellulose and tannin, is also caused by fungal enzymatic activity (Cannon, 1999). Many fungal species grow and develop in the soil, but only a few have adapted to the unfavourable conditions prevailing in acidic or alkaline soils (Jeewon, Hyde, 2007). Some studies have shown the influence of edaphic properties on the growth and development of fungi (Lauber et al., 2008; Rousk et al., 2010).

Different subtypes of *Chernozem* (*CH*) are dominant at the investigated area, which is the best soil for agricultural production. *Chernozem* provide optimal opportunity for all types of field production. The river valleys are abundantly represented by different types of alluvial soils (*Fluvisol*, *FL*) and are the most productive land for vegetable production. *Fluvisol* ecological characteristics depend largely on the flooding and groundwater regime (Nešić, 2011). Meadow and gleyed soils are also high quality soils, but their production potential can be realized only when climatic conditions are optimal. Most of the *Vertisol* (*VR*) in Vojvodina, Serbia are heavy textured, and thus have unfavourable water-air properties (Belić et al., 2011). *Cambisol* (*CM*) occur on mountain terrain that is suitable for production of fruits and grapes. *Arenosol* (*AR*) in Subotička and Deliblatska sandstone represent the area with the prevailing initial soils (Nešić, 2011).

This paper presents an analysis of the abundance of fungi population in eight soil types that have very different physical and chemical properties as well as different land use. Soil texture, organic matter content, carbonate content, pH and cation exchange capacity (CEC) can all significantly affect the diversity and abundance of soil fungi, which is why the aim of this study was to determine the influence of soil properties on the biodiversity of fungi. It is likely that we currently

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know at least 30% of the total diversity of soil fungi, and the number of species of soil fungi is expected to be considerably higher than the 3300 species currently known (Gams, 2007). This research contributes to a better knowledge of the biodiversity and the mycobiota present in soil samples of different types and usage.

Materials and methods

Analyses of soil samples. Soil samples were taken in the summer of 2013, from different soil groups (WRB, 2014) in Serbia: *Arenosol* (*AR*) (N 46°07′09″, E 19°45′55″), *Leptosol* (*LP*) (N 45°09′27″, E 19°46′41″), *Chernozem* (*CH*) (N 45°20′31″, E 19°51′26″), *Cambisol* (*CM*) (N 45°09′43″, E 19°46′31″), *Fluvisol* (*FL*) (N 45°14′50″, E 19°51′02″), *Vertisol* (*VR*) (N 45°18′07″, E 21°03’32″), *Gleysol* (*GL*) (N 45°06′29″, E 20°57′03″) and *Solonetz* (*SN*) (N 45°31′21″, E 20°11′44″). The representative soil samples were taken from the surface (0–20 cm depth) layer using a soil probe. At every sampling point three replicates were taken approximately 10 m apart. Some physical and chemical properties of soil were determined: 1) texture – using the pipette method (Na-pyrophosphate is used for preparing soil samples for analysis) (Thun et al., 1955); 2) pH value – potentiometrically in the suspension of soil and water, and soil and 1 M KCl (1:2.5, w/v); 3) $CaCO_3$ content – volumetrically, using Scheibler calcimeter (SSR Uniglas, Serbia); 4) organic matter (OM) content – by dichromate wet oxidation method; 5) cation exchange capacity (CEC) – soil extraction with sodium acetate and ammonium acetate, and the concentration of Na^+ in the extract, by inductively coupled plasma.

Fungal isolation and identification. Selective water agar media amended with streptomycin were used to isolate fungi from soil samples by the particle-plating method. The particle-plating method was used, because it usually yields higher numbers of taxa than the dilution plating method. Soil particles weighing 0.0001 g were placed in a Petri dish with medium (5 pieces per Petri dish, in seven replicates). A total of 35 soil pieces (0.0035 g of soil dry weight) per sample were analysed after seven days of incubation at room temperature (25–28°C). The emerging fungal colonies were observed microscopically and transferred to suitable medium for further analysis of morphological characteristics. Final identification was done according to the keys of Leslie and Summerell (2006) and Watanabe (2010). The total number of colonies of each species was recorded, and for further data analyses, the number of colonies of fungus species 0.0035 g^{-1} dry weight soil/soil type was converted to the abundance of soil fungus – number of colony forming units (CFU) per g of dry weight soil/soil type.

