ECOLOGICAL CONDITIONS OF SELECTED WOODY PLANTS IN THE URBAN AREA NITRA

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Abstract

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Urban greenery is an inevitable element of modern cities. Since urban soils have considerable influence on urban greenery growing, we characterized urban soils under sugar maple, Austrian pine and little-leaf linden in park Sihoť and Klokočina district in the town Nitra. Great part of soils in Nitra is strongly influenced by man (mainly by former building activities), therefore the most spread soil type is Calcaric Urbi-Anthropic Regosols with alkaline pH. Our results confirmed high spatial differences of soil forming substrate and soil properties in urban areas. High compaction in deeper parts of some profiles inhibits proper roots penetration. Great differences in macronutrient content between profiles are probably the consequence of using fertilisers in some parts of the park. Since both studied areas were out of high traffic and contained carbonates, significantly ($P < 0.001$) higher content of heavy metals (beside cadmium) in park Sihoť with compared to Klokočina district was probably due to higher clay content and longer period of uninterrupted exposition of soil surface to urban pollution in park Sihoť. Lead exceeded limit values stated for trees (1–3 $mg.kg^{-1}$) in each profile. According to the Decree of Ministry of Agriculture of SR the available cadmium content exceeded the limit 0.3 $mg.kg^{-1}$ in each profile beside lime in park Sihoť. Humus content and quality in Klokočina district was significantly ($P < 0.001$) lower and had great spatial variability with compared to park Sihoť. The reason could be lower age of trees in Klokočina and abandoned use of organic fertilisers. Determined soil properties did not have negative influence on health state of selected woody plants beside lime in park Sihoť, which slightly suffered with drought.

Key words: urban area, health of woody plants, soil chemical and physical characteristics

Introduction

The urban environment quality is vital importance as the majority of people now live in cities. Therefore, urban green space is a crucial element in modern city planning. Vegetation has health and aesthetic functions for men, beautifies the city, stabilizes microclimatic air circulation, cleans urban air, decreases speed of wind, lowers noise and keeps average of air temperature to a moderate level (Supuka, 1998). According to expert results, broadleaved trees fix 10.25 t $CO_2.ha^{-1}.year^{-1}$ while 9.61 t $CO_2.ha^{-1}.year^{-1}$ is fixed by evergreens in the condition of the Czech Republic (Lapka, Cudlínová, 2005). Woody vegetation and parks have high environmental, ecological and social influence not only in central town areas but also at their outskirts (Supuka et al., 2005).

Soil is an important ingredient of urban ecosystems and represents the basic support system for terrestrial ecosystems because of their role in providing nutrients, oxygen, heat, and mechanical support to vegetation. Generally, soil properties have considerable influence on plants growing and its health condition, on the other side, also plants distinctly influence soil-forming process and soil properties.

Soils in megalopolises are specific ingredients of an open, non-resilient, and unstable ecosystem requiring external maintenance for its functioning. Urban civilization existing during millennia produced specific soils, which were formed by intricate combinations of natural soil forming factors and peculiar urban environment. The main factor of soil formation in towns is the land use type (industrial zones, settlement areas, natural gardens, etc.) (Stroganova, Prokofieva, 2001).

Urban soils have got many various and diverse soil properties. Quality of urban soils does not depend upon crop production parameters like at agricultural soils, but it is based on their specific site use in urbanized areas. Social-economic and environmental functions as buffering, sanitary, water retention, nutritional, etc. have priority in assessment of urban soils (Sobocká, 2003).

Material and methods

The town Nitra is situated on south-west part of the Slovak Republic (latitude 48.19 N; longitude 18.04 E). The most spread soil-forming substrates are loess and fluvial sediments of river Nitra and main soil types are Fluvisols, Mollic Fluvisols, Haplic Luvisols and rarely on different substrates Cambisols. Average temperature is 10.2 degrees of Celsius and precipitation 539 mm per year (Špánik et al., 2002).

Nitra town park is located in north-west part of town close to the old meander of river Nitra. It has acreage 20 ha and consists of three parts. The oldest one Sihoť was established in second half of 19th century. New and joining parts were established in the half of the 20th century.

Klokočina district is located in the west part of Nitra. Building of Klokočina district began around year 1970 and trees were planted 20–25 years ago.

