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NUTRITIONAL RESOURCES OF SOIL IN THE LOCALITIES OF MONUMENTAL LARGE-LEAVED LINDEN (*Tilia platyphyllos f. aurea*) ALLEYS

ZAWARTOŚĆ SKŁADNIKÓW W GLEBACH NA STANOWISKACH ZABYTKOWYCH ALEI LIPY SZEROKOLISTNEJ (*Tilia platyphyllos f. aurea*)

Abstract: An estimation was carried out regarding the nutrient resources (macro- and micronutrients), sodium (ballast ion), heavy metals (cadmium and lead), soil reaction and salinity in soil samples taken from the monumental localities of large-leaved linden alleys (*Tilia platyphyllos f. aurea*) in Lubon (Wielkopolska province). It was found that among factors which could deteriorate the appearance (possible chloroses) and health of the studied plants was chemism of soil. The majority of the analysed soils was characterized by a decreased content of phosphorus and at the same time by an excess of potassium, calcium, and magnesium, as well as by the standard content of nitrogen. A high content of calcium in the soil contributed to a deterioration of the mutual quantitative proportion between calcium and magnesium which could have caused some difficulties in the uptake of magnesium, as well as potassium and the majority of micronutrients. Contents of metalic micronutrients (iron, manganese, zinc and copper) were within the range of standard. The determined contents of cadmium and lead did not exceed the admissible norms. In case of the alleys with a higher intensity of road traffic, excessive contents of sodium were found in the soil. However, the salinity of the studied soils was within the admissible range (EC > 0.4 mS $\cdot$ cm^{-1}). High content of alkalizing components (calcium, magnesium, potassium, sodium) exerted an influence on the soil reaction which was incorrect from the point of view of plant growth and nutrition, showing a strong alkalization (pH was in the range of 7.30 to 10.95).

Keywords: monumental alleys, soil, nutritive components, soil reaction

In Lubon (a town bordering with Poznan) including about 25 000 inhabitants, lying in the neighbourhood of a post-Evangelical Church devoted to St.Barbara (built in the years 1908–1912), there are seven monumental alleys of large-leaved linden (*Tilia platyphyllos f. aurea*) including totally 462 trees [1, 2]. The age of these monumental trees is estimated for 75–85 years.

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The objective of the presented studies was the estimation of the chemism of soils sampled from underneath the monumental linden trees from the point of view of their salinity (content of water soluble salts) and soil reaction, as well as the nutritive components (macro- and micronutrients), sodium (regarded as a ballast ion) and heavy metals (cadmium and lead). The recognition of the mentioned chemical soil parameters may supply an additional element in the elaboration of a protection program and even a fertilization program for the monumental alleys which could contribute to an improvement of their appearance and health conditions.

Material and methods

The estimation of the nutritive resources of soil (macro- and micronutrients), sodium, heavy metals, soil reaction and salinity in the localities of the monumental large-leaved linden alleys (*Tilia platyphyllos f. aurea*) localized in Luboń (Wielkopolska province) was carried out in the year 2008. In the moment of the nomination of these alleys as nature monuments (in 1995), in the Central Register of Nature Forms Protection, they included 462 trees grown along the following streets in Lubon: E. Bojanowski square (26 trees), 11 Listopada street (88 trees), J. Poniatowski street (89 trees), Lipowa street (94 trees), H. Kołłątaj street (66 trees), Szkolna street (56 trees) and Klonowa street (14 trees) [1, 2].

