SOIL MICROBIOCOENOSIS OF BLOWN SAND OF THE BORSKÁ NÍŽINA LOWLAND

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Abstract

Ďugová O., Šimonovičová A., Jandák J.: Soil microbiocoenosis of blown sands of the Borská nížina lowland. Ekológia (Bratislava), Vol. 26, No. 2, p. 143–150, 2007.

Blown sands of the Borská nížina lowland are a unique ecosystem unknown from the viewpoint of microbiology. During the years 2002–2005 we studied the representation of physiological groups of soil microorganisms, their biomass, respiration and genus-species composition in the sites Mláky 1, 2 and sand dune Borová. Microbiological analyses confirmed that the studied soils have unfavourable life conditions. Total biomass of microorganisms, their respiration activity and qualitative representation showed very low values.

Key words: blown sands, Borská nížina lowland, biomass of soil micororganisms, soil respiration, microscopic fungi

Introduction

Sand dunes and the areas of blown sands in the alluvia of large rivers and their tributaries are the most endangered sites in Central Europe. Sand dunes can be characterized by psamophilous plant and animal communities belonging to the most endangered ones in Europe. In the Slovak Republic eolitic (blown) sands are a rarely occurred soilforming substratum. In Slovakia the total spatial representation of blown sands is only 1.2%, that is not quite 600 km^2 of the area of the country, but their ecological significance is very high.

In Slovakia such valuable sites can be found in the Borská, Podunajská and Východoslovenská nížina lowlands, but their historical development is different (Kalivodová et al., 2001). Less attention was paid to the biota of these significant areas. In the last years we obtained rich data of flora and fauna, but there are no data of soil microbial communities, therefore we aimed our investigation at microbial-ecological study of blown sands of the Borská nížina lowland.

Material and methods

From the viewpoint of geological division the studied area is a part of the Viedenská panva basin, that can be characterized by a strong evolution of Tertiary sediments and significant representation of Quaternary sediments. Simultaneously also eolitic (wind) and fluvial activity took part in the geological development of this area. Due to this fact in the Záhorie area, that includes the Borská nížina lowland, too, two extent rock complexes have been created – eolitic sands and fluvial sediments. Eolitic sands are the most distributed complex of the area.

Soil samples were collected from the study areas Mláky 1, Mláky 2 and sand dune Borová, from the depth of 0–15 cm and from five sampling sites. Eutric Regosols are the studied soil type. The vegetation cover of the studied area is not homogenous.

The richest floristic representation appear in the sampling site Mláky 1, where the species *Corynephorus canescens, Calamagrostis epigeios, Poa anfustifolia, Festuca rupicola, Carex caryophyllea, C. hirta, Calluma vulgaris, Rumex acetosella, Potentilla arenaria, Tithymalus cyparissias, Thymus serpyllum, Spergula morisonii, Veronica dilenii, Solidago virg-aurea, Eryngium campestre* can be found. As to flora richness the sites Mláky 2 and Borová are similarly equal. The species *Calluma vulgaris, Callamagrostis epigeios, Corynephorus canescens, Carex hirta, Festuca rupicola, Phragmites australis* appear in the sampling site Mláky 2. In the sampling site Borová can be found the following floristic representation: *Corynephorus canescens, Bromus tectorum, Festuca rupicola, Rumex acetosella, Spergula morisonii, Carex hirta, Viola tricolor, Cerastium semidecandrum, Veronica dilenii* (species determined by H. Ružičková). In this site the species *Viola tricolor* has a very significant representation. It forms bunches visible from a great distance. Similarly as in other sites pines growing individually and not in canopy are also characteristical.

Soil samples from the mentioned sites were collected from May to October in 1-month intervals during the years 2002–2005, always from the depth of 1–15 cm. Before analytical elaboration they were stabilized 4 weeks at 4–6 ^{o}C and riddled through a 2 mm sieve. In samples prepared in this way, always in three repetitions we determinated the biomass of soil microorganism expressed by carbon of microbial biomass C_{bio} by the method SIR (Schinner et al., 1993), basal and potential respiration activity (Števlíková et al., 2002), abundance of microorganisms, i.e. sporuluting, non-spurulating and cellulolytic bacteria (Števlíková et al., 2002), genus and species representation of soil micromycetes (Domsch et al., 1980; Klich, 2002).

For determination of the physical properties of the studied soils we collected undisturbed as well as sifted soil samples from the depth of 1–6 cm and identified: reduced volume mass, total porosity, retential water capacity, aeration (Black, 1965). Pipettor method was used for textural and microaggregational analysis.