Morphological, physical and chemical parameters were characterized for six soil profiles of depth 0.5–0.6 m:

A) Sihoť park location (sampling was done in November 25, 2004):

- Profile 1 (control) was located under sugar maple (*Acer saccharinum* L.) and it was minimally influenced by man. Soil type was classified as Eutric Fluvisols (ISSS-ISRICFao, 1994).
- Profile 2 under Austrian pine (*Pinus nigra* A r n o l d) was classified Calcaric Urbi-Anthropic Regosols (ISSS-ISRICFao, 1994).
- Profile 3 under little-leaf linden (*Tilia cordata* M i l l.) was classified Calcaric Urbi-Anthropic Regosols (ISSS-ISRICFao, 1994).

B) Soil properties under the same trees were characterized also in Klokočina district, where all studied profiles were classified as Calcaric Urbi-Anthropic Regosols (WRB, 1994). Sampling was done in October 7, 2005:

- Profile 1 was located under sugar maple (*Acer saccharinum* L.)
- Profile 2 under Austrian pine (*Pinus nigra* A r n o l d.)
- Profile 3 under little-leaf linden (*Tilia cordata* M i l l.)

Studied profiles were analysed for following chemical properties:

soil reaction – potentiometrically in H_2O, $CaCl_2$ and in KCl; exchangeable base ions (Ca^{2+}, Mg^{2+}, K^+, Na^+) and hydrolytical acidity by Kappen's method (Hanes et al., 1995); carbonate content by volumetric method (Čurlík et al., 2003); 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, Grishina, 1981); humus fractionation – according to Kononova and Belchikova method (1961); spectral analyses of humus substances (HS) and humic acids (HA) – 6400 Spectrophotometer (Jen Way); total nitrogen content - N_T – by Kjeldahl (Fecenko, 1991); available and unavailable forms of heavy metals in DTPA solution (Fiala et al., 1999).

Basic physical and hydrophysical parameters (Hanes et al., 1995) were determined only in till depth of high content of rocky fragments and artefacts.

Soil texture was determined by pipette method (Hanes et al., 1995). Each analysis was done in 3 repeats and in paper are written average values. For statistical analysis was used analysis of variance ANOVA – LSD-procedure.

Since urban soils are important component of human environment and have considerable influence on growing the urban greenery, the aim of the work reported here was to characterize urban soils under selected woody plants in park Sihoť and Klokočina district in the town Nitra.

Results and discussion

Beside the soil under Sugar maple in park Sihoť, each soil profile was classified as Calcaric Urbi-Anthropic Regosols (ISSS-ISRICFao, 1994). Calcaric Urbi-Anthropic Regosols contained different artefacts like bricks, glass, pottery, plastic, rock fragments, concrete etc. As consider soil morphology, we can conclude, that substrate for Calcaric Urbi-Anthropic Regosols in park Sihoť consists of mixture of soil and building material. This material was probably covered by layer of humus horizon formed on other locality. In Klokočina district were artefacts found in entire studied soil profiles.

Sobocká (2006) stated that the soil genesis in urban ecosystems is conditioned by young age (substrate soils), prevailingly by heterogeneous material, extreme soil properties, abundance of dust and various contaminants and pathogenic germs. Very important diagnostic features of soils are artefacts presence as well as "human-transported material" which separate anthropogenic soils apart natural soils.

Soil physical properties

When consider Sihoť park locality, the Eutric Fluvisols profile under maple can be taken as control variant for its minimal influencing by human. Soil physical properties of studied Eutric Fluvisols were very similar to ones determined by Szombathová et al. (2004) 2 km away in SAU garden, formed on the same fluvial substrate.

Particle density (ζ_s) depends on density of soil minerals and organic matter. It is relatively stabile soil parameter (Hanes et al., 1997). Higher ζ_s under pine and lime with compared

T a b l e 1. Soil physical and hydrophysical properties in Sihoť and Klokočina localities.

