ESTIMATION OF ALUMINIUM POLLUTION IN OAK STANDS ON THE KROTOSZYN PLATEAU

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ABSTRACT

Estimation of the degree of aluminium absorption by oak stands on the Krotoszyn Plateau and on reference areas is reported in this paper. Soil pH, the content of exchangeable aluminium in soil and the content of aluminium in the xylem and roots of *Quercus robur* L. were determined. The performed studies show a very strong acidification of soils from the investigated areas of the Krotoszyn Plateau; pH vs. 1 M KCl did not exceed 4.0, whereas the content of exchangeable Al in some places was > 50 mg/100 g. The results also showed an elevated content of aluminium in the wood and roots of oaks growing on the Krotoszyn Plateau as compared to oaks in Zawiercie (near a Steel Mill), where the reaction of soil is neutral. The content of Al in the xylem of oaks from the Krotoszyn Plateau was over the range 3.8-9.9 µg/g, in the roots 198-499 µg/g, that in the xylem and roots of oaks in Zawiercie was 1.5 µg/g and 56 µg/g, respectively.

KEY WORDS: *Quercus robur*, Krotoszyn Plateau, pH, aluminium.

INTRODUCTION

Oak stands on the Krotoszyn Plateau (West-Central part of Poland) are suffering from the collapse of their health condition, leading to decline. This process, however, was conducive to developing intense studies and observations aimed at finding the reason of oak decline (Siwecki 1987, 1989, Siwecki and Ratajczak 1991, Ważny 1991, Woźny and Siwecki 1991). This problem, however, has not been clearly explained.

The present paper is a part of a wide research program, the objective of which is to evaluate the influence of industrial pollutions on the decline of oak stands on the Krotoszyn Plateau. In the earlier paper (Opydo 1994) the degree of oak stand pollution (soil and wood) with heavy metals – zinc, cadmium, lead and copper was determined. The present work deals with an increasing process of soil degradation as a result of its gradual acidification. A decreasing pH of soil is favourable to the release of aluminium Al^{3+} ions from the crystal soil mineral net, which constitute an essential component of the soil sorption complex when they appear in the soil solution. This is the so-called exchangeable aluminium, which may induce a number of unfavourable phenomena affecting plant development and growth chiefly through the root system (Kabata-Pendias and Pendias 1979, Stienen and Bauch 1988, Sharpe et al. 1993). In this connection pH of soils was measured, the content of exchangeable aluminium in soils and the aluminium content in the wood and roots of oaks were determined. The studies covered oak stands on four investigated areas established by the Institute of Dendrology in Kórnik, Polish Academy of Sciences. In view of a small number of reference monographs the studies also covered stands in

the copper region (near the Głogów Smelter), in Zawiercie (near a Steel Mill) and in Kórnik (Experimental Forest Zwierzyniec).

MATERIALS AND METHODS

Characteristics of the oak stands under study are presented in Table 1. All the stands contained the same oak species – *Quercus robur* L.

Soil samples were taken at three depths: 0-20 cm, 20-40 cm and 40-60 cm. The reaction of soil was evaluated by the potentiometric method. Soil pH was measured in the soil+water (1:2.5) suspension and in the soil+1 M KCl (1:2.5) suspension. The content of exchangeable aluminium was determined by the method of Sokołov. This method consists in determination of aluminium content from the difference between exchangeable acidification estimated in 1 M KCl and the remaining acidification after removal of Al^{3+} by NaF.

Wood samples were taken from several oak trees on each investigated forest area with a Pressler's bore at height of 1.30 m from the ground. Roots samples were also taken from several trees on each investigated area – from the main and lateral roots. They were dried up (105°C, 24 h), and then, disintegrated. Wood and roots mineralization was done in a mixture of 30 % H_2O_2 + conc. HNO_3 . Aluminium concentrations were measured by adsorptive stripping voltammetry, using a hanging mercury drop electrode. For aluminium complexation, solochrome violet SR was used in the case of Al determination in the xylem of trees and alizarin S in the case of Al determination in roots (Opydo 1995).