Data analysis. The Sorensen index of similarity (IS) was used to compare fungal communities in different soil types according to the formula:

$$IS = (2C/A + B) \times 100,$$

where C is the number of species found in both A and B soil samples, A – the total number of species found in soil sample A, B – the total number of species found in soil sample B.

The diversity of samples of different soil types was analysed by the Shannon-Wiener index (H') and calculated according to the formula:

$$H' = -\sum_{i=1}^{n} p_i \ln p_i$$

where p_i is the proportion of number of colonies of the i-th species to the total number of colonies when $i = 1, 2, 3, \ldots, n$.

The relationship between soil fungi and soil physical and chemical properties was analysed using the ordination method with canonical correlation analysis (CCA).

Results and discussion

Analyses of physical and chemical soil properties. Physical and chemical properties of eight different soil types investigated (Table 1) were consistent with previous results of the authors who investigated those soil types in Serbia (Belić et al., 2011; Nešić, 2011). *Arenosols* are formed on Aeolian sand characterized by a very fine sandy texture and therefore having an unfavourable water and air regime. Ranker has a coarse sandy loam texture. In contrast, *Chernozem* has a favourable loamy clay texture, as well as *Cambisol* which is characterized by a loamy clay texture. The *Fluvisol* investigated was characterized by clayic loamy texture while the *Solonetz* was characterized by a loamy clay texture and was moderately humic. CEC is one of the most important factors affecting soil fertility, because it prevents leaching and the loss of cations from the soil. The CEC can vary in a very wide range in different soils (Schiefer et al., 2015), from 1–2 to more than 100 $cmol^+ kg^{-1}$, but in most of the soils in Vojvodina, it usually varies in the range of 25–35 $cmol^+ kg^{-1}$ (Ćirić et al., 2016), as shown in Table 1.

Diversity of soil fungi. An analysis of the biodiversity of eight different soil types identified a total of 38 different fungal species grouped in 24 genera. The total number of species identified in samples S1–S8 was 10, 15, 17, 9, 9, 16 and 16, respectively. The most common soil fungi identified were organic matter decomposers, but there were many phytopathogenic fungal species such as *Fusarium* spp. (eight different species), *Macrophomina phaseolina*, *Dreschlera* sp. and *Bipolaris* sp., mostly found in soil samples from arable

Table 1. Physical and chemical properties of the soil types investigated (mean values ± SD)

Sample code	Soil group	Land use	Particles content %				OM %	$CaCO_3$ %	pH		CEC $cmol^+ kg^{-1}$
			coarse sand	fine sand	silt	clay			1 M KCl	H_2O	
S1	*Cambisol*	forest	1.4 ± 0.5	33.2 ± 1.7	35.9 ± 1.5	29.5 ± 0.7	1.71 ± 0.09	0 ± 0	3.59 ± 0.04	4.96 ± 0.04	25.3 ± 2.9
S2	*Leptosol*	meadow	52.7 ± 3.7	26.9 ± 6.2	14.4 ± 2.7	6.0 ± 0.9	8.82 ± 0.41	0 ± 0	6.00 ± 0.09	6.82 ± 0.12	57.7 ± 5.1
S3	*Arenosol*	arable	9.7 ± 1.8	77.1 ± 2.3	6.9 ± 1.5	6.3 ± 1.0	1.69 ± 0.08	2.7 ± 0.4	7.46 ± 0.08	8.03 ± 0.07	18.6 ± 2.1
S4	*Solonetz*	arable	6.4 ± 1.7	27.7 ± 1.5	36.3 ± 2.7	29.6 ± 2.4	2.73 ± 0.12	0 ± 0	6.00 ± 0.04	7.65 ± 0.05	25.0 ± 2.4
S5	*Gleysol*	meadow	3.4 ± 0.6	26.4 ± 1.3	24.6 ± 0.6	45.6 ± 1.8	3.69 ± 0.22	3.1 ± 0.3	7.03 ± 0.06	7.70 ± 0.02	30.0 ± 1.8
S6	*Vertisol*	garden	1.6 ± 0.5	26.8 ± 2.0	31.6 ± 2.1	40.1 ± 0.7	3.66 ± 0.28	0.3 ± 0.1	5.99 ± 0.07	6.98 ± 0.06	29.6 ± 1.5
S7	*Fluvisol*	garden	1.8 ± 0.1	39.4 ± 1.5	36.7 ± 2.5	22.1 ± 1.0	1.87 ± 0.19	3.7 ± 0.3	7.17 ± 0.01	8.01 ± 0.03	22.4 ± 3.1
S8	*Chernozem*	arable	0 ± 0	36. 2± 1.1	30.2 ± 0.7	33.6 ± 0.4	2.54 ± 0.14	0.4 ± 0.1	6.00 ± 0.05	7.00 ± 0.07	21.9 ± 0.9

