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SOIL COMPACTION IN URBAN PARKS AND GREEN SPACES OF THE NITRA CITY AS A FAVOURABLE GROWTH CRITERION FOR WOODY PLANTS

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Abstract

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In the city of Nitra soil compaction was measured using a conic resistance penetrometer P-BDA 3A. The observed sites were: the urban park Sihoť (P), housing estate Chrenová 1 (CH) and housing estate Klokočina (K). The soil compaction was measured under the tree crowns of four woody species: *Acer saccharinum* L., *Negundo aceroides* Nutt. *Pinus nigra* Arnold., *Tilia cordata* Mill. in a 3–4 m distance from the tree trunk. The locality most used by inhabitants – visitors are the green spaces of the housing estate Klokočina, less Chrenová 1 and least the urban park Sihoť. The highest penetration resistance was measured at Klokočina, the urban park Sihoť and the housing estate Chrenová 1 showed almost the same measurement results. Also a difference between the woody species was found, the highest penetration resistance was measured under *Acer saccharinum* and the lowest under *Pinus nigra*. As an example here are values of the penetration resistance under the tree crown of *Tilia cordata* at the depth of 10 cm given by the sites: P = 1.8 MPa, CH = 1.8 MPa, K = 2.8 MPa. The actual soil humidity was measured on the site P = 18.8%, K = 17.2%. The soil bulk density was measured on the site P = 1.69, K = 1.45 g. cm^{-3}. The withering point was measured on the site P = 17.47%, K = 14.52%. The data correspond to the soil compaction. On the Klokočina locality the lowest woody plant growths and early defoliation of *Tilia cordata* were observed.

Key words: urban parks, soil compaction, growth conditions

Introduction

Urban parks and other green spaces form part of urban settlement structure. They can have a natural, synanthropic or man-made origin as a type of a cultural or historical-park vegetation (Feriancová, 2003; Kaliszuk, Szulczewska, 2006; Reháčková, Pauditšová, 2006; Supuka et al., 2005). All vegetation elements that are located in settlements grow in soil or movable pots, on terraces or roof gardens (Feriancová, 2004; Kühn, 2006). In many cases they are the soils or artificially layered substrates with specific physical and chemical properties. Such soils are called anthropogenically influenced

or urban in towns by many authors (Bedrna et al., 1996; Bullock, Gregory, 1991; Craul, 1992; Sobocká et al., 2007). They effect and condition the growth and development of woody plants, vegetation elements and park composition units to a great degree.

Soil compaction is an important soil characteristic. Soil compaction is a cumulative process where at negative effects on soil are recognized. Approximately to the pressure of 0.10 MPa, reverse changes can be expected but at higher pressures a stable compaction can be occurred depending on humidity situation, particle grain size distributionand organic matter in soil (Bajla, 1998; Bublinec, in Supuka et al., 1991). The pressure of 0.15 MPa will manifest itself till the depth of 0.35–0.40 m, higher values even deeper. The compacted soil originates as a consequence of construction activity, direct thoroughfare by cars, machines or other mechanisms, secondary by vibrations from traffic, permanent treading of soil in the park areas and green spaces by visitors, stamping down by animals, flooding or frequent watering. Among natural processes it can be listed as fire, rain and drought rotating in soil without a vegetation cover (Craul, 1992; Hillel, 1982; Rolf, 1994).

Kozlowski (1999) gives that soil structure changes, bulk density increase, hydrological situation change, soil aggregate destructions, porosity decrease, capillarity failure, aeration and infiltration ability are results of soil compaction.

Water accessibility for plants is reduced causing their physiological dysfunction, changes in the metabolite production and growth inhibition.

At measuring the soil compaction in urban parks of northern Florida a 70–99% reduction of the infiltration ratio of precipitation water in soil (Gregory et al., 2006) was found. On other sites the compaction caused water retention and diffusion ability deterioration of underground water supply from surface rainfalls (Richard et al., 2001).