TABLE 1. Condition of the oak stands under study.

Location	Research area	Age of trees	Classes of damaged trees ^x
Krotoszyn Plateau	Jasne Pole 1	136	3 and 4
	Jasne Pole 2	106	0 and 1
	Jasne Pole 3	104	3 and 4
	Potarzyca	106	2 and 3
Copper basin	Biechów	about 80	0 and 2
	Bogomice	about 80	0 and 2
Krakowsko-Częstochowska Upland	Zawiercie	about 130	0
Kórnik	Experimental Forest Zwierzyniec	about 100	0

^x 0 – healthy trees; 1 – slightly damaged trees; 2 – medium damaged trees; 3 – strongly damaged trees; 4 – dead trees.

RESULTS AND DISCUSSION

Results of soil analysis are presented in Table 2. The performed studies show a very significant decrease in pH of soils from the areas of the Krotoszyn Plateau, copper region and Kórnik. In these cases, soil pH vs. H₂O below 4.5 and soil pH vs. KCl < 4. This qualifies the studied soils as very acid.

The largest decrease in soil pH may be observed on the investigated areas Jasne Pole 1, 2 and in Potarzyca. Such a strong soil acidification entails the release of significant amounts of aluminium Al³⁺ ions from the soil.

The content of aluminium in the wood of oak trees is presented in Table 3. An elevated content of aluminium can

be observed in the wood of oak trees from the areas characterizing by a high content of exchangeable Al in comparison to oak trees from Zawiercie, where this phenomenon does not occur.

The largest concentrations of Al were found in the xylem of oak trees from the investigated areas of Jasne Pole 2 (9.9 µg/g), Potarzyca (8.7 µg/g) and Jasne Pole 1 (5.4 µg/g). Just on these areas the content of exchangeable aluminium in the soil was the highest amounting 53.8, 42.8 and 54.0 mg/100 g, respectively.

Aluminium absorption by oak trees is more visible, when results concerning roots are compared (Table 3). The content of Al in the roots of oak trees from Zawiercie (56 g/g) is con-

TABLE 2. Soil reaction and mobile aluminium content. Results of soil analysis from the Krotoszyn Plateau and comparative areas.

Research area	Soil layer cm	pH vs. H ₂ O	pH vs. KCl	Mobile Al mg/100g
Jasne Pole 1	0-20	3.8	3.0	20.3
	20-40	4.3	3.8	36.5
	40-60	4.5	3.3	54.0
Jasne Pole 2	0-20	3.9	3.4	53.8
	20-40	4.5	3.8	31.0
	40-60	4.8	3.8	20.4
Jasne Pole 3	0-20	4.9	4.0	6.5
	20-40	4.8	4.0	7.0
	40-60	4.9	3.6	10.1
Potarzyca	0-20	4.4	3.4	42.8
	20-40	4.6	3.4	42.3
	40-60	5.0	3.4	22.1
Biechów	0-20	4.9	4.0	4.5
	20-40	4.9	3.8	5.3
	40-60	5.7	4.9	0.1
Bogomice	0-20	3.7	3.4	9.9
	20-40	3.9	3.6	14.0
	40-60	4.0	4.0	4.4
Zawiercie	0-20	7.5	6.9	–
	20-40	7.5	7.0	–
	40-60	7.0	6.5	–
Kórnik	0-20	4.5	3.8	8.9
	20-40	4.6	4.0	7.0
	40-60	4.6	4.0	5.7

TABLE 3. Concentration of aluminium in the wood and roots of oak ($\mu\text{g/g}$).

