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The influence of different vegetation on soil chemical properties in Arboretum Mlyňany

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Abstract

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Differences in some chemical properties of soil under oak *Quercus cerris* (L.), cherry laurel *Prunus lauroerasus* (L.), and yew *Taxus baccata* (L.) woody plants in Arboretum Mlyňany were studied. Originally, oak-hornbeam forest was naturally present on studied area therefore soil under oak woods was taken as control variant. Obtained results showed, that changed type of vegetation distinctly influenced soil chemical characteristics. Studied profiles significantly (P = 0.01–0.05) differed in phosphorus and potassium contents, in pH H_2O and hydrolytic acidity. Profiles differed highly significantly (P = 0.01–0.001) in percentage of hot water soluble (C_{hws}) and oxidisable (C_L) carbon of C_T, sorption capacity and pH KCl values. The highest contents of potassium and phosphorus were found in A horizon under each studied woods. We suppose that mentioned macronutrients come from decomposed litter. Significantly (P < 0.001) the highest organic carbon content (C_T) was found in A horizon under cherry laurel wood (C_T = 26.51 g kg^{-1}), under oak (C_T = 22.63 g kg^{-1}), and under yew wood it was 20.71 g kg^{-1}. Type of vegetation influenced also humus quality. Low humus quality (ratio HA/FA) confirmed, that mainly under yew and oak was high amount of aggressive fulvic acids.

Key words

forest, pH, organic carbon, oak, cherry laurel, yew

Introduction

Arboretum Mlyňany was established in year 1892 by Dr. Štefan Ambrózy-Migazzy. The goal was to collect mainly sempervirent leafy woody plants and to prove their viability under climate conditions of Slovakia. Nowadays resides in Arboretum manor house Dendrobiological Institute SAS. Special care is taken studying and saving endangered woody species (Bero et al., 1992). Solicitude for conservation and sustainable utilization (mainly protection in situ, protection out situ and utilization biodiversity components) is the goal of EU Biodiversity strategy (Macák, 2006).

One of basic factors influencing successful plant growing is soil. However, plant cover and tree species have fundamental effects on soil properties. Tree species can influence soil chemical properties by several mechanisms. Differences in litter quality and nutrient status, nutrient uptake and activity, interception of atmospheric deposition, canopy interactions and leaching as well as alterations of the microclimate and soil's biological community can cause differences in the physical and chemical characteristics of topsoils under various species. The presence or absence of a decomposer community as influenced by soil pH may also play a role in the soil organic matter differentiation in relation to soil acidification (Hagen-Thorn et al., 2004; Nierop et al., 2003).

Conifer ecosystems contribute more tissue to the soil annually than do deciduous or grassland ecosystems, yet this tissue is of very low quality with respect to decomposition. In contrast, the A-horizon of grassland soils exhibits organic matter with high quality, relative to deciduous or conifer systems. Therefore soil under conifer 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).

The aim of this study was to investigate the impact of different tree species (oak, yew and cherry laurel) on some soil chemical characteristics in Nature Reserve Arboretum Mlyňany.

Material and methods

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 locality climatically belongs to warm and dry part of Slovakia. Arboretum is situated on Neocene clay, sand and rubble sand, covered with loess, mostly carbonate-less (Steinhübel, 1957; Škobla and Kováč, 1967).

Nature Reserve Arboretum has special garden architecture, where dominates green colour of original Ambrozy‘s collections and colourfulness and richness of new collections, divided according to geographic zones to: East-Asia woody plants area, North America woody plants area, Korea woody plants area, exposition of Slovak woody plants (mainly preserved endangered taxons ex situ) (Bero et al., 1992).

The main soil type on study area is Stagni-Haplic Luvisol.

Soil pits trenched in Nature Reserve Arboretum Mlyňany:

Soil pit No. 1 was trenched under oak wood *Quercus cerris* (L.).

Soil pit No. 2 was trenched under cherry laurel wood *Prunus lauroerasus* (L.).

Soil pit No. 3 was trenched under yew wood T*axus baccata* (L.).

Soil profiles were characterised for morphological, physical, chemical and microbiological properties. Soil samples for chemical analyses were grinded, then sieved over sieve with holes diameter of 2 mm. For analyse soil organic matter was used sieve with holes of 0.25 mm.