In urban parks of Sofia a reduction of organic matter mineralization process and reduced carbon and nitrogen contents were identified (Doichinova et al., 2006). In addition to similar properties of the compacted soil, in urban parks of Helsinki a decreased microbial activity, water respiration, decreased contents of humus and nutrients were found (Malmivaara-Lämsä, Fritze, 2003).

In the parks of the Tel Aviv city on the sites intensively used by visitors some features of soil compaction like a reduction in species composition on the vegetation cover, canopy and aboveground biomass were found (Sarah, Zhevelev, 2007). In the Brno parks of Lužánky a Scheberova zahrádka, on trodden pathways sites a change in humidity, bulk density and decreased nutrient contents were found. On the same sites the numerousness of soil edaphone – earthworms was decreased (Pižl, Schlaghamerský, 2007).

Water deficit in compacted soils contributed towards the water deficit in needles of *Pinus radiata* (Sheriff, Nambiar, 1995). The soil compaction causes decrease of the mineral nutrients content in stands of *Pinus contorta* and sprouts of many forest woody plants (Conlin, van den Driessche, 1996).

The presented research results demonstrate that the soil compaction limits the conditions for a favourable growth of vegetation elements in urban parks and green spaces.

Material a methods

The purpose of this paper was to evaluate the degree of soil compaction on three areas of parks and green spaces with different levels use intensity by visitors in the city of Nitra. Measurements were performed in October 2005 under the crowns of 4 woody species at a distance of 3–4 m from the tree trunk. The species were: *Acer saccharinum* L., *Negundo aceroides* N u t t., *Pinus nigra* A r n o l d., *Tilia cordata* M i l l. The age of woody plants was 50–60 years, their height 8–12 m, crown width 8–10 m. Open grass areas on the same localities served as reference areas.

Characteristics of the studied green spaces in the city of Nitra

The urban park at Sihoť creates a central space of greenery for recreation and cultural activities with citywide importance from spring to autumn. The daily attendance rate in summer season is about 300–1000 visitors, the maximum is reached over the weekends. Besides the movement of visitors along the paths and roads, the visitors often move freely on lawns and grass areas and under the trees. The park is situated near the Nitra river on original alluvial soils.

The Chrenová housing estate is divided into several housing sectors; the measured locality was Chrenová 1 with the number of inhabitants of about 5 thousand. The inter-blocks green areas are large, about 36 m^2 per 1 inhabitant. The use intensity by inhabitants is medium, regarding the largeness of green areas. Chrenová 1 is also localized on alluvial soils but at greater distance from the river Nitra as is the urban park.

The Klokočina housing estate – a quarter with 18 thousand inhabitants, inter-block green areas are about 15 m^2 per 1 inhabitant. The areas with vegetation are most loaded by visitors. The original soil is Haplic Luvisol on slight slope.

Soils on both housing estates have been affected by construction buildings activities compared to the park soil that has been changed in minor way of all soil.

Device and method of soil compaction measurement

Soil compaction was measured using the method of cone penetometry with a device marked P-BDA 3A that was developed at the Department of Mechanics and Engineering of the Faculty of Technology of the Slovak University of Agriculture (Bajla, 1998; Bajla, Hrubý, 1999). Basic characteristics of the device are: maximum measuring depth – up to 500 mm, measuring step of the depth – 10 mm, penetration cone – base diameter 12.83/20.30 mm and the apex angle 30°, the scope of penetration resistance measuring 0–6 MPa. The measured penetration resistance was recorded into memory which is part of the penetrometer. The measurements were PC evaluated and processed statistically, the results are presented in a graphic version.

On the measured localities physical rollers from soil were excavated, the depth was 10–15 cm, to find out humidity and soil bulk density.