Locality	depth [m]	ρ_s	ρ_d	P	Θ	V_{AM}	Pk	Pn	Ps	V_A	Θv
		[t.m^{-3}]		[% vol.]							
Acer	0.0–0.1	2.57	1.16	54.86	30.67	24.19	39.33	2.73	12.80	14.28	14.90
Sihoť	0.1–0.2	2.54	1.31	48.42	32.69	15.73	39.48	2.40	6.54	6.54	16.69
(control)	0.2–0.3	2.56	1.36	46.87	32.48	14.39	40.16	1.87	4.84	5.98	16.01
	0.3–0.4	2.62	1.40	46.56	31.00	15.56	40.60	2.55	3.41	4.67	17.93
Pine	0.0–0.1	2.61	1.13	56.70	26.29	30.41	33.53	5.73	17.44	20.00	14.10
Sihoť	0.1–0.2	2.62	1.20	54.20	23.42	30.78	30.32	5.04	18.84	21.19	14.28
Lime	0.0–0.1	2.68	1.40	47.76	28.50	19.26	35.74	2.54	9.48	10.44	10.96
Sihoť	0.1–0.2	2.68	1.69	36.94	18.80	18.14	27.30	1.55	8.09	9.05	17.47
	0.2–0.3	2.68	1.71	36.19	18.78	17.41	30.46	1.26	4.47	5.31	14.12
Acer	0.0–0.1	2.45	1.46	40.40	16.62	23.78	32.30	4.04	4.06	5.90	15.28
Klokočina	0.1–0.2	2.53	1.59	37.15	13.11	24.04	29.47	2.96	4.72	6.01	13.82
	0.2–0.3	2.57	1.64	36.19	13.07	23.12	30.06	2.66	3.47	4.35	13.44
Pine	0.0–0.1	2.61	1.37	47.51	29.19	18.32	32.91	2.56	12.04	12.84	13.07
Klokočina	0.1–0.2	2.62	1.40	46.56	26.69	19.87	30.81	2.93	12.82	14.23	19.06
	0.2–0.3	2.63	1.55	41.06	21.84	19.22	29.52	3.02	8.52	10.38	16.72
Lime	0.0–0.1	2.59	1.29	50.19	30.45	19.74	37.42	3.16	11.11	12.77	16.24
Klokočina	0.1–0.2	2.60	1.45	44.23	23.55	20.68	32.34	3.07	10.52	11.89	14.95
	0.2–0.3	2.53	1.41	44.27	17.24	27.03	31.51	4.62	10.40	12.76	14.52
	0.3–0.4	2.45	1.60	34.69	15.87	18.82	31.47	3.35	1.41	3.22	11.59

Notes: ρ_s – particle density, ρ_d – bulk density dray , P – porosity, Θ – water content , V_{AM} – soil aeration, Pk – capillary pores, Ps – semicapillary pores, Pn – non-capillary pores, V_A – air porosity, Θv – wilting point

to maple confirmed different soil-forming substrate of Calcaric Urbi-Anthropic Regosols in Sihoť (Table 1). Distinctly different were values of bulk density (ζ_d) and porosity (P). These parameters are highly changeable and express compacted or loose soil state. We found, that C and D horizons under lime were strongly compacted (ζ_d = 1.69–1.7 t.m^{-3}; P = 36.94–36.19%) (Table 1). Hanes et al. (1995) referred, that compacted soil horizon exhibiting ζ_d values exceeding 1.7 t.m^{-3} for sands and about 1.35 t.m^{-3} for clays tend to inhibit root penetration. High ζ_d and low porosity may adversely affect soil biological properties and decrease microbial biomass due to oxygen deficiency in the compacted soils (Tan et al., 2005). However, porosity or total pore space does not give any indication of pore size distribution. Optimal pore distribution is 1/3 macropores – for aeration and 2/3 meso and micropores for water retention and accumulation (Bedrna et al., 1989).

In spite of soil samples were taken in the same day in park Sihoť, the soil moisture was distinctly higher in control variant under Sugar maple with compared to the others. This is evidence that capillary pores under maple were continual and capillary elevation of water from groundwater undisturbed.

Soil water is significant for four reasons: 1) trees require large amounts of water to supply their transpirational needs and nearly all of it must come from the soil; 2) the soil must be capable of supplying the water in adequate amounts when the trees require it; 3) the soil must hold sufficient amounts of water in storage to carry the needs of trees over a period of time until the supply is replenished; and 4) the soil water, as solution, is involved in the exchange and transport of nutrients and other soluble salts (Brady in: Craul, 1992).

In Klokočina district we did not find soil weakly influenced by man, therefore on this area we do not have the control variant. High differences in values ζ_s between soil profiles and also within profiles in Klokočina district refer about high spatial variability of soil-forming substrate (Table 1). Sobocká (2003) stated that soils occurring in urban areas have high soil heterogeneity at horizontal level, i.e. soil profiles are changing in many cases abruptly by distance of several centimetres. Also heterogeneity at vertical level is typical like stratification of soil horizons or their remnants presence.