OM – organic matter, CEC – cation exchange capacity lands or gardens. A few species were isolated that are known to be good antagonists to phytopathogenic species and usable for biological control, e.g., *Trichoderma* spp., *Gliocladium* sp. and *Penicillium* spp. (Table 2).

The biomass of fertile soils can be even up to 20 t ha^{-1}, and the largest share of the total amount of soil biomass is 98% fungi, 1.90% bacteria and up to 0.10% actinomycetes (Lee, Pankhurst, 1992). The CFU of microorganisms per gram of soil is vast and usually in a range from 10^2 to 10^7 depending on the group of organisms and agroecological factors. In this study the CFU of fungi per gram of soil varied from 0.285 × 10^3 to 5.714 × 10^3. Variation in the total number of soil fungal species and their abundance can be noticed from one soil type to another. Fungal species that were present in all soil types (frequency 100%) were *Mortierella* sp. and *Penicillium* sp. 1 (Table 2). On the other hand, some species appeared only in one soil type (frequency 12.50%) such as *Aspergillus fumigatus*, *A.* section *clavati* sp., *Dreschlera* sp., *Epicoccum* sp., *Fusarium graminearum*, *F. sambucinum*, *F. semitectum*, *F. subglutinans*, *Periconia* sp., *Ramichloridium* sp., *Scolecobasidium* sp., *Trichoderma* sp. 2 and *Ulocladium* sp. The species distribution can be categorized according to the number of soil types in which each species was identified (species frequency in Table 2), and number of species with different distributions was shown in Figure 1.

Table 2. The abundance of soil fungi (CFU g^{-1} dry weight soil/soil sample × 10^3) identified in eight soil types