Soil samples from the layer of 0–20 cm were taken using Egner's stick, while for the deeper layers (20–40 cm and 40–60 cm), the soil auger was used. Because of an excessive hardness and density of soil, in case of two localities (at 11 Listopada street and on Bojanowski square), no samples were taken from the 40–60 cm layers. The roots of the large-leaved linden reach a depth exceeding 60 cm. Soil samples were taken under healthy, typical and randomly selected trees in the central part of the plantations, in 3 m distance from tree stems. Collected samples were chemically analysed by the universal method according to Nowosielski [3]. Extraction of macronutrients ($N\text{-}NH_4$, $N\text{-}NO_3$, P, K, Ca, Mg, $S\text{-}SO_4$), Cl and Na was carried out in 0.03 M CH_3COOH with a quantitative 1:10 proportion of soil to extraction solution. After extraction, the following determinations were made: $N\text{-}NH_4$, $N\text{-}NO_3$ – by microdistillation according to Bremer in Starck's modification; P – colorimetrically with ammonium vanado-molybdate; K, Ca, Na – photometrically; Mg – by atomic absorption spectrometry (AAS, on Carl Zeiss-Jena apparatus); $S\text{-}SO_4$ – nephelometrically with $BaCl_2$; Cl – nephelometrically with $AgNO_3$. Micronutrients (Fe, Mn, Zn and Cu) and heavy metals (Cd and Pb) were extracted from soil with Lindsay's solution containing in 1 dm^3: 5 g EDTA (ethylenediaminetetraacetic acid); 9 cm^3 of 25 % NH_4 solution, 4 g citric acid and 2 g $Ca(CH_3COO)_2 \cdot 2H_2O$. Micronutrients and heavy metals were determined by AAS method. Salinity was identified conductometrically as a soil electrolytic conductivity (EC in $mS \cdot cm^{-1}$), and pH – was determined by potentiometric method (soil : water = 1 : 2) [4].

Results and discusion

Results of soil chemical analyses referring to macronutrients content, pH and salinity are presented in Tables 1A and 1B. On the basis of our studies, one can state that the soil from the linden localities was characterized by a standard content of ammonium nitrogen which decreased with the increasing depth. A probable reason of this phenomenon could have been the washing out of this component caused by its sorption exchange [5]. In the studied soil samples, the determined values of nitrate nitrogen ($N\text{-}NO_3$) generally were slightly lower than those of ammonium nitrogen. This could have been caused by the washing out of nitrate nitrogen – resulting from its poor sorption [5].

In the studied soil profiles, differentiated phosphorus contents were found. The determined contents of phosphorus in the layer of 0–20 cm were distinctly higher in the layers lying lower (20–40, 40–60 cm) (except for the locality at E. Bojanowski square). This is a typical phenomenon occurring in mineral soils resulting, among others, from a greater content of organic matter in the 0–20 cm layer and from the chemical sorption of phosphorus with calcium and magnesium ions which occurred in the soil in excessive amounts [5, 6]. Generalizing, one can state that phosphorus content in some studied localities, particularly in the deeper soil layers, was insufficient (< 40 mg P $\cdot$ dm^{-3}) [7].

In the majority of the studied localities, there was an excessive content of potassium, particularly in the 0–20 cm layer. However, there appeared a typical tendency [5], resulting from sorption exchange, to the decrease of potassium in the deeper layers (20–40; 40–60 cm), except for the localities at Szkolna and H. Kołłątaj streets.

Soils in the studied localities were characterized by an excessive content of calcium [6], which was increasing with the increasing depth (exceeding even 5500 mg Ca $\cdot$ dm^{-3} in the 20–40 cm layer at Klonowa street). Excessive calcium content is unfavourable from the plant's point of view because it makes difficult the uptake of other nutritive components, among others of potassium, magnesium and micronutrients [6].

In the majority of the studied localities, increased or excessive contents of magnesium were determined. However, one can suppose that this fact exerted a positive effect on plant development by decreasing the mutual proportions between calcium and magnesium. Optimal for the growth and development of plants is the proportion between calcium and magnesium in soil which equals 6–9:1 [6], while the mean proportion from the studied samples – because of an excessive calcium content – was 17.2:1. In case of the majority of the studied localities, there was found a low or very low content of sulphate sulphur ($S\text{-}SO_4$) available to plants.