Results

The shape of the curve of soil penetration resistance in the locality of the urban park Sihoť is shown in Fig. 1. At the depth of 2 cm an average penetration resistance of 0.8 MPa was measured. In the depth of 20 cm the penetration resistance ranges 1.0–1.5 MPa with

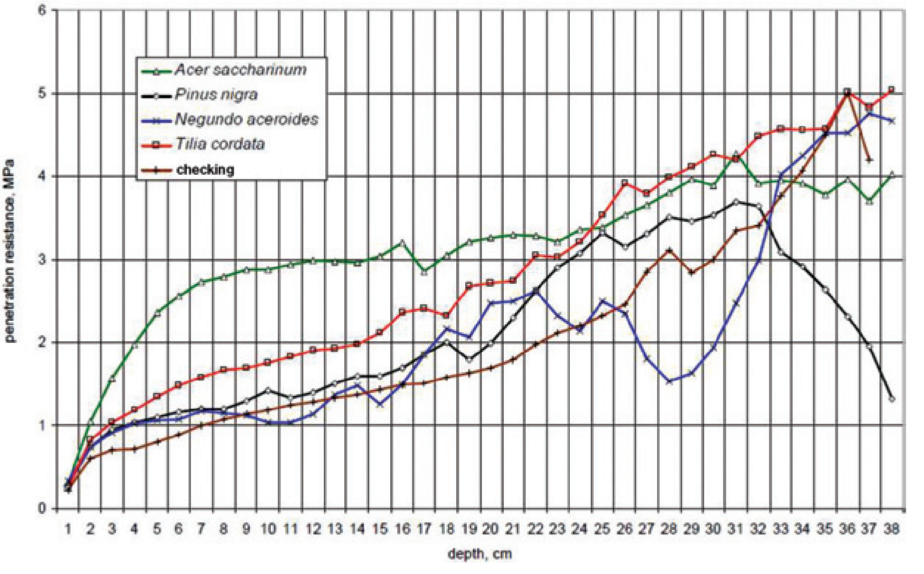

Fig. 1. Soil penetration resistance, Sihoť park.

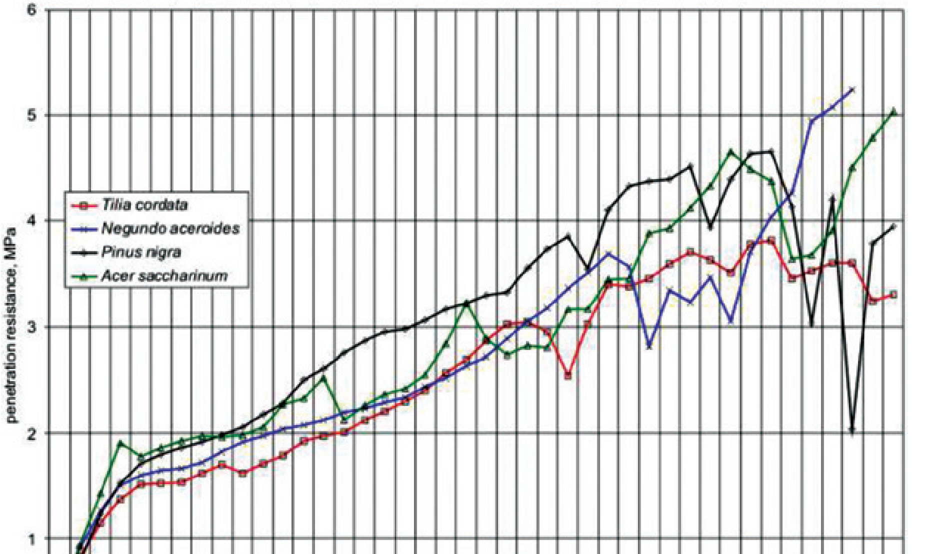

Fig. 2. Soil penetration resistance, Chrenová housing estate.

a balanced increasing trend. At the depth of 20 cm the penetration resistance was ranging 2.0–2.5 MPa and the maximum was 4.5 MPa in the depth of 38 cm at average.

