Soil properties under different vegetation types in the Arboretum Mlyňany

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Abstract

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The influence of oak trees, and introduced Himalayan pine and Japanese cedar on soil chemical and microbial characteristics was observed in the Arboretum Mlyňany. The original growth on the studied area was an oak-hornbeam forest, therefore the soil under the rest of oak forest was taken as a control. The obtained results showed that changed growth of tree species strongly affected soil microbial and chemical properties. Highly significant ($P < 0.001$) differences in A horizons between the studied stands were found for soil reaction, sorption characteristics, nutrient content (N, P, K), soil organic matter (SOM), and soil microbial biomass. Significantly ($P < 0.001$) the strongest acidity, the highest total organic carbon content (C_T), microbial biomass carbon (C_{mic}) and its proportion of C_T were found in A horizon of the soil under oaks. Higher microbial colonisation of oak soil was probably due to composition of susceptible organic matter and to biodegradation rather than by its amount. We suppose that lower humus quality under deciduous oaks was due to carbonate-less soil forming substrate and the longer period of influence the oak trees (more than 116 years) on soil compared to coniferous pine and cedar trees (45 years).

Key words

pH, carbon, microbial biomass, oak, Himalayan pine, Japanese cedar

Introduction

The Arboretum Mlyňany was established in year 1892 by Dr. Ambrózy-Migazzy and his gardener J. Mišák. It contains many domesticated and acclimatized exotic trees. In the Arboretum resides the Dendrobiological Institute SAS which takes care about, studies and saves endangered woody species (Tábor et al., 1992). Biodiversity conservation and sustainable utilization (mainly protection in situ, protection ex situ and utilization biodiversity components) are the goals of the EU Biodiversity strategy (Macák, 2006). An important national goal is to strengthen the national capacity for ex situ protection – mainly to increase the present net of ex situ institutions, to develop technologies, collections and databases (Sabo et al., 2005).

Soils represent the basic supporting system for terrestrial ecosystems because of their role in providing nutrients, water, oxygen, heat and mechanical support to vegetation. Soil properties considerably influence plant growth and species composition. On the other side, plant cover strongly affects soil forming process and soil chemical, physical and biological characteristics.

Tree species can affect soil properties by several ways. Differences in the physical and chemical characteristics of soils under various species can be caused by different chemical composition of litter and its quantity (Jurčová et al., 2002; Konôpková et al., 2000; Smolander et al., 2005; Tobiašová, 2001), nutrient status, uptake and root activity, rate of elements mobilization (Moszynska, 2001), interception of atmospheric deposition, composition of ground vegetation (Smolander et al., 2005), canopy interactions and leaching as well as alterations of the microclimate and soil's biological community (Priha et al., 1999). Microbial biomass plays the main role in the degradation of soil organic matter, thus microbes exert feed-back-effects on vegetation via mineralisation followed by release of mineral nutrients (Zechmeister-Boltenstern et al., 2000).

The objective of this study was to assess the effect of original oak and introduced tree species (Himalayan pine and Japanese cedar) on selected soil chemical and microbial properties in the Nature Reserve Arboretum Mlyňany.

Material and methods

The Nature Reserve Arboretum Mlyňany is located in south-western part of the Slovak Republic (E 18°21', N 48°19', altitude 165–217 m above sea level). The average annual temperature is 9.4 °C and sum of precipitation is 558 mm (Hrubík, 2000). The Arboretum is situated on Neocene clay, sand and rubble sand, covered with loess, mostly without carbonates (Steinhübel, 1957).

Arboretum consists of an original old Ambrozy's park and new collections, divided according to geographic zones to: East-Asia, North America and Korea trees area, and exposition of Slovak endangered taxons ex situ (Bero et al., 1992).