In consequence of excessive content of alkaline ions (calcium, magnesium, potassium and sodium) and a low content of sulphur, the soil reaction in the studied localities was incorrect: from a neutral one (pH = 7.30) to an alkaline one (pH = 10.95). A probable cause of a strong soil alkalization could have been the use of sodium chloride for ice melting on the road in winter, as well as the strongly alkaline dusts (containing among others: CaO, MgO, Na_2O, K_2O) as a side product from coal combustion in the households [8, 9]. Ash contains from 1.1 to 32.6 % of CaO. Soil alkalization certainly was caused by the production of calcium oxide and calcium

Table 1A

Content of macronutrients, pH and salinity in the soils of the localities with a higher road traffic intensity

Locality (street)	Depth [cm]	$N-NH_4$	$N-NO_3$	P	K	Ca	Mg	$S-SO_4$	pH (H_2O)	EC [$mS \cdot cm^{-1}$]
		$mg \cdot dm^{-3}$								
11 listopada	0–20	35.0	26.0	66.9	755.3	3959.8	324.6	84.9	7.32	0.13
	20–40	31.5	35.0	58.1	753.5	4113.2	355.1	67.9	7.30	0.05
Klonowa	0–20	49.0	28.0	81.5	736.0	3488.5	383.3	68.8	10.72	0.17
	20–40	24.5	24.5	4.7	135.3	5680.3	354.2	99.4	8.31	0.03
	40–60	21.0	28.0	7.8	197.4	5113.1	348.5	130.3	8.43	0.05
J. Poniatowski	0–20	24.5	17.5	61.1	730.7	2479.1	327.1	4.8	10.95	0.10
	20–40	28.0	24.5	Tr.	45.4	4103.1	71.4	4.6	8.72	0.03
	40–60	21.0	21.0	Tr.	28.1	4436.6	77.1	2.5	7.94	0.28
E. Bojanowski square	0–20	28.0	21.0	7.8	213.9	2270.7	101.7	7.1	10.77	0.94
	20–40	17.5	78.0	59.9	56.9	1100.1	294.1	4.9	8.01	0.04

Tr. – traces

Table 1 B

Content of macronutrients, pH and salinity in the soils of localities with a lower road traffic intensity

Locality (street)	Depth [cm]	$N-NH_4$	$N-NO_3$	P	K	Ca	Mg	$S-SO_4$	pH (H_2O)	EC [$mS \cdot cm^{-1}$]
		$mg \cdot dm^{-3}$								
H. Kołłątaj	0–20	21.0	28.0	16.6	178.9	2964.3	234.9	2.7	7.67	0.03
	20–40	24.5	24.5	12.6	161.6	2643.0	250.0	15.1	10.83	0.20
	40–60	28.0	46.0	11.0	719.0	1566.4	406.0	6.5	7.81	0.03
Lipowa	0–20	14.0	24.5	24.8	128.2	3671.5	299.6	13.1	7.79	0.02
	20–40	10.5	17.5	15.2	110.3	4189.1	288.1	54.3	10.55	0.17
	40–60	14.0	10.5	19.4	62.4	4763.5	285.1	50.4	10.60	0.15
Szkolna	0–20	14.0	36.0	54.4	622.0	4140.7	313.4	8.5	10.66	0.16
	20–40	28.0	24.5	41.9	81.3	4857.4	153.6	19.1	7.64	0.17
	40–60	17.5	38.0	39.9	756.9	1100.1	294.1	4.9	8.02	0.04

hydroxide increasing the soil pH above 7.4 [6, 9]. Soil alkalization limits the availability of nutritive components [10, 11].

In spite of an excessive content of some components (calcium, magnesium, potassium, sodium), the majority of the studied localities – except for the 0–20 cm layer at E. Bojanowski square – was characterized by an admissible level of salinity (EC > 0.4 $mS \cdot cm^{-1}$) [6].