Analyzed chemical parameters: soil reaction – potentiometrically in H_2O and in KCl; exchangeable base ions (Ca^{2+}, Mg^{2+}, K^+, Na^+) and hydrolytical acidity by Kappen‘s method (Hanes et al., 1995); phosphorus (P) and potassium (K) were analysed by method Melich III (Melich, 1984), then phosphorus colorimetrically on Spectrophotometer Jenway model 6400 and potassium on atomic absorption spectrophotometer AVANTA; total soil organic carbon (C_T) – by Tyurin method (Orlov and Grishina, 1981); humus fractionation – by Kononova and Belchikova method (1961); spectral analyses of humus substances (HS) and humic acids (HA) – 6400 Spectrophotometer (Jen Way); hot water soluble carbon (C_{hws}) – by method of Körchens and Schulz (1999); susceptibility of organic carbon to oxidation by 0.005M $KMnO_4$ solution in acidic medium of 0.0025 mol dm^{-3} H_2SO_4 – (C_L) (Loginow et al., 1993); total nitrogen content – N_T – by Kjeldahl (Fecenko, 1991). Each analyse were done in 3 repeats and in paper are written average values. For better understanding progressing processes in soil, some analyses (pH, C_T, N_T, P, K contents) were done for each 0.1 m layers down to the depth of 0.8 m. For statistical analyse was used analysis of variance ANOVA – LSD-procedure.

Results and discussion

Soil reaction was acid in each profile, but the strongest acidification was found in profile under yew (Tables 1–3). Higher acidity under coniferous is known and was confirmed by many authors: Hagen-Thorn (2004), Jahren (2005), Kromka et al. (2003), Podrázský et al. (2005), Smolander et al. (2005). Hagen-Thorn (2004) stated, that lower pH under coniferous (spruce) can be explained by slower litter decomposition in these species, which leads to the production of organic acids. Values of pH KCl were significantly higher ($P < 0.001$) under oak compared to other woods. Differences in pH values were found also between horizons of individual profiles. Soil reaction (pH KCl) was extremely acid mainly in luvic (Bt) and luvic-pseudogleic (Btg) horizons (Tables 1–3). In contrary to our results Podrázský et al. (2005) found B horizon less acidic than A horizon under spruce wood, but more acidic under basswood.

Strong acidification mainly Bt and Btg horizons was probably due to leaching of acidic products from decomposed litter and soil organic matter of upper horizons.

Acidity of Bt and Btg horizons could be increased by pseudogleyization process (studied soil was classified as Stagni Haplic Luvisol). It is known, that due to process of pseudogleyization and gleization are acidic ions as iron, aluminium and manganese in ionic form (Hanes et al., 1997). These ions could contribute to increase acidity of Btg and Bt horizons.

Jahren (2005) reported that the decomposition of plant tissues produces humus, which contains mainly organic groups including fulvic acids. The low pH of these acids may accelerate weathering process and the production of secondary minerals from primary minerals. In this way the decomposition of plant tissues might facilitate pedogenetic process, such as the in situ production of secondary clay. The needles of conifer trees result in low-pH soil conditions. The leachate of this evergreen foliage is usually 2 unites lower in pH value than leachate moving through deciduous litter, liberating organic acids that may participate in weathering process.

The highest contents of potassium and phosphorus were found in A horizon under each studied woods (Tables 1–3). Because of in Arboretum was not used any fertilizer we suppose, that mentioned macronutrients come from decomposed litter. Compared to A horizons phosphorus content sharply decreased in Bt and Btg horizons. Significantly lower content of phosphorus was found in whole profile under cherry laurel wood.

The distribution of potassium in profile was not the same as phosphorus. Rich for potassium were A horizons. Luvic-Bt horizons contained lower amount of K, but Btg and mainly Btg/C horizons were enriched for potassium. Higher content of potassium in Btg; Btg/C and C horizons can be explained by high mobility of monovalent cations in profile, when K^+ were transported by percolating water (moreover containing acidic products of decomposed organic matter which support the leaching process) from upper parts of profile to lower, where were adsorbed on sorption complex or precipitated with anions. Simultaneously other base cations were leached from upper horizons and accumulated in lower parts of profiles. The distribution of sum of base cations is in Tables 1–3. Consequently, the

Table 1. Soil sorption and pH values – oak

Horizon	Depth (m)	H	S	T	V	pH	pH
		(mmol kg^{-1})			(%)	H_2O	KCl
Au	0.0–0.15	157.9	50	207.9	24.1	4.62	4.17
Bt	0.15–0.50	133.0	65	198.0	32.8	4.58	4.12
Btg	0.50–0.80	44.2	201	245.2	81.8	5.38	4.55
C	1.00–1.10	28.3	388.9	417.3	93.2	5.70	4.87

H – hydrolytic acidity, T – cation exchange capacity, S – sum of bases (Na^+, K^+, Ca^{2+}, Mg^{2+}), V – base saturation