To assess the soil environment of the site, three soil pits were trenched:

- Soil pit No. 1 under oak wood *(Quercus Cerris,* L.) on Western gentle slope
- Soil pit No. 2 under Himalayan pine wood (*Pinus wallichiana,* Jacson) on Western gentle slope
- Soil pit No. 3 under Japanese cedar wood (*Cryptomeria japonica,* D. Don.) on North-Western gentle slope.

Analyzed chemical parameters: soil reaction – potentiometrically in H_2O, 1M KCl and 0.1M $CaCl_2$; exchangeable base ions (Ca^{2+}, Mg^{2+}, K^+, Na^+) and hydrolytical acidity by Kappen's method; exchangeable Al by method of Sokolov (Hanes, 1999); carbonates – volumetrically, phosphorus (P) and potassium (K) were analysed by method Melich III (Melich, 1984), then P colorimetrically on Spectrophotometer Jenway model 6400 and K on atomic absorption spectrophotometer AVANTA; total soil organic carbon (C_T) – by Tyurin method (Orlov et al., 1981); humus fractionation – by Kononova-Belchikova method (1961) – isolated humus substances (HS) and humic acids (HA); spectral analyses of humic acids – 6400 Spectrophotometer (Jen Way); susceptibility of organic carbon to oxidation by 0.005M $KMnO_4$ solution in acidic medium of 0.0025M H_2SO_4 – (C_L) (Loginow et al., 1993); total nitrogen content – N_T – by Kjeldahl (Bradstreet, 1965). Distribution of C_T, N_T, P, K contents and pH values were analyzed for each 0.1 m layers down to the depth of 0.8 m. Microbial biomass carbon (C_{mic}) was analyzed after the samples were stored for 8 weeks at 4 °C. Fumigation-extraction method (Vance et al., 1987) was used for C_{mic} determination.

Each analysis was done in 3 repeats and in this paper we report the average values. Analysis of variance ANOVA – LSD-procedure was used for statistical evaluation.

Results

The most considerable differences in the soil characteristics under different species were found near the soil surface (0.0–0.1 m), although differences in the lower layer of the A horizon, or other horizons were also large.

Soil reaction values in water were significantly ($P < 0.001$) (Table 5) the most acidic in A horizon and also in the whole soil profile under oak trees compared to coniferous pine and cedar trees. Soil acidity decreased with depth, where the influence of acids from decomposed litter was less intensive (Table 1).

Extremely high values of hydrolytic acidity (H) were found in umbric-A, and argic-Bt horizon under oak trees (H = 157.9 and 133.0 mmol kg^{-1}). High total acidity was in agreement with very high exchangeable Al content in the mentioned horizons.

Sum of base ions (S) and base saturation (BS) were the highest in soil profile under pine trees (Table 1). Differences in the mentioned parameters between the studied soils were highly significant ($P < 0.001$) (Table 5) mainly in A horizons, where the influence of vegetation was the most intensive. Lower parts of profiles, mainly B/C and C horizons were saturated with base ions, which may have been ensued from soil forming substrate (carbonate loess) or from transported base ions to deeper parts of profile by percolating water (Table 1). Whereas the soil profile under oaks did not contain carbonates, in B and C horizons under pine and cedar trees carbonates were identified.

The distribution of N, P, K across the profile is presented in Tables (2–3). Well-supplied with nitrogen, potassium and phosphorus were A horizons under each of the studied trees.

Compared to the other woods, significantly ($P < 0.001$) the highest pool of total nitrogen and available potassium was found in A horizon under cedar trees (Table 3). Significant differences were also found in distribution of macronutrients within the profiles. Nitrogen content gradually decreased with depth in each profile, but phosphorus and potassium only under pine and cedar trees.