The content of micronutrients, sodium (regarded as a ballast ion) and heavy metals: cadmium and lead (Tables 2A, 2B) were analysed as well. The determined iron contents were within the range of the standard [7]. There was a differentiation in the content of manganese, depending on the road traffic intensity. Excessive contents of manganese (> 25 $mg\ Mn \cdot dm^{-3}$) [7] were found in the 0–20 cm layer in the locality at 11 Listopada street (28.3 $mg\ Mn \cdot dm^{-3}$) and in the 20–40 cm layer in E. Bojanowski square (41.0 mg $Mn \cdot dm^{-3}$). The studied localities were characterized by a standard (within the range from 5.0 to 50.0 $mg\ Zn \cdot dm^{-3}$) of zinc content [7]. The highest Zn content was found in the 20–40 cm layer in the locality of Szkolna street (43.4 $mg\ Zn \cdot dm^{-3}$). Copper content in soil oscillated within the range of optimal contents, from 3 to 10 $mg\ Cu \cdot dm^{-3}$ [7]. Chlorides contents in the studied localities, independent of the road traffic intensity, were similar. In the majority of localities, they were within the admissible range, below 60 $mg\ Cl \cdot dm^{-3}$ [6]. The distinctly highest Cl content among the studied chloride samples was found in the 40–60 cm layer in the localities at Szkolna street (223.0 mg $Cl \cdot dm^{-3}$) and at H. Kołłątaj street (234.3 $mg\ Cl \cdot dm^{-3}$). Sodium content – regarded as ballast ion – in case of streets with a less intensive road traffic were within the admissible range (< 60 $mg\ Na \cdot dm^{-3}$). However, they were distinctly higher in localities with intensive road traffic. The highest content of sodium was determined in the 40–60 cm layer in the locality at Klonowa street (352.5 $mg\ Na \cdot dm^{-3}$). A probable reason of the excessive content of this ballast component was the use of the sodium chloride in winter for melting ice and snow layers. Sodium as a univalent cation exerts an unfavourable effect on soil structure. It destructs the crumble structure of soil which deteriorates the physical properties of soils and it can cause some disturbances in plant growth. In all studied localities, similar cadmium and lead values were found in soil and they were contained within the admissible limits [12].

Furthermore, in the studied localities, an excessive density of soil in its deeper layers (20–40 cm and 40–60 cm) was observed, as well as an increased soil dispersion in the 0–20 cm layer (in case of a higher road traffic indicating deteriorated air–water relations exerting a negative effect on the general plant conditions [9, 13]. Excessive soil covers around trees with materials which are not permeable or hardly permeable (like street asphalt or pavements) decrease the area in which tree root systems can easily develop [14, 15]. Generally, species of *Tilia* genus are rather more suited for plantation at streets with a less intensive road traffic or in a farther distance from the road [16]. An additional diagnostic instrument which can help in a better recognition of the mutual relations between the chemism of soil and the plants is the analysis of the content of nutritive components (sodium and heavy metals) in leaves sampled from the monumental linden alleys.

Table 2A

Content of micronutrients (Fe, Mn, Zn, Cu, Cl), sodium and heavy metals (Cd, Pb) in localities with a higher road traffic

Locality (street)	Depth [cm]	Fe	Mn	Zn	Cu	Cl	Na	Cd	Pb
		$mg \cdot dm^{-3}$							
11 Listopada	0–20	57.5	11.9	40.4	3.1	138.2	327.2	0.10	3.6
	20–40	56.5	28.3	37.6	1.8	145.3	329.3	0.08	2.6
Klonowa	0–20	37.3	5.3	39.7	4.0	> 30.0	274.2	0.12	4.2
	20–40	32.2	6.4	23.1	3.3	> 30.0	109.5	0.12	3.6
	40–60	31.7	8.8	27.2	1.6	45.6	352.5	0.06	2.6
J. Poniatowski	0–20	52.9	4.4	17.4	4.4	> 30.0	250.2	0.09	3.8
	20–40	74.8	6.0	17.9	3.6	> 30.0	100.5	0.09	4.3
	40–60	79.1	5.2	19.1	4.1	> 30.0	137.1	0.10	4.3
E. Bojanowski square	0–20	95.1	18.1	23.5	3.0	55.5	43.8	0.11	4.2
	20–40	135.5	41.0	17.2	2.4	> 30.0	223.0	0.10	3.6

Table 2B

Content of micronutrients (Fe, Mn, Zn, Cu, Cl), sodium and heavy metals (Cd, Pb) in localities with a lower road traffic

Locality (street)	Depth [cm]	Fe	Mn	Zn	Cu	Cl	Na	Cd	Pb
		$mg \cdot dm^{-3}$							
Lipowa	0–20	45.6	4.4	29.6	3.3	30.1	> 30.0	0.15	4.3
	20–40	42.9	5.4	29.8	3.9	32.5	> 30.0	0.14	4.3
	40–60	44.2	5.2	25.1	3.6	36.8	> 30.0	0.12	4.2
Szkolna	0–20	30.7	3.8	15.8	2.5	185.8	> 30.0	0.10	3.5
	20–40	40.6	3.4	43.4	3.4	63.1	> 30.0	0.16	4.2
	20–40	35.5	4.0	17.2	2.4	223.0	> 30.0	0.10	3.6
H. Kołłątaj	0–20	60.4	4.8	29.6	4.4	41.0	55.9	0.13	4.0
	20–40	74.9	4.8	28.6	4.7	44.4	35.7	0.15	3.7
	40–60	80.8	6.2	24.3	4.3	234.3	> 30.0	0.13	4.0