Very high soil compaction and low porosity were found under sugar maple and also in depth 0.3 m under lime (Table 1). Soil moisture was distinctly lower in studied profile under maple compared to pine and lime. In depth 0.1–0.3 even reached wilting point (Table 1).

Hrubík et al. (2005, 2006) investigated health state of selected trees on both locations during three years. They found, that beside limes in Sihoť park any of studied trees did not suffer with physiological or mechanical harm. Limes in park Sihoť slightly suffered with drought, what was observed as increased yellow colour of leaves. Also physical and textural results obtained in this study confirmed the lowest water content and total porosity, critically high bulk density and high content of sand in profile under lime in Sihoť (Tables 1, 2).

Soil chemical properties

Soil reaction pH_{KCl} was slightly acid in humus horizon of control Eutric Fluvisols in park Sihoť. Reaction of other profiles in Sihoť was significantly ($P < 0.001$) higher and even reached slightly alkaline values (Table 2). Craul (1992) stated that urban soils tend to have pH values somewhat different from their natural counterparts. In most cases, pH values are higher in the urban environment.

Higher soil reaction correspondent to higher content of carbonates in profiles, and lower values of hydrolytic acidity (H). Sorption complex was fully saturated by base cations (S) (Table 2).

Since original soil-forming fluvial substrate in park Sihoť contained only 0.3% of $CaCO_3$ (profile under sugar maple) we can conclude, that significantly ($P < 0.001$) higher content of carbonates in Calcaric Urbi-Anthropic Regosols was caused by anthropogenic influence (Table 4). Carbonates in park Sihoť mainly come from construction spots or secondary carbonated soils as remains of former building activities (concrete, lime, bricks…).

T a b l e 2. Soil sorption, pH values and soil textural composition in Sihoť and Klokočina localities.

Locality	Hori-zon	Depth	H	S	BS	pH	pH	Clay	Silt	Sand	Tex-ture
		[m]	[mmol.kg^{-1}]		[%]	$_{H2O}$	$_{KCl}$	%			
Acer	**Au**	0.0-0.15	25.1	305.3	92.4	6.75	5.59	30.05	62.53	14.09	ssi
Sihoť	**A/C**	0.15-0.3	8.8	313.8	97.3	7.40	6.37	34.25	62.56	9.86	ssi
(control)	**Cc**	> 0.30	5.6	365.3	98.5	7.86	6.61	37.66	58.61	3.72	ssi
Pine	**Adc**	0.0-0.15	3.2	nd	-	8.16	7.47	12.17	57.24	30.59	ssh
Sihoť	**A/Cc**	0.15-0.2	2.6	nd	-	8.26	7.58	13.24	51.38	35.38	ssh
	Cc	>0.20	2.3	nd	-	8.29	7.73	8.29	31.79	61.25	sp
Lime	**Adic**	0.0-0.10	3.5	nd	-	7.99	7.19	11.82	53.18	47.26	sh
Sihoť	**Cc**	0.1-0.20	3.5	nd	-	8.19	7.39	13.28	41.08	45.10	sh
	Dc	>0.20	3.5	nd	-	8.34	7.35	12.73	34.05	53.23	sh
Acer	**Adc**	0.0-0.20	5.8	529.8	99.0	8.08	7.35	17.81	42.49	39.88	sh
Klokočina	**Cc**	> 0.20	4.9	nd	-	8.26	7.41	15.30	50.16	35.54	ssh
Pine	**Adc**	0.0-0.20	6.8	529.8	98.7	7.85	7.02	1.91	66.29	31.80	ssh
Klokočina	**Cc**	>0.20	4.8	nd	-	8.37	7.48	13.18	46.79	40.03	sh
Lime	**Adc**	0.0-0.15	6.0	518.2	98.9	7.78	7.09	19.61	52.56	27.83	ssh
Klokočina	**Cc**	>0.15	6.4	464.6	98.6	7.99	7.16	20.92	50.46	28.62	ssh

Notes: H – hydrolytic acidity, S – sum of bases (Na^+, K^+, Ca^{2+}, Mg^{2+}), BS – base saturation, ssi – silty clay loam, ssh – silty loam, sp – sandy loam, sh – loam, nd – not done

Soil reaction in all profiles of Klokočina district was slightly alkaline and carbonates were present in whole soil profiles (Tables 2, 4). Original soil-forming substrate in Klokočina district was carbonate loess and formed soil was Haplic Luvisols (for Haplic Luvisols is typical leaching of carbonates and base cations from A and Bt to the C horizon, therefore A and Bt horizons use to be acid). We conclude that present alkalinity of substrate and whole profile was increased by calcareous residue building materials (i.e. bricks, concrete, etc.) mixed with original soil.