The penetration resistance curves have a relatively balanced increasing tendency and it means that the soil is compacted along the profile but not in soils clearly stratified with allochthonous layers of fill or construction materials. The shape of curves shows differencies in the soil compaction according to woody species. The value is the reference base – open grassy area. Similar soil condition is under *Negundo aceroides* and *Pinus nigra.* The highest soil compaction was measured under the crown of *Acer saccharinum* by 1 to 1.5 MPa and more comparing with other woody plants in the depth from 5 to 20 cm. In the depth above 25 cm the soil compaction is balanced on average, with valuable woody plants at a variance of 0.5–0.8 MPa. It was found during the excavation of samples that soils in those depths had undisturbed natural genetic horizons.

Another measured locality was the inter-block spaces of greenery at the housing estate of Chrenová 1. The relief and soil type conditions are similar to those at the urban park Sihoť. However at the housing estate an intense and large-scale construction works were executed with a possible mixing of soil horizons but with a distinct fall in the underground water level as a consequence of sewage and drainage systems and other embedded engineering networks. The courses of penetration resistance curves (Fig. 2) are very similar for all woody plant species what is rather a rare phenomenon among the evaluated woody plants.

Under the tree crowns in the upper layers up to 5 cm, that is in the top soil a biologically active level penetration resistance of 1–2 MPa were measured. Then the penetration resistance was kept within the range 1.8–2.2 MPa up to the depth of 15 cm. In the depth layer of 16–30 cm the penetration resistance was 2.5–3.5 MPa and in the depth of 30–45 cm the penetration resistance ranged 3.5 and 4.2 MPa.

Assessing individual woody species we can conclude that the highest penetration resistance was measured and the soil had the highest degree of compaction under the crown of *Pinus nigra*. The lowest soil compaction was measured under the crown of *Tilia cordata.*

The differences in soil compaction are relatively low. In the depth to 10 cm the variability according to species is only 0.5 MPa and in the depth to 30 cm about 1 MPa. The highest range is in the depth of 31–45 cm and reaches 2 MPa, the highest soil compaction was found with *T. cordata*.

The uniformity and proximity of penetration curve courses is an evidence of close relations of the green spaces used by inhabitants and uniformity of soil stratification without any marked synanthropic changes.

The results obtained from soil compaction measurements at the housing estate Klokočina are shown in Fig. 3. It is clear from the course of penetration curves that they have a great range and that a high soil compaction was measured with all woody plants already in the 5 cm depth where it reached 2–3 MPa. The compaction maximum values were measured in the depth of 15–40 cm with penetration resistance 4.0–4.5 MPa.

The highest compaction values were measured under the crowns of *Negundo aceroides, Acer saccharinum* is very close to them. The lowest compaction values were measured under the crown of *Pinus nigra*, where the maximum measured value of penetration resist-