No.	Species	Abundance (CFU g^{-1} × 10^3)								Frequency %
		S1	S2	S3	S4	S5	S6	S7	S8	
F1	*Acremonium* sp.							0.571	0.285	25.00
F2	*Alternaria* sp.	0.285	0.285	0.285	0.857	0.285		0.857		75.00
F3	*Aspergillus fumigatus*				0.285					12.50
F4	*A. niger*			1.428					2.857	25.00
F5	*A. parasiticus*			0.857	0.285			0.285		25.00
F6	*A.* section *clavati* sp.				0.285					12.50
F7	*Aspergillus* sp.	0.857						0.857	0.285	50.00
F8	*Bipolaris* sp.		0.285					0.571		25.00
F9	*Chaetomium* sp.			0.285	0.285				0.571	37.50
F10	*Cylindrocarpon* sp.			0.285					0.571	25.00
F11	*Dreschlera* sp.			0.285						12.50
F12	*Epicoccum* sp.						0.285			12.50
F13	*Fusarium graminearum*								0.571	12.50
F14	*F. oxysporum*		4.285	2.285	5.714	2.857	2.285	4.000	2.285	87.50
F15	*F. proliferatum*					0.285	0.285			25.00
F16	*F. sambucinum*							0.571		12.50
F17	*F. semitectum*							0.571		12.50
F18	*F. solani*		0.571	5.428	4.000	5.714	5.714	4.000	2.000	87.50
F19	*F. subglutinans*						0.285			12.50
F20	*Fusarium* sp.			0.571		0.285				25.00
F21	*Gliocladium* sp.						0.285	0.857		25.00
F22	*Hyalodendron* sp.	1.428	2.85		0.285					37.50
F23	*Macrophomina phaseolina*						0.857	1.142	3.428	37.50
F24	*Mortierella* sp.	2.571	1.428	1.714	2.857	1.714	1.142	1.714	1.714	100.00
F25	*Mucor* sp.		1.428	0.571					0.285	25.00
F26	*Paecilomyces* sp.	2.285	0.571			0.285				37.50
F27	*Penicillium* sp. 1	2.857	2.571	2.571	2.857	3.142	0.857	0.857	3.428	100.00
F28	*Penicillium* sp. 2	3.142	1.428	1.714	2.000	1.714	0.571		3.714	87.50
F29	*Penicillium* sp. 3	1.428	0.857	0.571					0.857	50.00
F30	*Periconia* sp.							0.285		12.50
F31	*Ramichloridium* sp.							0.571		12.50
F32	*Rhizopus* sp.		1.428						0.285	25.00
F33	*Micelia sterilia*	0.285	0.285						0.285	37.50
F34	Micelia with pycnidia			0.571			1.142			25.00
F35	*Scolecobasidium* sp.			0.857						12.50
F36	*Trichoderma* sp. 1	0.857	1.428	0.571						37.50
F37	*Trichoderma* sp. 2		0.857							12.50
F38	*Ulocladium* sp.							0.285		12.50
	Total per sample (CFU g^{-1} × 10^3)	15.99	17.99	20.85	19.43	16.28	13.99	17.99	23.42	
Total No. of species per sample		10	15	17	9	9	11	16	16	

S1 – *Cambisol*, S2 – *Leptosol*, S3 – *Arenosol*, S4 – *Solonetz*, S5 – *Gleysol*, S6 – *Vertisol*, S7 – *Fluvisol*, S8 – *Chernozem*

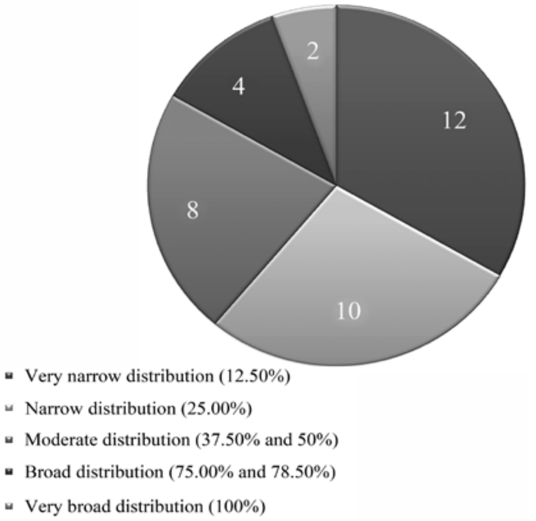


Figure 1. Number of fungal species with different distributions in eight different soil types

Generally, according to Table 2, the most predominant species were *Aspergillus* spp., *Alternaria* sp., *Fusarium* spp., *Mortierella* sp. and *Penicillium* spp. Kiković et al. (1997) found *Penicillium*, *Aspergillus* and *Cladosporium* spp. as common species in alluvium soil samples from Malo Rudare, Serbia. This result can also be compared to the results obtained by authors from all over the world where those species were also reported as common species in soybean soil rhizosphere in India (Maisuria, Patel, 2009), soil and litter samples of Forest Reserve in Trat Province in Thailand (Puangsombat et al., 2010) and litter samples from different forest types in China (Song et al., 2004). It is known that even in tropical forests, many taxa are similar to taxa found in temperate latitudes, and the numbers of species for a particular tropical soil are normally the same or even lower than those observed for soils in temperate regions (Gams, 2007). Fungi from the genera *Penicillium*, *Aspergillus*, *Cladosporium*, *Fusarium*, *Rhizopus*, *Mucor*, *Phoma* and *Verticillium* were even found in reservoirs of lakes and rivers in Serbia (Ranković, 2005). Similar fungal communities were found in Ohrid Lake in Macedonia, Bosnian River as well, and even in Estonian lakes (Čomić et al., 2010). This was expected because soil fungi spread easily and most of them have a cosmopolitan distribution and thermophilic and heat-resistant species are largely cosmopolitan (Gams, 2007).