Table 1. Soil sorption, pH values and carbonates in soil under oak, pine and cedar trees

Locality	Horizon	Depth [m]	H	S	CEC	Excha-ng. Al	BS	pH H_2O	pH KCl	pH $CaCl_2$	Carbonates
			[mmol kg^{-1}]				[%]				[%]
Oak	Au	0.00–0.15	157.9	50.0	207.9	44.4	24.1	4.62	4.17	4.58	0
	Bt	0.15–0.50	133.0	65.0	198.0	53.9	32.8	4.58	4.12	4.41	0
	Btg	0.50–0.80	44.2	201.0	245.2	2.6	81.8	5.38	4.55	5.02	0
	Btg/C	1.00–1.10	28.3	388.9	417.3	0	93.2	5.70	4.87	5.33	0
Pine	Au	0.00–0.25	29.8	239.0	268.8	0	88.9	6.31	5.18	5.80	0
	A/Bt	0.25–0.35	31.5	262.0	293.5	0	89.4	6.86	5.42	6.61	0
	Bt	0.35–0.60	5.9	286.0	291.9	0	98.0	8.26	7.08	6.35	6.4
	Bt/C	0.60–1.00	5.1	ND	ND	0	ND	8.41	7.34	7.49	9.9
	C	>1.0	4.4	ND	ND	0	ND	8.41	7.44	7.70	11.8
Cedar	Au	0.0–0.2	66.5	169.0	235.5	8.6	71.8	5.21	3.93	4.56	0
	Btg	0.2–0.8	51.6	241.0	294.6	7.0	82.3	5.12	3.68	4.47	0
	Btg/C	>1.0	6.1	267.0	273.1	0	97.8	8.02	6.88	7.27	4.4

H – hydrolytic acidity; CEC – cation exchange capacity; BS – base saturation; ND – no determination; S – sum of bases (Na+, K+, Ca^{2+}, Mg^{2+}); exchang. Al – exchangeable aluminium

Table 2. The content and fractions of organic carbon, and the content of nitrogen, phosphorus and potassium in soil under oak, pine and cedar trees

Locality	Horizon	C_T	N_T	P	K	$C_T : N_T$	C_{mic}	C_L	C_{mic}	C_L	C_{NL}
		[g kg^{-1}]		[mg kg^{-1}]			[g kg^{-1}]		[% of C_T]		
Oak	Au	22.63	1.56	52	183	14.5	0.906	2.397	4.00	10.60	89.4
	Bt	10.31	0.90	10	157	11.3	0.313	0.807	3.04	7.83	92.2
	Btg	5.60	0.68	20	151	8.8	0.248	0.378	4.43	6.75	93.2
	Btg/C	3.96	0.39	58	205	10.1	ND	0.309	ND	7.80	92.2
Pine	Au	11.54	1.14	14	185	10.1	0.073	2.512	0.63	21.77	78.2
	A/Bt	6.62	0.75	10	163	8.8	0.051	0.936	0.77	14.14	85.9
	Bt	3.86	0.71	10	133	5.4	0.106	0.398	2.75	10.32	89.7
	Bt/C	2.40	0.29	12	128	8.2	0.031	0.174	1.30	7.25	92.8
	C	3.15	0.25	14	95	12.7	ND	0.214	ND	6.79	93.2
Cedar	Au	12.15	1.74	14	225	7.0	0.044	1.891	0.36	15.56	84.4
	Btg	2.96	0.74	16	180	4.0	0.032	0.353	1.08	11.93	88.1
	Btg/C	1.85	0.60	12	138	3.1	ND	0.040	ND	2.16	97.8

C_T – total soil organic carbon; N_T – total nitrogen content; P – phosphorus content; K – potassium content; $C_T : N_T$ – ratio $C_T : N_T$; Cmic – microbial biomass carbon; C_L – organic carbon oxidisable by 0.005 mol dm^{-3} $KMnO_4$; C_{NL} – org. carbon susceptible to oxidation by 0.005 mol dm^{-3} $KMnO_4$

Total soil organic matter (SOM) is a key attribute of soil quality since it has far-reaching effects on soil physical, chemical and biological properties. The main indicator of the amount of organic matter is the organic carbon content. Significantly (P < 0.001) (Table 5) the highest organic carbon content (C_T) was found in A horizon of oak soil (C_T = 22.63 g kg^{-1}). In pine soil it was 11.54 g kg^{-1}, and in cedar soil (C_T = 12.15 g kg^{-1}) (Table 2).