The overall content of soil organic matter (C_{ox}) was established by Walklay-Black method modified by Novák and Pelíšek (Klika et al., 1954), active and exchange pH potenciometrically (Fiala et al., 1999) with evaluation according to Čurlík et al. (2003). Percentage of N_{tot} has been idetified according to Jodlbauer (Števlíková et al., 2002) with evaluation according to Bielek (1998).

Results and discussion

Sand soils are a special soil category with many specifications need to be taken into account if they are used as agricultural land. From the viewpoint of soil structure they are indicated by high content of sandy fractions (frequently more than 90%) with minimum share of fine clay as well as very low representation of dust elements. At deep deficite of organic matter there is no presumption for effective functioning of humus-clayic sorption complex, or its functions in relation to soil processes as well as to forming the parameters of soil regimes important in the soil- and yield-forming process.

Sandy soils retained little water, i.e. they have small absorption ability. They have enormous aeration and decreased stability against negative outside components. Such soils can be found also in the Borská nížina lowland. They are used either as agricultural land or they are conserved. Due to the lack of nitrates they are extremely acid (Bedrna et al.. 2001; Kalivodová et al., 2002; Šimonovič et al., 2001). Regarding the content of organic matters (C_{ox} and N_{tot}) the studied soils can be divided into two groups. The first one is formed by soils from the site Borová with higher content of nitrogen and carbon. The second one is formed by soils from the sites Mláky. Oppositely their content of organic matter is very low. From the aspect of rate C:N the life conditions of soil microorganisms are unfavourable in the sampling sites Mláky 1 and 2, because of the low rate. Oppositely in the site Borová the rate is higher, so there are more suitable life conditions for soil microorganisms. In the site Mláky 2 the humus or the amount of organic matter is of worse quality than in the site Mláky 1 and Borová (Table 1).

T a b l e 1. Basic chemical characteristics of study soil samples.

Sample	pH_{H_2O}	pH_{KCl}	% C_{ox}	% N_{tot}	C:N	% organic matter
Mláky 1	4.25	4.11	0.36	0.07	5.14	0.62
Mláky 2	4.63	4.08	0.14	0.03	4.67	0.24
Borová	4.72	4.04	2.10	0.20	10.50	3.62

The studied soils belonging to blown sands have a special temperature-water regime given by their physico-chemical properties. Their ability to retain water for plants is low. The reduced volume weight and porosity are almost equal (Table 2).

T a b l e 2. Values of reduced volume mass, porosity, water-bearing capacity, aeration.

Sample sites	OHR		Overall porosity		RVK		Aeration	
	$kg.m^{-3}$		% vol.		% vol.		% vol.	
	x	SMOD	x	SMOD	X	SMOD	x	SMOD
Mláky 1	1596	88	39.54	3.33	15.49	0.81	34.2	3.41
Mláky 2	1597	27	39.74	1.02	19.20	2.46	29.62	0.88
Borová	1550	48	40.82	1.83	14.38	3.58	36.62	1.44

Notes: OHR – reduced volume mass, RVK – water-bearing capacity, x – average, SMOD – conclusive difference

According to the soil texture of surface horizons it is sand (Němeček et al., 2001) with extremely low content of mineral colloids (Table 3).

T a b l e 3. Grain size composition of soil samples.

Sample sites	Content of elements (%)			
	Fraction (mm)			
	2.0 – 0.05	0.05 – 0.01	0.01 – 0.002	< 0.002
Mláky 1	95.79	1.77	2.44	2.57
Mláky 2	96.75	0.88	2.37	2.77
Borová	97.25	0.76	1.99	2.55

Thermal-water regime of blown sands and its impact on soil microflora can be seen in summer. Due to sun radiation the temperature of outside shells in summer increases to critical existential values for microorganisms. They respond to this fact by ceasing of their activity and transition to state of rest. The increased temperature of the surface layer of blown sands causes an increased evaporation of soil water. Its consequence is a soil shrinkage causing a decrease of many microorganisms. It is the highest in the first three weeks. In microbiological analyses we define the decrease of soil microorganisms as a decrease of soil mass and biological activity (Ďugová, in press).