Soil fungi with an abundance of less than 500 CFU g^{-1} wet weight soil can be considered as rare species (Puangsombat et al., 2010), while those with an abundance of more than 500 CFU g^{-1} wet weight soil can be considered as common species (Table 2). As seen in Table 2, one species can be rare in one soil type while it is common in another, for example, *F. oxysporum*. Rasulić et al. (2012) did not find any correlation between the land use and the total number of microflora and actinomycetes, ammonifiers, azotobacter and oligotrophiles. On the contrary, in this study, a correlation between the land use and the total abundance of soil fungi was found for samples S8, S3 and S4, which were all used as arable land and the total abundance was the highest compared to all other soil types.

Similarity index. Similarities of fungal communities in different soil type samples were analysed using Sorensen's Index. If Sorensen's index was higher than 55%, soil samples were considered to have similar fungal communities (Puangsombat et al., 2010). The highest similarity of soil fungi was noticed between S3 and S8 (72.72%), which were both arable-land with a low or moderate CEC and organic matter; followed by S1 and S2 (72.00%), which were forest and meadow, respectively and had no $CaCO_3$ and a high or moderate CEC (Table 3). Fungal community composition is known to be more similar in soils having similar soil moisture, organic matter, pH and electrical conductivity (Houston et al., 1998).

A value of Sorensen's index between 35–55% for soil samples indicates moderate similarity, while a value lower than 35% indicates a low similarity between samples. The lowest similarity between soil fungal communities can be noticed between sample S1 (*Cambisol*, forest) compared with samples S6 (28.57%) and S7 (30.77%), which were both used as garden soils (Table 3).

Table 3. Sorensen's index of similarity (%) of soil fungal communities between different soil groups

	S1	S2	S3	S4	S5	S6	S7	S8
S1	–	**72.00***	44.44	52.63	52.63	**28.57****	**30.77****	46.15
S2		–	**56.25***	**58.33***	**58.33***	38.46	38.71	**58.06***
S3			–	53.84	53.84	42.86	36.36	**72.72***
S4				–	**66.67***	50.00	48.00	40.00
S5					–	**60.00***	40.00	48.00
S6						–	44.44	44.44
S7							–	43.75
S8								–

Note. S1 – *Cambisol*, S2 – *Leptosol*, S3 – *Arenosol*, S4 – *Solonetz*, S5 – *Gleysol*, S6 – *Vertisol*, S7 – *Fluvisol*, S8 – *Chernozem*; * – values marked with one asterix indicate high similarities between compared soil samples; ** – values marked with two asterix indicate low similarities between compared samples.

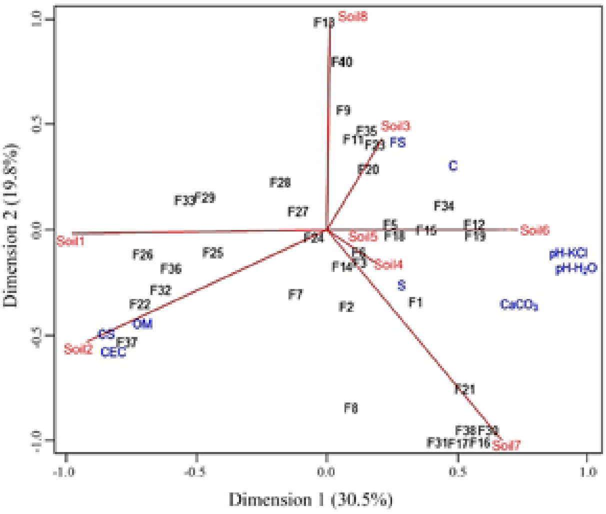
Diversity index. The Shannon-Wiener diversity index indicated the highest diversity of soil fungi in *Chernozem* (S8), *Fluvisol* (S7) and *Arenosol* (S3), all used as arable-land or garden soil (Table 4). The lowest diversity was recorded in a *Gleysol* (S5) under a meadow, which can be explained by poor aeration and a poor water regime that negatively affected biodiversity despite a high organic matter content and CEC. *Gleysol* is characterized by the anaerobic decomposition of organic residues, and at the bottom of the solum, anaerobic conditions are permanently present, while aeration is occasionally present in the upper horizons in the zone (Pekeč et al., 2011).