Alkalinity of soil in urban area was described by many authors: Norra et al. (2006) in Pforzheim, Sobocká et al. (2004) in Bratislava, Szombathová et al. (2004), and Zaujec (2000) in Nitra.

Contents of macronutrients (potassium and phosphorus) in studied profiles gradually lowered with depth (Table 3). Compared to control profile under maple in park Sihoť, significantly ($P < 0.001$) higher content of potassium and phosphorus was found in profile

T a b l e 3. The content of organic carbon (C_T), macronutrient (total nitrogen, phosphorus and potassium), and heavy metals (Cu, Zn, Cr, Pb, Cd and Ni) in Sihoť and Klokočina localities.

Locality	Hori-zon	C_T	N_T	P	K	C_T/N_T	Cu	Zn	Cr	Pb	Cd	Ni
		[g.kg^{-1}]		[mg.kg^{-1}]			[mg.kg^{-1}]					
Acer	**Au**	26.24	2.20	49	243	11.9	12.6	36.5	3.5	20.7	0.34	7.2
Sihoť	**A/C**	14.66	1.30	19	205	11.3	nd	nd	nd	nd	nd	nd
(control)	**Cc**	9.29	0.88	17	194	10.6	nd	nd	nd	nd	nd	nd
Pine	**Adc**	26.50	1.73	199	733	15.3	16.8	30.5	2.6	23.5	0.51	7.3
Sihoť	**A/Cc**	18.74	1.47	180	420	12.7	nd	nd	nd	nd	nd	nd
	Cc	13.53	0.99	190	228	13.7	nd	nd	nd	nd	nd	nd
Lime	**Adic**	16.21	0.67	36	173	24.2	7.5	13.1	1.7	13.7	0.28	5.5
Sihoť	**Cc**	6.68	0.61	22	108	11.0	nd	nd	nd	nd	nd	nd
	Dc	3.73	0.33	21	93	11.3	nd	nd	nd	nd	nd	nd
Acer	**Adc**	11.83	1.49	36	254	6.84	11.3	14.9	1.9	16.6	0.42	6.0
Klokočina	**Cc**	6.58	0.81	19	184	8.12	nd	nd	nd	nd	nd	nd
Pine	**Adc**	17.22	1.58	91	285	10.9	9.8	21.1	2.2	15.2	0.52	6.4
Klokočina	**Cc**	6.11	0.93	28	181	6.6	nd	nd	nd	nd	nd	nd
Lime	**Adc**	20.13	1.88	38	292	10.7	12.0	18.8	1.9	21.4	0.65	5.8
Klokočina	**Cc**	11.59	1.16	24	215	9.7	nd	nd	nd	nd	nd	nd

Notes: C_T – total soil organic carbon, P – phosphorus content, nd – not done, N_T – total nitrogen content, K – potassium content, C_T/N_T – ratio C_T/N_T, Cu, Zn, Cr, Pb, Cd and Ni contents were measured in depth 0.0–0.1m

under pine (Table 3). In contrary, macronutrients content was the lowest under lime. We suppose that great differences in macronutrient content between profiles are the consequence of using fertilisers in some parts of the park. Moreover, sandy substrate under lime supports easy leaching of macronutrients from profile, and therefore increases differences.

The contents of phosphorus and potassium macronutrients were significantly ($P < 0.001$) lower in Klokočina district compared to park Sihoť (Table 3). According to limit values of elements available to plants (Supuka et al., 2000) the pool of potassium under each studied woody plants was sufficient and exceed their demands.