On the basis of microbiological analyses it can be stated that blown sands of the Záhorie area are relatively poor in microbial biomass. It was confirmed by the values C_{bio} contained in microorganisms biomass that moved between 31.9 mg. C_{bio}.100 g^{-1} of dry matter (Mláky 1 – July 2004) and 188.7 mg C_{bio}.100 g^{-1} of dry matter (Mláky 1 – October 2005). During the whole studied period the lowest values of total biomass C_{bio} were identified in each plot in the summer months July and August. In this period the biomass moved between 31.9 mg. C_{bio}.100 g^{-1} of dry matter (Mláky 1 – July 2004) and 131.4 mg C_{bio}.100 g^{-1} of dry matter (Mláky 1 – August 2003). The values depend on the amount of precipitation in the given year. It is interesting that the greatest differences, or the greatest fluctuation in microbial biomass were observed always in the sampling site Mláky 1. In 2004 the values of microbial biomass were low but relatively balanced (Table 4).

The values of microbial biomass immediately show the increase of precipitation in the summer period 2005 when the highest values were recorded at all three sites (Table 4). The fact, that the amount of water precipitation in sandy dunes is the primary ecological factor and determining element, is proved also by the occurrence of fungi *Psathyrella ammophila.* It was identified only in 2005. In other years it has not been found in the dunes, it occurs only in the grassy part under the sand dunes, where is wetter environment.

During the process of respiration and organic material decomposition the microorganisms release CO_2 (Ďugová, 2003). In spring months we always recorded the highest values of basal production of CO_2 (138.5 mg.kg^{-1} of dry matter.24 h^{-1} – site Borová, May) with a decreased tendency in summer (lowest value 58.9 mg.kg^{-1} of dry matter.24 h^{-1} – site Mláky 2, August), when the values of microbial biomass decreased (Table 5), too. Stability of communities of soil microbiocoenoses is characterized by the rate of potential and basal production of CO_2. These values moved from 1.4 (Borová, May) to 4.0 (Mláky 2, September). According to these values the highest stability of the studied terrestrial ecosystems was confirmed

T a b l e 4. Carbon of microbial biomass in mg C_{bio}.100g^{-1} dry weight.

Month	Year 2003		
	Mláky 1	Mláky 2	Borová
April	120.3	123.7	118.1
May	122.2	136.2	125.6
June	119.8	121.0	114.4
July	58.5	118.6	80.0
August	131.4	93.7	68.7
September	109.6	120.0	56.0
October	100.1	109.3	80.3
Year 2004			
April	100.2	97.0	100.0
May	98.7	84.3	91.8
June	35.3	65.2	68.9
July	31.9	60.2	67.1
August	69.8	63.2	68.4
September	70.2	57.3	57.4
October	80.2	73.6	70.7
Year 2005			
April	187.6	153.2	157.8
May	165.4	134.4	145.7
June	96.2	93.2	126.7
July	90.6	117.5	97.1
August	111.1	115.7	115.8
September	188.7	120.0	119.7
October	114.3	126.0	100.5

in spring when the values moved from 1.4 (Borová) to 1.6 (Mláky 1 and 2), which is the minimum difference (Table 5).

T a b l e 5. Basal (B) and potential (P) productivity of CO_2 in mg.kg^{-1} dry weight.24 h^{-1} and ratio of potential (P) to basal (B) productivity of CO_2 in the year 2005.

Month	Mláky 1			Mláky 2			Borová		
	B	P	P/B	B	P	P/B	B	P	P/B
May	121.2	199.5	1.6	93.4	154.6	1.6	154.6	196.2	1.4
June	99.8	201.3	2.0	85.5	158.3	1.8	158.3	210.5	0.2
July	82.0	210.6	2.6	74.3	164.7	2.2	164.7	222.1	2.3
August	70.0	212.7	3.0	58.9	179.8	3.0	179.8	230.7	3.3
September	60.0	231.6	3.9	50.1	200.9	4.0	200.9	210.4	3.3
October	83.3	201.3	2.4	66.6	196.6	2.9	196.6	211.4	2.9

Also the representation of single physiological groups of microorganisms indicates the quality of microbial communities. Representation of bacteria (except of cellulolytic ones) is relatively rich in spite of the low to extremely low pH of the environment. In spring months, in the site Mláky 2 we always recorded higher abundance of bacteria than microscopic fungi. In the rest two sites microscopic fungi dominate. A significant change appears in summer months. At all three sampling sites the overall number of bacteria is three times larger than the overall number of microscopic fungi. Sporuluting bacteria forms significantly dominate that confirms the significant influence of moisture as primary ecological factor (Table 6).

T a b l e 6. Abundance of bacteria and microscopic fungi in 103 CFU.g^{-1} in the year 2003.