Table 2. Soil sorption and pH values – cherry laurel

Horizon	Depth (m)	H	S	T	V	pH	pH
		(mmol kg^{-1})			%	H_2O	KCl
Au	0.0–0.23	57.8	82	139.8	58.7	5.12	4.02
Bt	0.23–0.6	64.8	26	90.8	28.7	4.75	3.35
Btg	0.6–0.9	71.8	153	224.8	68.1	4.46	3.16
Btg/C	> 0.9	36.6	156	192.6	81.0	4.62	3.44

Table 3. Soil sorption and pH values – yew

Horizon	Depth (m)	H	S	T	V	pH	pH
		(mmol kg^{-1})			(%)	H_2O	KCl
Au	0.0–0.2	79.6	97.0	176.6	54.9	4.66	3.55
Bt	0.2–0.6	86.6	79.0	165.6	47.7	4.29	3.26
Btg	0.6–0.9	53.4	147.0	200.4	73.4	4.59	3.24
Btg/C	> 0.9	36.8	132.0	268.8	86.3	4.92	3.61

degree of base saturation increased in Btg and C horizons (Tables 1–3).

More particular distribution of pH and C, N, P, K contents in profiles is possible to see in Table 7.

Carbonates were not present in any of studied soil profile, what is in agreement with results obtained by Cifra (1958).

Significantly ($P < 0.001$) the highest organic carbon content (C_T) was found in A horizon of the soil under cherry laurel wood (C_T = 26.51 g kg^{-1}), under oak (C_T = 22.63 g kg^{-1}), and under yew wood it was 20.71 g kg^{-1} (Tables 4–6).

Type of vegetation influenced also SOM quality. The storage of susceptible organic matter to microbial oxidation (determined as organic carbon soluble in hot water (C_{hws}) and organic carbon oxidisable by $KMnO_4$ solution (C_L) was similar in profiles under yew and cherry laurel (mainly in A and Bt horizons). Lower content of labile carbon fractions was found under oak (Tables 4–6). Also percentage C_L of C_T was significantly higher ($P < 0.001$) in profiles under yew and cherry laurel (Tables 1–3).

Conteh et al. (1999) reported, that labile carbon determined by oxidation with $KMnO_4$ solutions is significantly related to fulvic acid, soil polysaccharides and soil microbial biomass carbon. The $KMnO_4$ oxidisable carbon mostly comprise of soil carbohydrates and some unidentified aromatic compounds. The association between C_L and fulvic acids, carbohydrates and microbial biomass carbon indicate that the term labile appropriate for $KMnO_4$ oxidisable carbon and non-oxidisable C (C_{NL}) is related to soil humin and non-labile polysaccharides.

Surprisingly, the C_T/N_T ratio was lower in profile under yew compared to oak and cherry laurel (Tables 4–6). It is known, that low carbon to nitrogen ratio suggest abundant nitrogen in the organic matter that would easily decompose. In each investigated soil profiles C_T/N_T ratio decreased with depth. It could be due to leached nitrogen to the lower parts of soil profiles, or due to higher content of carbon rich and less decomposed organic matter in A horizons. Priha et al. (1999) stated, that higher C-to-N ratios pointing on low nitrification activity and numbers of nitrifiers.

Table 7. The content of soil carbon, nitrogen, potassium and phosphorus and pH values under oak, cherry laurel and yew, measured in 0.1 m layers

Depth	C_T (g kg^{-1})			N_T (g kg^{-1})			K (mg kg^{-1})			P (mg kg^{-1})			pH KCl		
	Oak	Cherry laurel	Yew	Oak	Cherry laurel	Yew	Oak	Cherry laurel	Yew	Oak	Cherry laurel	Yew	Oak	Cherry laurel	Yew
0.0–0.1	30.6	29.7	21.0	2.01	2.09	1.94	193	98	403	60	10	54	4.24	4.00	4.47
0.1–0.2	14.2	23.3	20.3	1.11	1.40	1.55	145	90	380	12	10	30	4.09	3.92	3.98
0.2–0.3	10.5	9.1	12.6	0.94	0.69	1.23	143	63	165	10	6	14	4.11	3.50	3.19
0.3–0.4	8.3	10.8	8.2	0.77	1.38	1.51	145	63	163	10	8	14	4.08	3.40	3.14
0.4–0.5	8.2	11.1	7.1	0.78	1.12	0.75	170	58	185	8	8	14	4.21	3.40	3.03
0.5–0.6	5.7	7.4	4.8	0.55	1.28	1.01	188	73	138	12	8	20	4.39	3.47	3.08
0.6–0.7	6.2	6.2	4.6	0.57	0.74	0.59	205	143	155	20	8	16	4.61	3.32	3.22
0.7–0.8	4.9	5.1	4.7	0.93	0.85	0.66	208	153	170	25	6	12	4.65	3.32	3.26