Urban soils are often influenced by a high degree of contamination. The concentrations of Cu, Zn, Cr, Pb, Cd and Ni are presented in Table 3. In general, the concentrations of heavy metals were in wide range what is typical in urban areas. Considering heavy metals content in depth 0.0–0.1m the available lead exceed limit values stated for trees (1–3 mg.kg^{-1}) referred by Supuka et al. (2000) in each profile of both studied areas. According to the Decree of Ministry of Agriculture of SR No. 531/1994-540 the available lead did not exceed limit values (30 mg.kg^{-1}) in any of studied profiles, but cadmium content was exceeded limit 0.3 mg.kg^{-1} in each profile beside lime in park Sihoť locality. According to Geochemical atlas of soils of the Slovak Republic (Čurlík, Šefčík, 1999) the content of available Cd in Nitra in A horizon is 0.2–0.3 mg.kg^{-1} and in C horizon 0.2–0.4 mg.kg^{-1}. Lead in A horizon of Klokočina locality is 16–20 mg.kg^{-1}, in park Sihoť is 20–30 mg.kg^{-1}; and in C horizon of Klokočina is 14–18 mg.kg^{-1}and in park Sihoť 18–26 mg.kg^{-1}.

Xiangdong et al. (2004) made extensive soil survey in the highly urbanized Kowloon area of Hong Kong. They found hot spots to be the junctions of roads and/or near major roads that have a large amount of traffic. The concentrations of Cu, Ni, Pb and Zn in the hot spot were generally about 2.5 times higher than the rest of the urban area. Authors concluded, that the major sources of these metals may be vehicular emissions, and the mechanical parts and tyres of the vehicles as they are subjected to wear and tear. Moreover they found, that analysis of Pb isotopic composition suggests strong influences of anthropogenic origins of Pb in urban soils.

In contrary, Ljung et al. (2006) stated, that land use did not have the expected large influence on the total metal contents of the soils tested. The clay content together with the age of the site proved to be a more important factor. Sites with elevated clay contents had in general elevated metal contents, which were explained by the relatively high adsorption capacity of clay particles. The immobility of metals once they had entered the soil was the reason for increased metal content in soils. The soils at sites where land use had not been altered since the 1800s had increased metal contents compared to playgrounds constructed in the late 1900s. Norra et al. (2006) added that in urban soils with elevated concentrations of carbonates, phyllosilicates and Fe and elevated pH values increase adsorption capacity and accumulation of heavy metals. Vollmannová et al. (2002) concluded high petrification and decontamination function of liming in relation to heavy metals intake and accumulation by plants.

Since both studied areas were out of high traffic and contained carbonates, significantly ($P < 0.001$) higher content of heavy metals (beside cadmium) in park Sihoť compared to district Klokočina was probably due to higher clay content and longer period of uninterrupted exposition soil surface to urban pollution in park Sihoť.

As it was mentioned before, studied trees did not suffer with any physiological or mechanical harm (Hrubík et al., 2005, 2006) what means, that determined concentrations of heavy metals did not have harmful effect on trees. On the other side, studied trees more suffered with pests and in addition maple in Klokočina district with micromycetes *Sawadea bicornis*.

Humus content and quality are present in Table 4. Because fallen leaves are removed in autumn from the park we suppose, that humus content (determined as total organic carbon C_T) and quality were influenced by used peat or compost in the park. Pouyat et al. (2002) found slower organic matter decomposition in the urban core than in stands > 40 km away. He stated, that increase in forest floor mass may in part be due to the input of lower quality leaf litter (polluted) in these stands. The urban forest stands had significantly ($P = 0.02$) higher organic carbon densities (kg.m^{-2} to 1 m depth) than the suburban and rural stands.

T a b l e 4. Humus quality and carbonate content in profiles of Sihoť and Klokočina localities.

