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# CONTENT OF SOME NUTRIENTS IN SCOTS PINE, SILVER BIRCH AND NORWAY MAPLE IN AN URBANIZED ENVIRONMENT

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**Abstract**

In the late 18th and early 19th c., a drastic reduction in the area of forests due to their excessive exploitation occurred in Europe, which gave rise to the birth of afforestation efforts. The chemical composition of plants, including trees, depends on the many biotic and abiotic environmental factors. The aim of this study was to determine the content of some nutrients in needles and bark of Scots pine (*Pinus sylvestris* L.), leaves and bark of silver birch (*Betula pendula*) and Norway maple (*Acer platanoides* L.), depending on their location. The content of phosphorus, potassium, sodium, calcium and magnesium depended on a plant species, plant organ and the location of sample collection. The leaves of silver birch, compared to its bark, contained ten-fold more potassium and six-fold more phosphorus and magnesium. The content of phosphorus was the highest in silver birch leaves in the center of Olsztyn. The highest potassium content was observed in silver birch leaves and Norway maple bark in the center of Olsztyn. The calcium content was the highest in the leaves and bark of maple trees growing near State Road 51 and in the leaves of this species in the city center. The highest sodium content was detected in the leaves and bark of most tree species growing along State Road 51 and in the center of Olsztyn.

**Keywords:** needles, leaves, bark, Scots pine, silver birch, Norway maple, macronutrients.

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# INTRODUCTION

Forests provide us with a wealth of raw materials, of which woody biomass seem most important. A drastic reduction in the total area of forests due to their excessive exploitation which took place in Europe at the turn of the 18th and 19th c. led to the development of land afforestation policy (Augusto et al. 2002). The industrial value of raw materials obtained from forests is very high (Miller et al. 2006). The quality of the harvested wood depends on the type of a habitat and its fertility, soil pH, groundwater level, climatic conditions, soil microbial activity, tree species, age and growth as well as the degree of environmental pollution (Wang et al. 1996, Augusto et al. 2002, Washburn, Arthur 2003, Hagen-Thorn et al. 2004, Saramaki, Hytonen 2004, Rademacher 2005, Yang et al. 2009, Hilszczańska, Sierota 2012, Hellsten et al. 2013, Modrzewska, Wyszkowski 2014).

Such elements as carbon, oxygen, hydrogen, nitrogen, phosphorus, potassium, sodium, magnesium, calcium, sulfur and some trace elements play an essential role in the formation of tree biomass (Wang et al. 1996, Rytter, Stener 2003, Washburn, Arthur 2003, Saramaki, Hytonen 2004, Rademacher 2005, Hilszczańska, Sierota 2012, Parzych, Sobisz 2012, Hellsten et al. 2013). Depending on a tree species and development stage, phosphorus, calcium and magnesium are absorbed at different rates (Malik, Karnet 2009, Palviainen et al. 2010). Nitrogen and potassium in soil, which appear in water-dissolved salts, are characterized by the highest mobility, while magnesium is less mobile. Calcium in soil is immobilized by binding to organic matter (Thelin et al. 1998, Hellsten et al. 2013). The absorption of nutrients by plants is controlled by metabolic processes (Parzych, Sobisz 2012). During the first 10 years of tree growth, nutrients are accumulated in the biggest amounts (Palviainen et al. 2010) in the following order: N > Ca > K > Mg > P (Wang et al. 1996). The reason is most probably a higher nutrient demand in younger forest stands (Hellsten et al. 2013). It is most notable in leaves, while the content of elements is lower in other tree organs (Augusto et al. 2002, Rytter, Stener 2003, Hellsten et al. 2013). According to Augusto et al. (2002), conifer species absorb more elements from the air (around 35%) than deciduous tree species (25%), owing to a larger surface area of needles. Scots pine, silver birch and Norway maple, which belong to the dicotyledon plant family, are characterized by high calcium, magnesium and sodium accumulation capacity, but absorb potassium at a lower rate (Grzegorczyk et al. 2013). The environmental pollution, apart from its effect on soil properties (Wyszkowska, Wyszkowski 2002, 2003, Wyszkowski, Sivitskaya 2012), has a strong impact on the absorption and content of nutrients in plants (Ciećko et al. 2005, Wyszkowski, Wyszkowska 2009).

The aim of this study was to determine the content of some nutrients in the needles and bark of Scots pine (*Pinus sylvestris* L.), the leaves and bark of silver birch (*Betula pendula*) and Norway maple (*Acer platanoides* L.), depending on their location. The tree species were selected because of their widespread occurrence in Poland, resistance to environmental pollution, and leaf and bark types (PARZYCH, SOBISZ 2012).