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

Table 4. The content and quality of soil organic matter – oak

Horizon	Depth (m)	C_T (g kg^{-1})	N_T (g kg^{-1})	P (g kg^{-1})	K (g kg^{-1})	C_T/N_T	C_{hws} (g kg^{-1})	C_L (g kg^{-1})	C_{hws} (% of C_T)	C_L (% of C_T)	C_{NL} (% of C_T)
Au	0.00–0.15	22.63	1.56	0.052	0.183	14.5	0.636	2.397	2.81	10.60	89.4
Bt	0.15–0.50	10.31	0.90	0.010	0.157	11.3	0.293	0.807	2.84	7.83	92.2
Btg	0.50–0.80	5.60	0.68	0.020	0.151	8.8	0.160	0.378	2.86	6.75	93.2
C	1.00–1.10	3.96	0.39	0.058	0.205	10.1	0.120	0.309	3.03	7.80	92.2

C_T – total soil organic carbon, N_T – total nitrogen content, C_{hws} – hot water soluble organic carbon, C_T/N_T – ratio C_T/N_T, C_L – organic carbon oxidisable by 0.005 mol dm^{-3} $KMnO_4$, P – phosphorus content, C_{NL} – organic carbon susceptible to oxidation by 0.005 mol dm^{-3} $KMnO_4$, K – potassium content

Table 5. The content and quality of soil organic matter – cherry laurel

Horizon	Depth (m)	C_T	N_T	P	K	C_T/N_T	C_{hws}	C_L	C_{hws}	C_L	C_{NL}
		(g kg^{-1})					(g kg^{-1})		(% of C_T)		
Au	0.0–0.23	26.51	1.75	0.014	0.098	15.18	0.502	4.141	1.89	15.62	84.38
Bt	0.23–0.6	9.59	0.77	0.010	0.065	13.69	0.224	1.131	2.34	11.89	88.11
Btg	0.6-0.9	5.52	0.60	0.006	0.155	9.17	0.141	0.598	2.55	10.83	89.17
Btg/C	> 0.9	4.44	0.49	0.008	0.160	9.06	0.134	0.443	2.36	10.77	89.23

Table 6. The content and quality of soil organic matter – yew

Horizon	Depth (m)	C_T	N_T	P	K	C_T/N_T	C_{hws}	C_L	C_{hws}	C_L	C_{NL}
		(g kg^{-1})					(g kg^{-1})		(% of CT)		
Au	0.0–0.2	20.71	1.393	0.034	0.353	14.87	0.523	3.976	2.51	19.20	80.80
Bt	0.2–0.6	9.74	1.125	0.016	0.168	8.66	0.275	0.960	2.56	9.86	90.14
Btg	0.6–0.9	4.64	0.63	0.022	0.163	7.37	0.113	0.418	2.43	9.77	90.23
Btg/C	> 0.9	4.09	0.58	0.012	0.180	7.05	0.151	0.426	3.67	10.51	89.49

Humus quality (analysed by method of Kononova and Belchikova) was very low in each A and Bt horizons of studied soil profiles. Quality of humus increased in deeper parts of profiles (Table 8). Increasing humus quality was followed by increasing content of non -labile (C_{NL}) carbon fractions (Tables 4–6).

Humus quality was more or less the same in profiles under oak wood and yew wood (Table 8). Other results were published by Szombathova (1999). She reported qualitative parameters of humus analysed by the same method under oak-hornbeam forest in Báb, but found higher humus quality in A-horizons (HA/FA was 0.75 in – upland area and 0.93 – slope). We suppose that great difference in humus quality was due to soil forming substrate. In Arboretum the substrate was loam without carbonate content, but in Báb it was carbonate loess (climatic conditions are similar in both areas).

Also results of Howard et al. (1997) showed higher humus quality under oak and yew woods. But, similarly also his results showed small differences in humus quality in A-horizons under oak and yew (HA/FA under oak = 0.81 and under yew = 0.78).

Slightly higher humus quality was found in the soil under cherry laurel wood (Table 8).