The pool of organic matter susceptible to microbial oxidation (determined as labile organic carbon oxidisable by $KMnO_4$ solution – C_L) was similar in profiles under oak and pine trees (mainly in A and Bt horizons). Significantly (P < 0.001) (Table 5) the lowest pool of labile carbon was found in A horizon and whole profile under cedar trees (Table 2). On the contrary, comparing the percentage of labile carbon from C_T, the results are different: significantly (P < 0.001) the highest C_L of C_T was found in A horizon under pine and the lowest under oak trees (Table 2).

Generally, the C:N ratio controls the rate of SOM decay. Significantly (P < 0.001) the highest C:N ratio was found in soil profile under oaks (Table 2). Surprisingly, a very low C:N ratio (7.00) was found in A horizon under cedar trees.

Table 3. The content of carbon, nitrogen, potassium and phosphorus in soil under oak, pine and cedar trees measured in 0.1 m layers

Depth [m]	C_T			N_T			K			P		
	[g kg^{-1}]						[mg kg^{-1}]					
	Oak	Pine	Cedar	Oak	Pine	Cedar	Oak	Pine	Ccdar	Oak	Pine	Cedar
0.0–0.1	30.6	26.4	24.3	2.01	1.66	2.36	193	188	315	60	14	14
0.1–0.2	14.2	10.6	10.67	1.11	1.28	1.46	145	150	190	12	10	12
0.2–0.3	10.5	9.06	7.89	0.94	1.05	1.15	143	155	180	10	12	16
0.3–0.4	8.3	4.91	3.50	0.77	0.50	0.67	145	155	195	10	10	12
0.4–0.5	8.2	4.04	2.70	0.78	0.99	0.72	170	125	183	8	10	12
0.5–0.6	5.7	3.40	2.67	0.55	0.49	0.71	188	118	155	12	10	12
0.6–0.7	6.2	3.29	1.75	0.57	0.41	0.56	205	125	158	20	10	14
0.7–0.8	4.9	2.32	2.53	0.93	0.31	0.76	208	113	140	25	10	14
>1.0	3.9	3.15	1.85	0.39	0.25	0.60	205	95	138	58	14	12

C_T – total soil organic carbon; N_T – total nitrogen content; K – potassium content; P – phosphorus content

Table 4. Humus quality in soil profiles under oak, pine and cedar trees

Locality	Horizon	Depth [m]	C_T	C_{HS}	C_{HA}	C_{FA}	HA : FA	C_{HA}	$Q_{HA}^{4/6}$
			[g kg^{-1}]					[% of C_T]	
Oak	Au	0.00–0.15	22.63	8.97	2.44	6.35	0.38	10.8	4.58
	Bt	0.15–0.50	10.31	4.36	1.42	2.94	0.48	13.8	4.12
	Btg	0.50–0.80	5.60	2.38	1.28	1.10	1.16	22.9	3.91
	Btg/C	1.00–1.10	3.96	1.67	0.80	0.87	0.92	20.2	4.67
Pine	Au	0.0–0.25	11.54	5.28	1.99	3.29	0.61	17.2	5.13
	A/Bt	0.25–0.35	6.62	2.94	1.17	1.77	0.66	17.7	4.82
	Bt	0.35–0.6	3.86	1.88	0.91	0.97	0.94	23.6	5.50
	Bt/C	0.60–1.00	2.40	1.63	0.84	0.79	1.06	35.0	5.33
	C	>1.0	3.15	1.84	0.93	0.91	1.02	29.5	5.00
Cedar	Au	0.0–0.24	12.15	5.85	2.40	3.45	0.61	18.2	7.92
	Btg	0.24–0.8	2.96	1.82	0.91	0.91	1.00	30.7	3.00
	Btg/C	>1.0	1.85	0.91	0.77	0.14	5.50	61.6	ND