## MATERIAL AND METHODS

The study included five sites in the town of Olsztyn (north-eastern Poland), which were located close to the Municipal Heat Supply Company (MPEC), along a railroad in Dajtki housing district, along Road 51, in the center of Olsztyn between 22 Stycznia Street and Jedności Słowiańskiej Square and in Kortowo Forest (Figure 1). The tested trees were Scots pine (*Pinus sylvestris* L.), silver birch (*Betula pendula*) and Norway maple (*Acer platanoides* L.). The selected trees were the same age. Needle and leaf samples were collected from branches at the middle height of trees, during the

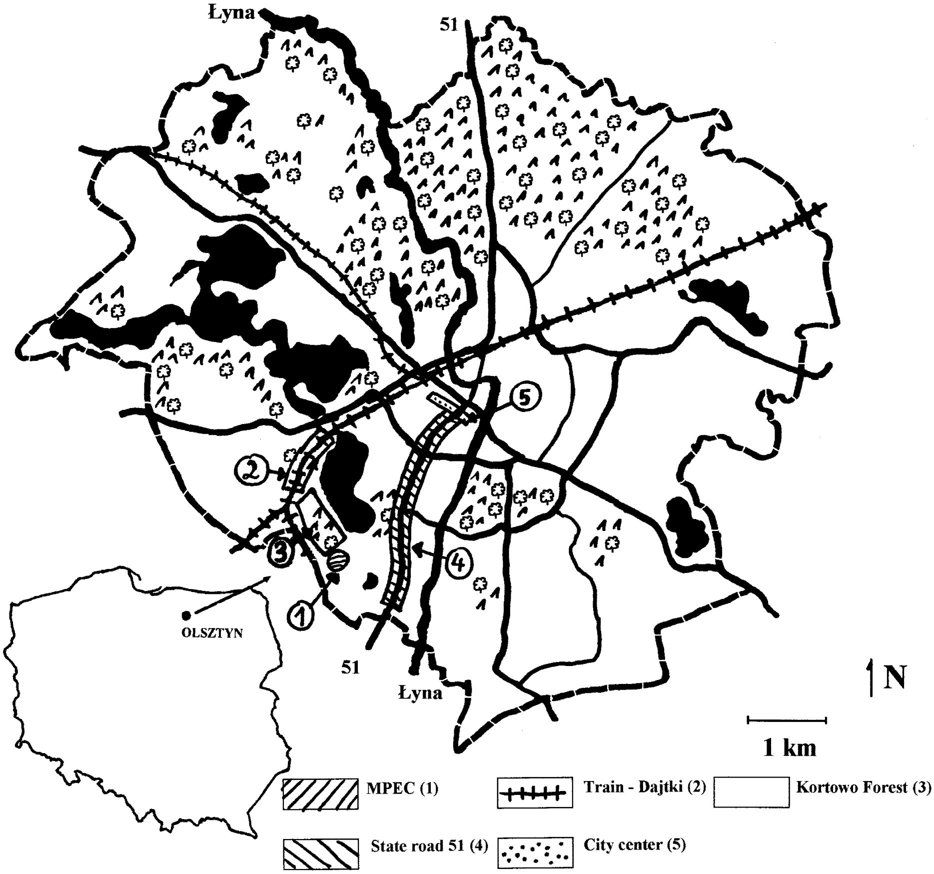


Fig. 1. Location of the sampling sites in Olsztyn

physiological dormancy of trees, in November 2013. The material for laboratory analysis was obtained from 5 trees at each site. Five samples (50 g of weight) of needles, leaves and bark were collected from each tree. Bark was sampled from the same trees at a height of 130 cm above the soil surface, without damaging the phloem. The sampled material was washed with distilled water. Samples from one place were combined in a single, average sample.

The plant material was comminuted, dried at 60°C and ground. A batch of 1 g of each sample was wet mineralized in concentrated sulphuric acid with an addition of hydrogen peroxide as a catalyst. The phosphorus content was determined by the colorimetric method (Ostrowska et al. 1991). Potassium ($K^{+}$), sodium ($Na^{+}$) and calcium ($Ca^{2+}$) were determined by atomic emission spectrometry (AES) and magnesium ($Mg^{2+}$) was assessed by atomic absorption spectrometry – AAS (Ostrowska et al. 1991). The results were analyzed statistically with a Statistica package (Statsoft, Inc. 2011), using a two-factor analysis of variance (Anova).