Sample sites	NB	SB	CB	∑ B	∑ MF	B/MF
April						
Mláky 1	24.1	28.0	0.5	52.6	56.7	0.9
Mláky 2	1.3	19.1	0	31.4	26.2	1.2
Borová	13.6	15.7	0	29.3	34.9	0.8
May						
Mláky 1	29.8	34.8	0.1	64.6	66.6	1.0
Mláky 2	23.7	30.2	0	53.9	41.2	1.3
Borová	25.6	29.3	0.1	55.0	60.9	0.9
July						
Mláky 1	30.1	35.6	8.8	72.5	23.3	3.1
Mláky 2	22.5	27.7	0	49.7	17.6	2.8
Borová	26.0	37.2	5.7	68.9	25.6	2.7

Notes: NB – non sporulated bacteria, SB – sporulated bacteria, CB – cellulolythic bacteria, – ∑ B – bacteria total, – ∑ MF – microscopic fungi total, B/MF – relationship of bacteria and microscopic fungi

Genus and species representation of soil micromycetes is relatively poor (15 genera and 20 species) and almost balanced among single sites (Table 7). The site Mláky 1 (15 identified representatives) is characterized by significant dominance of species of the genera *Penicillium*. Extremely acid soil pH is suitable for them (Table 1). The least, only 13 representatives of soil mycocoenoses were identified in soils of the site Mláky 2. Only from this site were isolated the species *Aureobasidium pullulans, Humicola fuscoatra* and *Paecilomyces varioti*. In both sites the representation of the class Zygomycetes (*Mortierella* sp., *Rhizopus arrhizus, Zygorhynchus heterogamus*) is very poor, but adequate to percentual presence of organic matter (Table 1).

From the site Borová were identified 18 representatives of soil mycocoenosis, that is variegated and balanced. Only from this site were identified the species *Aspergillus* sk. *niger, A. ochraceus, Cladosporium cladosporioides, Mucor* sp., *M. plumbeus, Penicillium*

T a b l e 7. Composition of microscopic fungi in study samples.

Microscopic fungi	Mláky 1	Mláky 2	Borová
Alternaria alternata	+	+	-
Aspergillus fischeri	+	-	-
A. glaucus	-	+	-
A. sk. *niger*	-	-	+
A. ochraceus	-	-	+
Aureobasidium pullulans	-	+	-
Cladosporium cladosporioides	-	-	+
Chaetomium globosum	-	+	+
Clonostachys rosea	+	-	+
Humicola fuscoatra	-	+	-
Mortierella sp.	+	+	+
Mucor sp.	-	-	+
M. plumbeus	-	-	+
Mycelia sterilia	+	+	+
Paecilomyces sp.	+	+	+
P. varioti	-	+	-
Penicillium sp.	+	+	+
P. aspergilloides	+	+	+
P. decumbens	+	-	+
P. expansum	-	-	+
P. janthinellum	+	-	-
P. rubrum	+	-	-
Rhizopus arrhizus	+	+	+
Trichoderma sp.	+	+	+
T. koningii	+	-	+
Verticillium sp.	-	-	+
Zygorhynchus heterogamus	+	-	-

expansum and *Verticillium* sp. The amount of organic matter and ratio C:N are reflected by the representation of the species of the class Zygomycetes. They are the most abundant ones (Table 7).

The occurrence of the species *Clonostachys rosea* (sites Mláky 1 and Borová) is interesting. In spite of the fact it is a common species with wide tolerance of pH (from 3.2 to 10.5), it rarely occurs in sandy soils of dune vegetation (Domsch et al., 1980). On blown sands of the Záhorie area the soil micromycetes species of genera *Mucor, Zygorhynchus, Rhizopus, Acremonium, Aspergillus, Trichoderma, Paecilomyces, Penicillium, Cladosporium, Alternaria* and *Arthrinium* (Šimonovičová, Thach, 1995) were identified.

The species composition of soil micromycetes significantly differs in dependence on environmental conditions. Species from genera *Penicillium* and *Alternaria* have richer representation in the rhizosphere of herbs and pines than in free soil. It is valid mainly in the site Borová, where the plots of pine stands alternate with the plots without vegetation. The richer species representation under pines is given by more suitable soil conditions under the trees. Their branches reaching up to the surface serve as protection against solar radiation, they reduce temperature changes and keep the ground longer moistered than those without pines (Ďugová, in press).

Translated by K. Kis-Csáji

The contribution is a part of grants VEGA No. 2501/25 and 1/2352/05.

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Received 24. 4. 2006