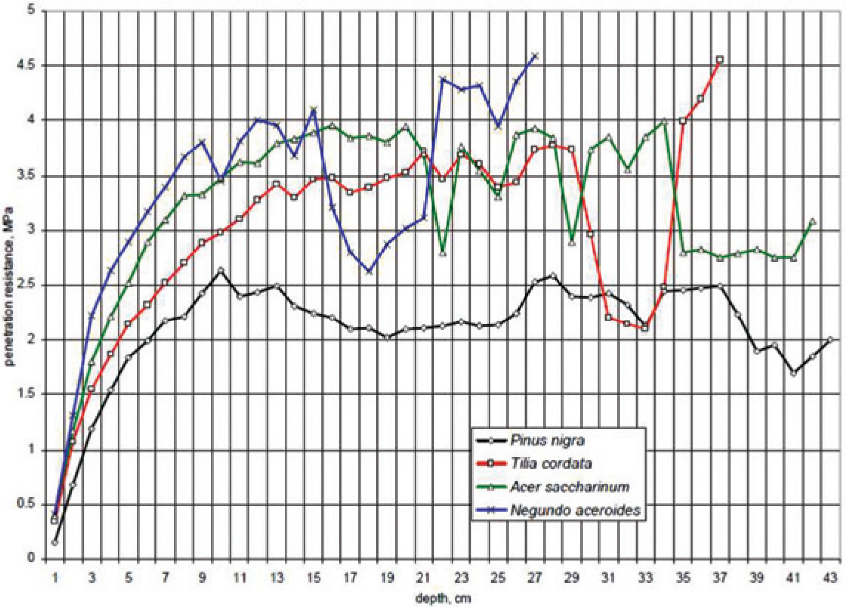

Fig. 3. Soil penetration resistance, Klokočina housing estate.

ance was along the whole profile 2.0–2.5 MPa and that is by 100% less than with A*cer saccharinum* and *Negundo aceroides*.

The excavated soil samples and also the obtained results shows non-uniformity of soil stratification affected synantropically by building activities. Each woody plant besides its own specific affects on the soil has a different root stratification in the soil profile. The soil load is different and relatively uniform but at the housing estate Klokočina the highest of all the three studies localities. There are the worst conditions for the growth and development of woody plants from the hydro-pedological point of view.

Comparing soil compaction of all three localities of the city of Nitra, we can find out that the localities park- Sihoť (P) and Chrenová 1 (CH) are close to each other with the penetration resistance values; Klokočina (K) has markedly the highest values of soil compaction. As an example the penetration resistance under the tree crowns of *Tilia cordata* in the depth of 10 cm according to localities: P = 1.8 MPa, CH = 1.8 MPa, K = 2.8 MPa. In the depth of 25 cm the values were as follows: P = 3.2 MPa, CH = 3.0 MPa, K = 3.6 MPa.

On the studied localities also other soil characteristics were evaluated which are closely related to limits for a favourable growth of woody plants. They were the bulk density, instantaneous soil moisture and withering point. Considering the fact that these results have been elaborated fully in another contribution (Szombathová et al., 2009) we will show only basic values pointing to the differences between the localities.

In the urban park Sihoť under the crown of the woody plant *Tilia cordata* at the soil depth of 10–20 cm the following values were found out: bulk weight, 1.69 g.cm^{-3} instantaneous soil moisture 18.80%, withering point 17.47%. On the locality of Klokočina these values were as follows: bulk weight, 1.45 g.cm^{-3}, instantaneous soil moisture 17.24%, withering 14.52%.

All values on the locality of Klokočina are lower and manifested as a deficit of accessible moisture for woody plants, early defoliation and decreased increment of internodes during current year.

Discussion

The results of the soil compaction showed that Klokočina is relatively the worst locality for potential woody plants growth in green spaces of the housing estate where there is also the greatest load on the areas by the inhabitants (visitors).

From the point of view of the measured penetration resistance we have obtained results within 1.0 MPa (non-compacted soil horizons) to 4.5 MPa (compacted soil horizons). Similar results were measured in soil of the park areas in northern Florida and namely, 0.858 MPa on non-compacted soil horizons and 4.382 MPa on compacted soil horizons in the depth of 30cm (Gregory et al., 2006).

Our research results document that a higher soil compaction was measured under coniferous species than under broad-leaved tree crowns. Such was also the result of measurements in urban parks of Helsinki (Malmivaara-Lämsä, Fritze, 2003), and in Tel Aviv (Sarah, Zhevelev, 2007). It is related to a higher biotic activity and higher humus content is soils under the broad-leaved species.

It is logical that more by organic mater enriched soils have a lower penetration resistance that the dry ones, it was found out not only during our research activities but in a publication according to Kozlowski (1999). Similar results of soil compaction measurements in relation to the bulk weight were obtained in the parks of Brno (Pižl, Schlaghamerský, 2007).

In our further research our intention is to evaluate the production of herbaceous cover in relation to the soil compaction.

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