## RESULTS AND DISCUSSION

The average content of phosphorus, potassium, sodium, calcium and magnesium in pine needles, birch and maple leaves and the bark of these trees varied widely and depended on a tree species (Figure 2). The lowest variation was found for sodium, whose average concentrations in the needles, leaves and bark of the three tree species were similar. It should be stressed that phosphorus, potassium and magnesium concentrations in needles and leaves were much higher than in tree bark. The biggest differences in the average phosphorus, potassium, calcium and magnesium content between needles/leaves and tree bark were observed in the case of silver birch. The content of these nutrients in the needles and leaves was higher than in the bark. The average potassium content was higher in Scots pine needles and the average magnesium content was higher in Norway maple leaves and in Scots pine needles than in the bark. A slightly higher calcium content was in Scots pine and Norway maple bark than in the needles and leaves of these trees. A similar tendency was also found by Hellsten et al. (2013), who observed a much higher potassium and magnesium content in the leaves than in the bark of Swedish birches. The studies conducted by Arthur et al. (1999) and Hellsten et al. (2013) also showed that the calcium and magnesium content was higher in a birch forest stand than in the other tree assemblages. Rademacher (2005) found similar calcium levels in the needles, leaves and bark of trees. Hellsten et al. (2013) showed that conifer bark generally contained significantly less magnesium than leaves of other trees. Augusto et al. (2002), Palviainen et al. (2010) and Hellsten et al. (2013) also noted that the leaves of the above trees contained more nutrients than bark and roots.

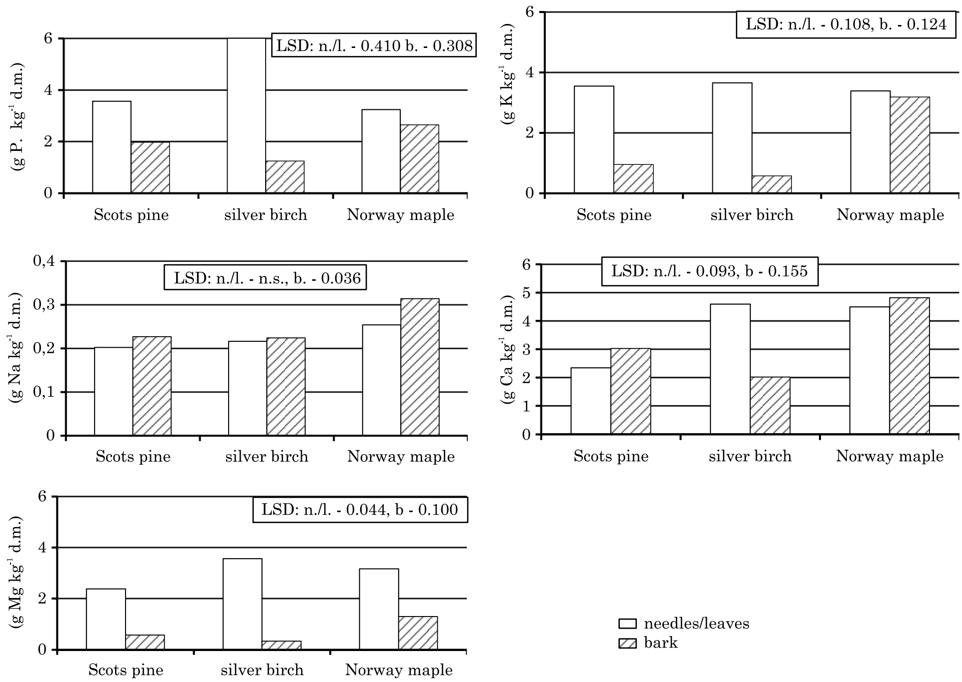


Fig. 2. The average content of phosphorus, potassium, sodium, calcium and magnesium in the needles and bark of Scots pine (*Pinus silvestris* L.), leaves and bark of silver birch (*Betula pendula*) and Norway maple (*Acer platanoides* L.): n./l. – needles/ leaves, b. – bark; differences significant at $P = 0.05$, n.s. non-significant

Augusto et al. (2002) and Hellsten et al. (2013) demonstrated that deciduous tree species were characterized by a higher content of the these nutrients than conifer species.