Summing up, one can state that it is advisable to apply a fertilization with magnesium (in the form of magnesium sulphate) in order to decrease the Ca:Mg proportion which should also increase the low level of sulphur in soil. It would be also beneficial to apply nitrogen fertilization (eg application of ammonium phosphate) in the spring period. Furthermore, it is asolutely necessary to stop using NaCl for melting snow layers in winter and to replace this treatment with the ecological $CaCl_2$ which can remove the excess of sodium from the soil by phytoremediation by plants. A beneficial action is also the tendency to use gas instead of using coal for house heating because it would decrease the amounts of alkalizing dusts. One can expect that after the consideration of the above suggestions, there will appear biological results improving the growth and development of the monumental linden alleys.

Conclusions

1. The studied soils were characterized by an insufficient content of phosphorus and at the same time by an excessive content of potassium, calcium, manganese and a standard content of nitrogen.

2. High content of calcium in soil exerted an influence on the deterioration of the mutual quantitative proportion between calcium and magnesium showing an average value of 17.2:1. An excessive wide proportion between these components causes impediments in the uptake of magnesium, as well as of potassium and micronutrients (ion antagonism).

3. Standard contents of metalic micronutrients (iron, manganese, zinc and copper) were determined in the soil.

4. Excessive sodium content in the soil of localities with a higher intensity of road traffic were shown. The studied soils were characterized by cadmium and lead content within the admissible range.

5. Salinity of the studied soils was within the admissible range ($EC > 0.4\ mS \cdot cm^{-1}$). Soil reaction was neutral to strongly alkaline (pH was within 7.30–10.95) which could have been an impediment in plant nutrition with magnesium, potassium and the majority of micronutrients.

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ZAWARTOŚĆ SKŁADNIKÓW W GLEBACH NA STANOWISKACH ZABYTKOWYCH ALEI LIPY SZEROKOLISTNEJ (*Tilia platyphyllos f. aurea*)

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Abstrakt: Dokonano oceny zasobności w makro- i mikroelementy, sód (jon balastowy), metale ciężkie (kadm i ołów), odczynu oraz zasolenia gleb pobranych ze stanowisk zabytkowych alei lipowych (*Tilia platyphyllos f. aurea*) w Luboniu (województwo wielkopolskie). Wykazano, że wśród czynników mogących powodować pogorszenie wyglądu (ewentualne chlorozy) i zdrowotności roślin jest chemizm gleby. Większość analizowanych gleb charakteryzowała się zmniejszoną zawartością fosforu, przy jednoczesnym nadmiarze potasu, wapnia i magnezu oraz standardowej zawartości azotu. Duża zawartość wapnia w glebie wpływała na pogorszenie wzajemnych relacji ilościowych między wapniem a magnezem, co powodować mogło utrudnienia w pobieraniu magnezu, a ponadto potasu i większości mikroelementów. Zawartości mikroelementów metalicznych (żelaza, manganu, cynku i miedzi) mieściły się zakresie standardowym. Oznaczone zawartości kadmu i ołowiu nie przekraczały dopuszczalnych norm. W przypadku alei o większym natężeniu komunikacyjnym wykazano nadmierne zawartości sodu w glebie. Zasolenie badanych gleb mieściło się jednak w zakresie dopuszczalnym (EC > 0,4 mS · cm^{-1}). Duża zawartość składników alkalizujących (wapnia, magnezu, sodu, potasu) wpływała na odczyn gleb, który był wadliwy z punktu widzenia wzrostu i żywienia roślin, wykazując silną alkalizację (pH w zakresie 7,30–10,95).

Słowa kluczowe: zabytkowe aleje, gleba, składniki pokarmowe, odczyn