Sampling location	Al content in	
	wood	roots
Jasne Pole 1	5.4 ± 0.3	499 ± 34
Jasne Pole 2	9.9 ± 0.7	139 ± 12
Jasne Pole 3	3.8 ± 0.1	279 ± 17
Potarzyca	8.7 ± 0.3	193 ± 7
Biechów	3.3 ± 0.2	
Bogomice	3.8 ± 0.2	
Zawiercie	1.5 ± 0.1	56 ± 2
Kórnik	3.8 ± 0.2	

Confidence intervals of means at a 95 % confidence level, $n = 8$.

siderably lower than that in the roots of trees from the Krotoszyn Plateau ($192\text{--}499 \mu\text{g/g}$). However, in all the cases the content of Al in xylem and roots does not seem to be high. Though the literature has no communications on Al content in the xylem of oak trees, $6.1\text{--}23.8 \mu\text{g/g}$ Al (Matusiewicz and Barnes 1985) and $3.2\text{--}8.3 \mu\text{g/g}$ Al (Berneike et al. 1987) were found in spruce xylem. Fine roots of spruce were found to have $2800\text{--}4400 \mu\text{g/g}$ Al (Berneike et al. 1987) and roots of red oak – $2300\text{--}3130 \mu\text{g/g}$ Al (Sharpe et al. 1993). On the other hand, Al concentration in soil extracts above $5 \mu\text{g/g}$ appears to be toxic to many plants (Kabata-Pendias and Pendias 1979). Therefore, concentrations of exchangeable aluminium found in soil and exceeding 50 mg/100 g ($500 \mu\text{g/g}$) in some places, should not be neutral to trees. Perhaps low pH and a high content of mobile aluminium affect an increased uptake of copper through oaks on the areas of the Krotoszyn Plateau. In the work by Opydo (1994) an elevated content of copper was found in the wood of oaks from the areas of Krotoszyn Plateau as compared to the reference areas (copper content in oaks from Kórnik constitutes $0.6 \mu\text{g/g}$, $1.1 \mu\text{g/g}$ from Zawiercie, $3.9\text{--}15.8 \mu\text{g/g}$ from the copper region and $7.0\text{--}26.5 \mu\text{g/g}$ from the Krotoszyn Plateau). It is known, that the degree of copper assimilation by plants is affected by such factors as temperature, reaction of the environment, Al, Ca, Fe, Zn, P and N contents in soil (Kabata-Pendias and Pendias 1979).

On the basis of the obtained results it may be inferred that copper absorbed by oaks and low pH of soils as well as considerable amounts of exchangeable aluminium in soil constitute factors, which may weaken trees making them more susceptible to pathogenic fungi and to attacks of harmful insects. These assumptions are supported by a good condition of oak stands growing on the ecologically threatened area near the Steel Mill in Zawiercie. This area, however, due to its location on the limestone rock – Krakowsko-Częstochowska Upland is characterized by neutral and alkaline soils.

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OCENA STOPNIA ZANIECZYSZCZENIA GLINEM
DRZEWOSTANÓW DĘBOWYCH PŁYTY KROTOSZYŃSKIEJ

STRESZCZENIE

W pracy oceniono stopień absorpcji glinu przez drzewostany dębowe zlokalizowane na Płycie Krotoszyńskiej oraz na powierzchniach referencyjnych. Oznaczono: pH gleby, zawartość glinu wymiennego w glebie oraz zawartość glinu w ksylemie i w korzeniach dębów *Quercus robur* L. Przeprowadzone badania wykazują bardzo silne zakwaszenie gleb z powierzchni badawczych Płyty Krotoszyńskiej; pH wzgl. 1 M KCl nie przekracza 4,0, natomiast zawartość Al wymiennego miejscami > 50 mg/100 g. Stwierdzono również podwyższenie zawartości Al w drewnie i w korzeniach dębów rosnących na Płycie Krotoszyńskiej, w porównaniu z drzewostanami zlokalizowanymi w Zawierciu, gdzie odczyn gleby jest obojętny. Zawartość Al w ksylemie dębów z Płyty Krotoszyńskiej mieści się w zakresie 3,8-9,9 µg/g a w korzeniach w zakresie 198-499 µg/g, natomiast zawartość Al w ksylemie dębów z Zawiercia wynosi 1,5 µg/g a w korzeniach 56 µg/g.

SŁOWA KLUCZOWE: *Quercus robur*, Płyta Krotoszyńska, pH gleby, aluminium.