C_T – total soil organic carbon; C_{HS} – carbon of humus substances; C_{HA} – carbon of humic acids; C_{FA} – carbon of fulvic acids; HA : FA humic acids to fulvic acids ratio; $Q_{HA}^{4/6}$ – absorbance ratio of humic acids

Microbial biomass carbon content (C_{mic}) was significantly higher in A horizon and also in the whole soil profile under oaks compared to the coniferous stands (Table 2).

Significantly (P < 0.001) (Table 5) the highest amount of C_{mic} was found in A horizon of oak soil (C_{mic} = 0.906 g kg^{-1}), even though the proportion of C_L (as a potentially susceptible organic matter to microbial utilization) of total organic carbon content was the lowest at this site (Table 2). Extremely low C_{mic} contents across the whole soil profile, including the litter layer (results not presented in this paper) were found in coniferous stands (under pine trees = 0.073 g kg^{-1}, and under cedar trees 0.044 g kg^{-1}).

Microbial biomass carbon, as the percentage of the total soil organic carbon (C_{mic}/C_T) in humus layer was significantly (P < 0.001) higher under deciduous trees (4.00%) than coniferous (0.63% under pine, and 0.36% under cedar) (Table 2).

The quality of humus evaluated by HA : FA ratio increased with depth in each profile studied (Table 4). Increased humus quality in deeper parts of profiles was in accordance with increased percentage of non-labile organic carbon (C_{NL}) (Table 2).

Significantly (P < 0.001) (Table 5) the lowest humus quality was found in A and Bt horizons under oaks (HA : FA ratio was only 0.38–0.48). Surprisingly, humus quality under coniferous pine and cedar trees was higher in both profiles (Table 4).

Also degree of humification calculated ($C_{HK} = C_{HK}/C_T$*100 in %) under oak trees indicated significantly (P < 0.001) (Table 5) smaller proportions of SOM transformed to extracted humic acids compared to pine and cedar stands.

Discussion

On the base of their morphological, physical and chemical properties, we classified soil types under pine trees as Haplic Luvisols and under oak and cedar trees as Stagni-Haplic Luvisols (MSCS, 2000).

Table 5. Statistical evaluation: Analysis of variance in A horizons, LSD procedure

Parameter	Oak	Pine	Cedar	Significance
H – Hydrolytic acidity [mmol kg^{-1}]	157.9 c	29.8 a	66.5 b	***
S – Sum of bases [mmol kg^{-1}]	50 a	239.0 c	169.0 b	***
CEC – Cation exchange capacity [mmol kg^{-1}]	207.9 a	268.8 c	235.5 b	***
BS – Base saturation [%]	24.1 a	88.9 c	71.8 b	***
pH H_2O	4.62 a	6.31 c	5.21 b	***
pH KCl	4.17 b	5.18 c	3.93 a	**
pH KCl	4.17 a	5.18 b	3.93 a	***
pH $CaCl_2$	4.58 a	5.80 b	4.56 a	***
C_T – Total organic carbon [g kg^{-1}]	22.63 c	11.54 a	12.15 b	***
C_L – Labile organic carbon [g kg^{-1}]	2.397 b	2.512 c	1.891 a	***
N_T – Total nitrogen [g kg^{-1}]	1.56 b	1.14 a	1.74 c	***
C_{mic} – Microbial biomass carbon	0.906 c	0.073 b	0.044 a	***
C_T/N_T ratio	14.5 c	10.1 b	7.0 a	***
P – Phosphorus [mg kg^{-1}]	52 b	14 a	14 a	***
K – Potassium [mg kg^{-1}]	183 a	185 a	225 b	***
C_{mic} – of C_T [%]	4.00 c	0.63 b	0.36 a	***
C_L – of C_T [%]	10.60 a	21.77 c	15.56 b	***
Non-labile org. carbon – C_{NL} of C_T [%]	89.4 c	78.2 a	84.4 b	***
C_{HS} – Carbon of humus substances [g kg^{-1}]	8.97 c	5.28 a	5.85 b	***
C_{HA} – Carbon of humic acids [g kg^{-1}]	2.44 b	1.99 a	2.40 b	***
C_{FA} – Carbon of fulvic acids [g kg^{-1}]	6.35 c	3.29 a	3.45 b	***
$C_{HA} : C_{FA}$ – Humic to fulvic acids	0.38 a	0.61 b	0.61 b	***
$Q_{HA}^{4/6}$ – Absorbance ratio of HA	4.58 a	5.13 b	7.92 c	***
Degree of humification	10.8 a	17.2 b	18.2 c	**
Degree of humification	10.8 a	17.2 b	18.2 b	***