Table 8. The quality of humus in profiles under oak, cherry laurel and yew

Locality	Horizon	Depth (m)	C_T	C_{HS}	C_{HA}	C_{FA}	HA/FA	$Q_{HA}^{4/6}$
			(g kg^{-1})					
Oak	Au	0.00–0.15	22.63	8.97	2.44	6.35	0.38	4.58
	Bt	0.15–0.50	10.31	4.36	1.42	2.94	0.48	4.12
	Btg	0.50–0.80	5.60	2.38	1.28	1.10	1.16	3.91
	C	1.00–1.10	3.96	1.67	0.80	0.87	0.92	4.67
Cherry laurel	Au	0.0–0.23	26.51	8.15	2.77	5.38	0.52	4.64
	Bt	0.23–0.6	9.59	4.15	1.31	2.84	0.46	4.43
	Btg	0.6–0.9	5.52	1.88	0.89	0.99	0.90	4.60
	Btg/C	> 0.9	4.44	1.42	0.89	0.53	1.68	4.50
Yew	Au	0.0–0.2	20.71	8.51	2.38	6.13	0.39	4.84
	Bt	0.2–0.6	9.74	4.64	1.49	3.15	0.47	4.03
	Btg	0.6–0.9	4.64	2.23	0.97	1.26	0.77	4.83
	Btg/C	> 0.9	4.09	1.84	0.91	0.93	0.98	5.40

HA/FA – humic acids to fulvic acids ratio, C_{HS} – carbon of humus substances, $Q_{HA}^{4/6}$ – absorbance ratio A4/6 of humic acids, C_{HA} – carbon of humic acids, C_{FA} – carbon of fulvic acids

Conclusions

Results obtained in this study showed, that changed type of vegetation has strong influence on soil chemical properties.

Studied profiles significantly (P = 0.01–0.05) differed in phosphorus and potassium contents, in pH H_2O and hydrolytic acidity (H). Profiles differed highly significantly (P = 0.01–0.001) in organic carbon content (C_T), percentage of hot water soluble (C_{hws}) and oxidisable (C_L) carbon of C_T, sorption capacity (T) and pH KCl values.

Soil reaction was acid in each profile, but the strongest acidification was formed in profile under yew.

Strong acidification mainly Bt and Btg horizons was probably due to leaching of acidic products from decomposed litter and soil organic matter of upper horizons. Moreover, acidity of Bt and Btg horizons could be increased by pseudogleyization process.

A-horizons were containing the highest amounts of potassium and phosphorus. We suppose that mentioned macronutrients come from decomposed litter.

Low humus quality (ratio HA/FA) confirmed, that mainly under yew and oak was high amount of aggressive fulvic acids. Quality of humus increased in deeper parts of profiles.

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Vplyv rôznej vegetácie na chemické vlastnosti pôdy v Arboréte Mlyňany

Súhrn

V práci sme sledovali rozdiely vo vybraných chemických vlastnostiach pôd pod porastmi dubov (*Quercus cerris* L.), vavrínovca (*Prunus lauroerasus* L.) a tisov (*Taxus baccata* L.) v Arboréte Mlyňany. Pôvodným porastom bol dubovo hrabový les, preto sme zachovaný dubový porast vybrali za kontrolný variant. Získané výsledky ukázali, že zmena vegetácie výrazne ovplyvnila chemické vlastnosti pôdy. Sledované pôdne profily sa preukazne odlišovali (P = 0,01–0,05) v obsahu fosforu a draslíka, v hodnotách pH H_2O a hydrolytickej kyslosti (H). Profily sa vysoko preukazne (P = 0,001–0,01) líšili v zastúpení horúcou vodou rozpustného (C_{hws}) a oxidovateľného roztokom $KMnO_4$ (C_L) uhlíka z celkového obsahu uhlíka (C_T), v hodnotách sorpčnej kapacity (T) a pH KCl. Pôdna reakcia bola kyslá až veľmi kyslá vo všetkých sledovaných profiloch, no najsilnejšia kyslosť bola v profile pod tismi. Najvyššie obsahy draslíka a fosforu boli v A horizontoch pod všetkými sledovanými drevinami. Predpokladáme, že tieto makroživiny pochádzajú z rozloženého opadu drevín. Preukazne (P < 0,001) najvyšší obsah C_T bol v A horizonte pod vavrínovcami (C_T = 26,51 g kg^{-1}), pod dubmi (C_T = 22,63 g kg^{-1}) a pod tismi 20,71 g kg^{-1}. Druh vegetácie tiež ovplyvnil kvalitu organickej hmoty. Zastúpenie C_L z C_T bolo preukazne vyššie v profiloch pod tismi a vavrínovcami. Nízka kvalita humusu (pomer HK : FK) potvrdila, že najmä pod tismi a dubmi bolo vysoké zastúpenie agresívnych fulvokyselín. Kvalita humusu sa v hlbších vrstvách profilu zvýšila.