Locality	Hori-zon	Depth [m]	Carbo-nates [%]	C_T [g.kg^{-1}]	C_{HS} [g.kg^{-1}]	C_{HA} [g.kg^{-1}]	C_{FA} [g.kg^{-1}]	HA/FA	C_{HA} [% of C_T]	$Q_{HA}^{4/6}$
Acer	**Au**	0.0-0.15	-	26.24	7.20	3.11	4.09	0.76	11.85	4.38
Sihoť	**A/C**	0.15-0.3	-	14.66	4.63	2.19	2.17	1.01	14.94	3.88
(control)	**Cc**	> 0.30	0.3	9.29	2.55	1.82	0.73	2.49	19.59	3.28
Pine	**Adc**	0.0-0.15	6.9	26.50	6.27	3.58	2.69	1.33	13.51	3.84
Sihoť	**A/Cc**	0.15-0.2	7.3	18.74	4.05	2.48	1.57	1.58	13.23	3.54
	Cc	>0.20	14.3	13.53	3.34	2.23	1.11	2.01	16.48	3.20
Lime	**Adic**	0.0-0.10	0.4	16.21	4.19	2.17	2.02	1.07	13.39	3.80
Sihoť	**Cc**	0.10-0.20	1.3	6.68	2.01	1.17	0.84	1.39	17.51	2.58
	Dc	>0.20	1.8	3.73	1.09	0.87	0.22	3.95	23.32	2.31
Acer	**Adc**	0.0-0.20	2.8	11.83	4.19	1.87	2.32	0.81	15.81	3.82
Klokočina	**Cc**	> 0.20	17.3	6.58	1.62	0.78	0.84	0.93	11.85	3.67
Pine	**Adc**	0.0-0.20	3.5	17.22	4.89	2.34	2.55	0.92	13.59	4.29
Klokočina	**Cc**	>0.20	8.3	6.11	1.79	0.99	0.80	1.24	16.21	4.06
Lime	**Adc**	0.0-0.15	1.5	20.13	4.72	2.11	2.61	0.81	10.48	4.06
Klokočina	**Cc**	>0.15	1.6	11.59	2.82	1.48	1.43	1.03	12.77	3.67

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

High content of sand under lime in park Sihoť probably caused increased mineralization of organic matter and movement of humic acids by percolating water down to the C horizon (increased content of humic acids and HA/FA ratio, and decreased absorbance ratio $Q_{HA}^{4/6}$ in C horizon). The quality of humus was significantly ($P < 0.001$) the lowest in A horizon of control profile under Sugar maple in park Sihoť. The reason should be lack of carbonates in A horizon and also permanent wetness coming from capillary elevation of water. Moreower, low humus quality in A horizont is typical for undisturbed forest soil. Szombathová et al. (2001) reported similar humus quality in A horizon of upland area HA:FA = 0.75 and on slope HA:FA = 0.93 under protected oak-hornbeam forest in Báb locality.

Humus content and quality in Klokočina district was significantly ($P < 0.001$) lower and had great spatial variability with compared to Sihoť park. It was probably due to lower age of trees in Klokočina and therefore lower time of influence the trees on soil. Besides, the soil in Klokočina district was not dressed with any organic fertilisers. Similarly Sachenbroch et al. (2005) found significantly greater soil organic matter content and quality on old residential and park sites compared to new resident sites. Also Pouyat et al. (2002) found, that organic carbon density was 44 and 38% higher in low residential and institutional areas than the commercial land-use type.

On the base of results obtained in this study we conclude, that soil properties in studied urbanized area are highly diverse, therefore additional intensive investigations are needed, since urban areas expand and nowadays over 50% of the worlds population lives in urban areas.

Conclusion

High differences in values ζ_s between soil profiles and also within profiles refer about high spatial variability of soil-forming substrate.

Some profiles (in Klokočina under maple and in Sihoť and Klokočina under lime) were strongly compacted in deeper parts what inhibits proper root penetration.

Since original fluvial substrate in park Sihoť contained only 0.3% $CaCO_3$ we can conclude, that distinctly higher content of carbonates and alkalinity have anthropical origin and mainly come from former building activities (concrete, lime, bricks…).

In Klokočina district the alkalinity of soil was increased by calcareous residue of building materials mixed with original soil.

Great differences in macronutrient content between profiles are probably the consequence of using fertilisers in some parts of the park Sihoť.

Lead exceeded limit values stated for trees (1–3 $mg.kg^{-1}$) in each profile of both studied areas. According to the Decree of Ministry of Agriculture of SR the available cadmium content exceeded limit 0.3 $mg.kg^{-1}$ in each profile beside lime in Sihoť park.

Because fallen leaves are removed from the park we suppose, that humus content and quality were influenced by used peat or compost in the park.

Humus content and quality in Klokočina district was significantly ($P < 0.001$) lower and had great spatial variability compared to park Sihoť. The reason could be lower age of trees in Klokočina and abandoned use of organic fertilisers.

Beside limes in park Sihoť any of studied trees did not suffer with physiological or mechanical harm. Limes in park Sihoť slightly suffered with drought, what was observed as increased yellow colour of leaves.

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