Different letters in one row means values of parameter are significantly different: ** P < 0.01, *** P < 0.001

Our results showed lower pH values under deciduous oak trees compared to coniferous pine and cedar trees. Such results are not in agreement with general knowledge according to which conifer litter is more acidic than deciduous leaf litter and acidification of the soil is more pronounced in the first case. The leachate of this evergreen foliage is usually by 2 units lower in pH value than the leachate moving through deciduous litter, liberating organic acids that may participate in weathering processes (Jahren, 2005). Many authors confirmed strong soil acidity in pine and cedar forests (Farley et al., 2004; Hirano et al., 2000 cit. Kato et al., 1995; Kromka et al., 2003, Yamashita et al., 2004).

We suppose, that significantly ($P < 0.001$) stronger soil acidity under deciduous oaks was due to longer period of their influence on soil (older than 116 years) compared to younger pine and cedar trees (around 45-year-old). Hagen-Thorn et al. (2004) stated that studies in younger plantations, not more than 30-year-old, in temperate regions usually showed an influence on the forest floor only. They observed more distinct differences in soil chemistry in 40- to 50-year-old plantations of different species in upper 0.0–0.1 m, than in lower 0.2–0.3 m soil layer.

Other factor intensively influencing soil acidity is soil-forming substrate. In our study, the substrate under oaks was loess without carbonates, but under pine trees it was carbonate loess. Carbonates were also in Btg/C horizons under cedar trees. Presented carbonates have a high buffering capacity, therefore the soil reaction was neutral or alkaline.

Very low values of soil reaction in solutions KCl and $CaCl_2$ were found in Au and Btg horizons under cedar trees. We suppose that it was due to pseudo-gleyic process. Oak and cedar soil was classified as Stagni-Haplic Luvisol, which usually contains impermeable or slightly permeable layer, therefore soil layer above it is seasonally wet. During wet periods, ion exchange reactions involve iron and manganese in a sequence of reduction-oxidation cycles displacing ions in the reduced phase. Acidic ions as iron, aluminium and manganese are in mobile ionic forms, thus they can contribute to increase in acidity (Hanes et al., 1997).

Since no fertiliser was used in the Arboretum, we suppose that higher concentration of N, P, K macronutrients in humus horizon was due to the decomposed litter. Zimermann et al. (2002) examining a chestnut forest found that an amount of approximately 35% of available soil nutrients are returned each year in litterfall and he stated that the differences in amounts of the returned organic matter and nutrients in the litter could be explained by the site conditions (geology, chemistry, microbiology), the former cultivation, and the biochemical cycles and physiological function of the nutrients.