Among all the tested trees, the leaves of silver birch trees growing in the city center had the highest phosphorus content: 10.00 g $kg^{-1}$ DM on average (Table 1). The highest phosphorus content in maple leaves and pine needles was recorded close to the MPEC (7.520 g $kg^{-1}$ DM) and along the railroad in Dajtki (4.560 g $kg^{-1}$ DM). At the other sites, the phosphorus content was higher than 1.900 g $kg^{-1}$ DM. The phosphorus content in the bark of trees ranged from 0.740 g $kg^{-1}$ DM in silver birch from the center of Olsztyn to 3.440 g $kg^{-1}$ DM in Scots pine along the railroad in Dajtki. The potassium content in silver birch leaves and Norway maple bark in the city center was the highest (5.988 and 6.119 g $kg^{-1}$ DM, respectively). The potassium content in pine needles collected from the site close to the MPEC (4.427 g $kg^{-1}$ DM) and in the center of Olsztyn (4.267 g $kg^{-1}$ DM) was much higher than in pine needles from the other measuring stations. A similar relationship was demonstrated by Bajorek-Zydroń et al. (2007) and Yang et al. (2009) in trees growing in former mining areas. For example, the needles of pine trees growing on a spoil bank of the Bełchatów Brown Coal Mine were characterized by a

Table 1

Content of phosphorus, potassium, sodium, calcium and magnesium in the needles and bark of Scots pine (*Pinus silvestris* L.), leaves and bark of silver birch (*Betula pendula*) and Norway maple (*Acer platanoides* L.), g $kg^{-1}$ d.m.

| Place | Needles/Leaves | | | Bark | | |
|---|---|---|---|---|---|---|
| | Scots pine | silver birch | Norway maple | Scots pine | silver birch | Norway maple |
| Phosphorus | | | | | | |
| MPEC | 3.760 | 8.940 | 7.520 | 2.320 | 2.260 | 3.020 |
| Train - Dajtki | 4.560 | 2.900 | 2.680 | 3.440 | 1.320 | 3.380 |
| Kortowo Forest | 2.920 | 8.180 | 2.100 | 1.160 | 1.000 | 2.440 |
| State Road 51 | 3.980 | 8.840 | 1.920 | 1.220 | 0.900 | 2.280 |
| City center | 2.600 | 10.00 | 1.960 | 1.700 | 0.740 | 2.120 |
| LSD | $a$ – 0.529, $b$ – 0.410, $a \cdot b$ – 0.917 | | | $a$ – 0.398, $b$ – 0.308, $a \cdot b$ – 0.689 | | |
| Potassium | | | | | | |
| MPEC | 4.427 | 3.615 | 3.875 | 1.127 | 0.747 | 1.025 |
| Train - Dajtki | 2.966 | 2.551 | 1.897 | 1.401 | 0.571 | 3.894 |
| Kortowo Forest | 2.949 | 3.171 | 2.405 | 0.455 | 0.306 | 2.866 |
| State Road 51 | 3.118 | 2.938 | 4.864 | 0.735 | 0.627 | 2.042 |
| City center | 4.267 | 5.988 | 3.888 | 1.038 | 0.631 | 6.119 |
| LSD | $a$ – 0.139, $b$ – 0.108, $a \cdot b$ – 0.241 | | | $a$ – 0.160, $b$ – 0.124, $a \cdot b$ – 0.278 | | |
| Sodium | | | | | | |
| MPEC | 0.158 | 0.244 | 0.199 | 0.164 | 0.259 | 0.126 |
| Train - Dajtki | 0.141 | 0.163 | 0.175 | 0.189 | 0.150 | 0.242 |
| Kortowo Forest | 0.143 | 0.187 | 0.247 | 0.173 | 0.189 | 0.255 |
| State Road 51 | 0.361 | 0.221 | 0.330 | 0.306 | 0.294 | 0.501 |
| City center | 0.208 | 0.264 | 0.319 | 0.303 | 0.228 | 0.448 |
| LSD | $a$ – n.s., $b$ – n.s., $a \cdot b$ – n.s. | | | $a$ – 0.046, $b$ – 0.036, $a \cdot b$ – 0.080 | | |
| Calcium | | | | | | |
| MPEC | 2.118 | 4.590 | 2.820 | 2.987 | 3.488 | 4.314 |
| Train - Dajtki | 2.079 | 4.107 | 4.977 | 3.204 | 2.475 | 4.769 |
| Kortowo Forest | 2.975 | 4.519 | 4.583 | 3.195 | 0.637 | 4.782 |
| State Road 51 | 2.550 | 4.757 | 5.220 | 3.038 | 1.378 | 5.167 |
| City center | 1.993 | 4.996 | 4.868 | 2.709 | 2.118 | 5.054 |
| LSD | $a$ – 0.120, $b$ – 0.093, $a \cdot b$ – 0.209 | | | $a$ – 0.201, $b$ – 0.155, $a \cdot b$ – 0.348 | | |
| Magnesium | | | | | | |
| MPEC | 2.624 | 3.406 | 2.011 | 0.347 | 1.306 | 0.545 |
| Train - Dajtki | 2.491 | 3.408 | 3.373 | 1.351 | 0.102 | 1.820 |
| Kortowo forest | 1.649 | 3.711 | 3.418 | 0.020 | 0.015 | 1.007 |
| State Road 51 | 2.535 | 3.628 | 3.666 | 0.319 | 0.191 | 1.290 |
| City center | 2.610 | 3.669 | 3.378 | 0.860 | 0.074 | 1.831 |
| LSD | $a$ – 0.057, $b$ – 0.044, $a \cdot b$ – 0.099 | | | $a$ – 0.129, $b$ – 0.100, $a \cdot b$ – 0.223 | | |