Relationship of soil fungi with soil physical and chemical properties. The relationship between the soil fungi with soil physical and chemical properties was analysed by canonical correlation analysis (CCA) and the results in Figure 2 show that some fungi correlated positively with organic matter, CEC and the percentage of coarse sand (CS), fine sand (FS), silt (S) and clay (C).

The soil fungi with the closest and most positive relationship to organic matter, CEC and coarse sand (CS) were *Trichoderma* spp. (F36, F37), *Rhizopus* sp. (F32), *Paecilomyces* sp. (F26), *Mucor* sp. (F25) and *Hyalodendron* sp. (F22). These fungi appeared in

Table 4. Total number of species, total abundance and Shannon-Wiener's diversity index of soil fungi in different soil types

Soil samples	Soil group	Total No. of species	Total abundance, CFU g^{-1} dry weight soil	Shannon-Wiener's diversity index
S1	*Cambisol*	10	15.996×10^3	2.09
S2	*Leptosol*	15	18.564×10^3	**2.25**
S3	*Arenosol*	17	20.850×10^3	**2.43**
S4	*Solonetz*	9	19.425×10^3	1.86
S5	*Gleysol*	9	16.282×10^3	1.75
S6	*Vertisol*	11	13.993×10^3	1.94
S7	*Fluvisol*	16	17.994×10^3	**2.39**
S8	*Chernozem*	16	23.422×10^3	**2.40**



$CaCO_3$ – calcium carbonate, OM – organic matter, CEC – cation exchange capacity; content of particles in soil: CS – coarse sand, FS – fine sand, S – silt, C – clay

Figure 2. The relationship of soil fungi with physical and chemical soil properties analysed by canonical correlation analysis (CCA)

soils S1, S2, S3 and additionally S8 for *Mucor* sp. and *Rhizopus* sp., and S4 for *Hyalodendron* sp. (Fig. 2). The adsorptive complex of soil depends on the clay content, clay type and humus content (Belić et al., 2011). A higher adsorptive capacity is characteristic of heavy textured soils, especially with higher amounts of montmorillonite clay and organic matter. It is known that species such as *Mucor* sp. prefer high moisture content, while both *Mucor* sp. and *Trichoderma* spp. prefer higher amounts of organic matter (Grishkan et al., 2005). This was confirmed by our research in which the presence of *Mucor* sp. and *Trichoderma* sp. was found in soil samples with such characteristics. These two species were found even at the bottom or littoral samples of eutrophic reservoirs (Ranković, 2005). *Penicillium* spp., *Trichoderma* spp., *Cladosporium* sp., *Herbarum* sp., *Alternaria* sp., *Mucor* sp., *Aspergillus* spp. and *Rhizopus nigricans* have been reported as users of both single carbohydrates and recalcitrant substances (Song et al., 2004), which can explain the positive relationship of those fungi with organic matter in this study as well.

Soils that contain much clay and dust can better retain water and nutrients and provide favourable conditions for microbial activity (Ćirić et al., 2012). In this study, a positive relationship with the clay content was found for *Aspergillus parasiticus* (F5), *Fusarium proliferatum* (F15), *F. solani* (F18) and unidentified mycelia with pycnidia (F34). Those species were mostly identified in soils S3, S4, S5 and S6, and additionally in S2, S7, S8 (for *F. solani*) and S7 (for *A. parasiticus*) (Fig. 2).