Special distribution of potassium (K) and phosphorus (P) contents was found in soil under oaks where the second maximum in the mentioned macronutrients content started at a depth of 0.5 m. We suppose that it was due to eluviation process associated with potassium ions leaching from the upper parts of profile, transporting them by percolating water to the lower parts, and binding by soil colloids. The process of leaching was probably supported by fulvic acids, which highly predominated in humus composition (HA : FA = 0.38 in A horizon). In spite of the fact that phosphorus is generally considered as a less mobile macronutrient, it had also its second maximum at 0.5 m from the surface.

Hagen-Thorn et al., (2004) stated that different species may have different even contradictory effects on various components of the P cycle and pools in different soil layers. Higher concentrations of the Fe and Al in the soil solution due to lower pH levels probably lead to higher amount of P precipitated with Al and Fe, and the resulting salts are insoluble.

The labile and total pools of organic carbon were found the highest in oak soil, however, the percentage of labile sub-pool from the total carbon was the lowest just in the soil under oaks. This finding suggests that organic matter in oak soil was more resistant against biodegradation compared to the pine and cedar soil.

Total organic carbon consists of C with varying turnover rates dependent on the relative C unstability of each component. Soil with larger amounts of high-quality C or high-labile C will release higher amounts of CO_2 – since the soil microbial populations can utilize more such C substrates (Mungai et al., 2006). Labile organic matter pools can be considered as fine indicators of soil quality influencing soil functions in specific ways and much more sensitive to changes in soil management practice (Haynes, 2005). The C oxidisable with $KMnO_4$, ie the "labile" carbon mostly comprises soil carbohydrates and some unidentified aromatic compounds, fulvic acids and microbial biomass carbon. Non-oxidisable carbon (C_{NL}) is related to soil humin and stable polysaccharides (Conteh et al., 1999).

In each of the investigated soil profiles $C_T : N_T$ ratio decreased with depth, probably as a result of nitrogen leached to the lower parts of soil profiles, or due to higher content of carbon and less decomposed organic matter in A horizons (Table 2). Studies of many authors confirmed decreasing tendency in C : N ratio with increasing depth of soil profile (Beyer et al., 1993; Hagen-Thorn et al., 2004; Zimmermann et al., 2002). Baytes (1996) concluded that as soil forming process hardly occurred in the soils studied, progressive humification could be expected as decreasing C : N ratio and found with depth in mineral horizons suggesting an increasing degree of SOM decomposition.

Higher $C_T : N_T$ ratio in oak soil suggests that SOM under oak trees had lower quality and therefore it was more resistant to biodegradation compared with the studied conifers (Table 2).

Our findings of higher microbial biomass carbon content (C_{mic}) in deciduous oak soil compared to coniferous stands are in accordance with the results of previous studies dealing with different types of forest ecosystems (Bauhus et al., 1998; Priha et al., 2001; Smolander et al., 2002), although in most of these cases, the deciduous stands were represented by birch. However, according to study of Hackl et al. (2000) it may be suggested that the content of C_{mic} can differ even under the same tree species growing on different soil types.

We suppose that higher abundance of microbes under oaks was due to structure of C_L rather than by its amount itself. However, according to Smolander et al. (2002) soil microbial biomass and activities appeared to be correlated with the total concentration of dissolved organic carbon rather than with its characteristics.

At the all experimental sites C_{mic} tended to decrease with depth. In this case, however, relatively high microbial colonization of soil in Bt or Btg horizon under oaks was determined. The reason of such a phenomenon could be the abundance of organic compounds available for microbial decomposition leached from upper to lower soil horizons by the lessivage process.

Similarly to our findings, the tendency of wider C_{mic}/C_T ratio in soil under deciduous compared with coniferous was reported by Bauhus et al. (1998) or Smolander et al. (2002) who reported higher values for C_{mic}/C_T ratio under deciduous (birch = 2.5%) compared to those under coniferous (pine 1.7%). In the most cases, the C_{mic}/C_T widened with depth, indicating a more intensive decline in organic matter with declining depth than it is the case of microbial biomass. According to Šimek et al. (2002), the C_{mic}/C_T ratio is higher in less fertile soils with low total organic carbon content.