LSD for: $a$ – place of sampling, $b$ – tree species, $a \cdot b$ – interaction; significant at $P$ = 0.05, n.s. – non-significant.

higher phosphorus and potassium content compared to a fresh mixed coniferous forest growing in an adjacent habitat (Bajorek-Zydroń et al. 2007). Yang et al. (2009) found higher phosphorus and potassium levels in pine needles from industrial than from non-industrial areas. A study by Hellsten et al. (2013) showed that trees contained most nitrogen and phosphorus in the winter-spring period.

The highest sodium content was determined in trees along Road 51, namely 0.501 g $kg^{-1}$ DM in Norway maple, 0.306 g $kg^{-1}$ DM in Scots pine and 0.294 g $kg^{-1}$ DM in silver birch bark, as well as in pine needles (0.361 g $kg^{-1}$ DM) and maple leaves (0.330 g $kg^{-1}$ DM) – Table 1. The highest sodium content in silver birch leaves was found in the city center – 0.264 g $kg^{-1}$ DM. The leaves and bark of maple trees growing along Road 51 were characterized by the highest calcium content: 5.220 and 5.167 g $kg^{-1}$ DM, respectively. The leaves of birches growing in the city center had an equally high calcium content – 4.996 g $kg^{-1}$ DM. In the other sites, less sodium and calcium was recorded both in tree leaves and bark. The lowest calcium content was found in Scots pine needles in the center of Olsztyn (1.993 g $kg^{-1}$ DM) and silver birch bark in Kortowo Forest (0.637 g $kg^{-1}$ DM). The magnesium content in the tree needles and leaves was similar at most of the sites, although it showed some dependence on a tree species. More variation in its content was found in tree bark. The cause of the higher sodium content in the needles, leaves and bark of trees growing along the road could be the use of road salt for better surface grip in the winter period, which was also confirmed by Mazur et al. (2011). According to Rytter and Stener (2003) and Hellsten et al. (2013), calcium can accumulate in older tree tissues.

Based on the test results (Table 1), the concentrations of nutrients in tree needles, leaves and bark can be arranged in the following decreasing order: Scots pine needles – P = K > Mg = Ca > Na, silver birch leaves – P > Ca > K > Mg > Na, Norway maple leaves – Ca > K > P = Mg > Na, Scots pine bark and silver birch bark – Ca > P > K > Mg > Na, Norway maple bark – Ca > K > P > Mg > Na. Hagen-Thorn et al. (2004) showed that calcium, magnesium and potassium depended on the accumulation of nutrients in soil, from which they were transported to plant organs. This could explain differences in concentrations of macronutrients in tree needles, leaves and bark discovered in our research. According to Hagen-Thorn et al. (2004), nutrient content depended more on a tree species than on a location, which was confirmed in our study. Hagen-Thorn et al. (2004) suggested another reason, such as different water consumption by individual tree species, which in turn is mainly dependent on the leaf area.

# CONCLUSIONS

1. The content of phosphorus, potassium, sodium, calcium and magnesium depended on a woody plant species, tree organ and the site of sample collection.

2. The leaves of silver birch, compared to its bark, were characterized by a ten-fold higher potassium content and six-fold higher phosphorus and magnesium content.

3. The content of phosphorus was the highest in silver birch leaves in the center of Olsztyn. The highest potassium content was determined in silver birch leaves and Norway maple bark in the center of Olsztyn.

4. The calcium content was the highest in the leaves and bark of maple trees growing near Road 51 and in the leaves of this species in the city center. The highest sodium content was in the leaves and bark of most tree species growing along Road 51 and in the center of Olsztyn.

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