A positive relationship with FS was found for *Fusarium subglutinans* (F19), *Fusarium* sp. (F20), *Epicoccum* sp. (F12) and *Chaetomium* sp. (F9), which occurred mostly in soils S3 and S6, as well as S4 (*Chaetomium* sp.) and S5 (*Fusarium* sp.) (Fig. 2). Some species such as *Paecilomyces* sp. and *Chaetomium* sp. are able to grow in the presence of Na and Ca salts (Steiman et al., 2004), which are characteristic of the solonetz soil type in which this species was identified in this study. *Solonetz* is known to have a strong textural differentiation; the surface horizon has a lighter, usually loamy, texture and the subsurface horizon is very clayic and alkaline (Belić et al., 2012).

No relationship between soil fungi with pH and $CaCO_3$ was observed in any soil samples, which partly agrees with the results of Puangsombat et al. (2010).

Conclusions

1. Among all 38 identified soil fungi, the most common were organic matter (OM) decomposers. Generally, predominant species were *Aspergillus* spp., *Alternaria* sp., *Fusarium* spp., *Mortierella* sp. and *Penicillium* spp.

2. The highest similarities in soil fungi composition were noticed between *Arenosol* and *Chernozem*, both used as arable lands, while the lowest similarities in soil fungal communities were noticed between forest *Cambisol* compared with *Vertisol* and *Fluvisol*, both used as garden soils.

3. The highest diversity, as expected, was recorded in *Chernozem* (arable land), while the lowest diversity was recorded in *Gleysol* (meadow) that had poor aeration and a poor water regime, which negatively affected biodiversity.

4. *Trichoderma* spp., *Rhizopus* sp., *Paecilomyces* sp., *Mucor* sp. and *Hyalodendron* sp. had a positive relationship with organic matter, cation exchange capacity (CEC) and coarse sand (CS), while a positive relationship with the clay content was found for *Aspergillus parasiticus*, *Fusarium proliferatum*, *F. solani* and unidentified mycelia with pycnidia.

5. Fungal characterization of different soil types provides important information relating to soil fertility, and these are the first results of fungal biodiversity screening in soil types in Serbia.

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Dirvožemio savybių įtaka dirvožemio grybų įvairovei

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Santrauka

Tyrimo tikslas – nustatyti dirvožemio savybių įtaką dirvožemio grybų biologinei įvairovei. Išanalizavus aštuonių skirtingų dirvožemio tipų, turinčių nevienodą dirvožemio granuliometrinę sudėtį, ą organinių medžiagų ir karbonatų kiekį, pH, katijonų mainų gebą ir žemės naudojimą, grybų įvairovę nustatytos 38 skirtingos grybų rūšys, kurios buvo sugrupuotos į 24 gentis. Iš visų identifikuotų dirvožemio grybų dažniausi buvo organinių medžiagų skaidytojai. Dažniausiai pasitaikančios rūšys buvo *Aspergillus* spp., *Alternaria* sp., *Fusarium* spp., *Mortierella* sp. ir *Penicillium* spp. Didžiausias grybų bendrijų panašumas buvo nustatytas ariamoje žemėje su maža arba vidutine katijonų mainų geba ir organinių medžiagų kiekiu, o mažiausiai panašumų buvo tarp miško rudžemio (*Cambisol*) ir sodo dirvožemių. *Shannon-Wiener* indeksas parodė didžiausią juodžemio (*Chenozem*), salpžemio (*Fluvisol*) ir smėlžemio (*Arenosol*) grybų įvairovę, kai šie dirvožemiai buvo naudojama kaip ariama žemė arba sodo dirvožemis. Mažiausia įvairovė nustatyta pievoje šlynžemyje (*Gleysol*) dėl prastų aeracijos ir vandens režimo. Kanoninės koreliacijos analizė išryškino dirvožemio grybų ryšį su visais dirvožemio aplinkos veiksniais ir parodė, kad kai kurie dirvožemio grybai buvo teigiamai susiję su organinėmis medžiagomis, smėlio ir molio kiekiu.

Reikšminiai žodžiai: biologinė įvairovė, dirvožemio grybai, žemės naudojimas.