Generally, the conifer soil might have a thick, undecomposed upper horizon with relatively low levels of organic matter below, the grassland might have well-decomposed and well-distributed organic matter throughout the soil profile, and the deciduous system would exhibit properties intermediate to the conifer and grassland profiles (Jahren, 2005).

Sifnificantly lower HA : FA ratio in deciduous soil compared to coniferous suggests, that under deciduous oaks the aggressive fulvic acids dominated in humus composition (Table 4). Lower humus quality under deciduous was confirmed by higher value of colour quotient and lower degree of humification. Similarly to our results, Lesná et al. (2003) also found higher HA : FA ratio under coniferous Norway spruce compared to European beech. But in contrary, degrees of humification were higher under beech, and colour quotient $Q_{4/6}$ showed HA of the beech stand to be more condensed and therefore higher quality than of spruce stand.

In a similar way, Howard et al. (1998) showed higher humus quality in A-horizons under oaks (on limestone average HA : FA = 0.81 and on slates = 1.02). On the contrary, low humus quality in A horizon was found by Bayer et al. (1993) in oak forest on boulder marl substrate with carbonates in deeper subsoil HA : FA = 0.44–0.6.

We suppose that lower humus quality under deciduous oaks resulted from carbonate-less soil forming substrate and also longer presence of oak trees (more than 116 years) influencing the soil compared to coniferous pine and cedar trees (around 45 years). Therefore, the influence of the studied coniferous has not been fully proved.

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Vlastnosti pôdy pod rôznymi druhmi drevín v Arboréte

Súhrn

V práci sme sledovali vplyv porastov dubov (*Quercus Cerris,* L.), borovice himalájskej (*Pinus wallichiana,* Jacson) a krypromérie japonskej (*Cryptomeria japonica,* D. Don.) na vybrané chemické a mikrobiálne vlastnosti pôd v arboréte Mlyňany. Pôvodným porastom bol dubovo hrabový les, preto sme zachovaný dubový porast vybrali za kontrolný variant. Získané výsledky ukázali, že zmena drevinových druhov výrazne ovplyvnila chemické a mikrobiálne vlastnosti pôdy. Vysoko preukazné ($P < 0{,}001$) rozdiely najmä v A horizontoch medzi sledovanými porastmi boli zistené v hodnotách pH, sorpčných vlastnostiach, obsahu živín (N, P, K), kvalite a kvantite pôdnej organickej hmoty (POH) i mikrobiálnej biomase. Preukazne ($P < 0{,}001$) najvyšší obsah celkového organického uhlíka (C_T) a najsilnejšia acidita boli v A horizonte pod dubmi. Najnižšie zastúpenie mikrobiálne ľahko rozložiteľnej organickej hmoty (C_L) z C_T a najvyšší pomer C : N svedčí o tom, že POH v A horizonte pod dubmi bola značne rezistentná voči biodegradácii. Uhlík mikrobiálnej biomasy (C_{mic}) ako i jeho podiel z C_T boli preukazne ($P < 0{,}001$) najvyššie v pôde pod dubmi, a to predovšetkým v A horizonte. Vysoká kolonizácia tejto pôdy mikróbmi bola pravdepodobne spôsobená skôr zložením C_L než jeho množstvom. Preukazne ($P < 0{,}001$) najnižšia kvalita humusu (HA : FA = 0,38 v A horizonte) potvrdila, že najmä pod dubmi bolo vysoké zastúpenie fulvokyselín. Predpokladáme, že nízka kvalita humusu pod dubmi bola v dôsledku nekarbonátového pôdotvorného substrátu a dlhej doby vplyvu porastu dubov (viac ako 116 rokov) na pôdu v porovnaní so sledovanými ihličnanmi – borovicou himalájskou a kryptomériou japonskou (okolo 45 rokov).

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