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THE INFLUENCE OF DIFFERENT CONCENTRATIONS OF CADMIUM ON STRUCTURAL CHARACTERISTICS OF POPLAR CLONES ROOT

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ABSTRACT. The effect of different cadmium concentrations (10^{-7} and 10^{-5} M Cd) on the root structural characteristics and the cadmium content in roots, stems and leaves were examined for poplar clones. Weakly expressed structural changes were recorded for the clones 30-2/95 and B-81. The changes in root cross section areas were caused by a variable number of layers of parenchyma cells in cortex, as well as by changes in the size of central cylinder, because of the development of new vascular elements. Among the examined organs, significantly the highest cadmium concentration was recorded in roots. The amount of cadmium in plant organs was clone specific. The clone I-214 was singled out because of its high cadmium accumulation in the root and significant structural stability.

KEY WORDS. poplar, root, cadmium, anatomy

INTRODUCTION

The presence of heavy metals in concentrations higher than permitted, causes the pollution of agro ecosystems. Mostly, the pollution by cadmium and other heavy metals is of anthropogenic origin (Smith, 1994). In smaller amounts, cadmium is taken into the soil with mineral phosphate fertilizers (He and Singh, 1995). Heavy metals in soils are a huge problem for an environment, because most of them are very stable for hundreds or even thousands of years. Because of those facts, contaminated grounds require a special way of utilization (Bogdanović et al., 1997).

Most of the plants take in and transport cadmium by the xylem, in the form of Cd^{2+} ions (Leita et al., 1996). The same author states that cadmium shows weak retranslocation ability, so its concentration in fruits and seeds is small, even if the soil is very polluted.

The increased cadmium concentration causes disorders in division of cells, and direct consequences are also changes in anatomical structure of plant organs – the reduction of the number and the size of vascular bundles in beans (Lamoreaux and Chaney, 1978), the reduction of the size of epidermal cells (Petrovic et al., 1992), the reduction of the leaf and mesophyll thickness, the size and the number of vascular bundles, the lumen of vessels, the size of epidermal and bulliform cells in wheat leaves (Brdar, 1997), structural changes on poplar and willow roots (Lunackova et al., 2003/4). Liu et al. (2003/04) cited that in small concentrations, using short treatment, cadmium does not influence the growth of the root, but has stimulating effect. When present in high concentration, it causes partial blockade of water transport in vessels, the appearance of resin matters and degradation of vascular cells (Lamoreaux and Chaney, 1977).

Poplar characteristics, like high adaptability, fast growth, easy propagation and high transpiration intensity (Cain and Ormord, 1984), make this species suitable for fitoremediation (Chappell, 1997).

Plant species show different ability to the accumulation of heavy metals in their organs. In higher concentrations they are mostly accumulated in the roots (Florijn and Van Beusichem, 1993; Gàrate et al., 1993).

Taking into consideration all of this, the aims of our research were to examine if different cadmium concentrations cause changes in the root anatomical structure of poplar clones, as well as to examine clone specific ways of cadmium accumulation in plant organs.

MATERIAL AND METHODS

For the analyses, woody cuttings of three poplar clones were used (*Populus nigra* – clone 30-2/95, *Populus deltoids* - clone B–81, and *Populus x euramericana* – clone I-214). Nine cuttings from each genotype were placed in 12 hydroponic pots (volume 2.5 liters, three cuttings per pot). Plants were grown in pure water till root development for 45 days. After that period, plants were transferred to the Hoagland nutrient solution, supplemented with cadmium. There were three treatments: control, containing 0 M Cd and nutrient solution containing 10^{-7} and 10^{-5} M Cd. Plants were grown in controlled chamber at the temperature of $21 \pm 1^{o}C$ and constant light, without photoperiod.

After 45 days of exposure to cadmium treatments, root structural characteristics and cadmium content in plant organs were analyzed. Root cross sections were made using Leica CM 1850 cryostat, at temperature -18°C to –20°C, at cutting intervals of 20 μm. Sections were observed and measurements made using Image Analyzing System Motic 2000. Cadmium content was measured using Atomic Absorption Spectrophotometer. Data were statistically processed using STATISTICA for WINDOWS version 6.0.

RESULTS AND DISCUSSION

For most of the plants grown under different cadmium concentrations, the root cross section area was not significantly different, compared to the control samples. The significant reduction of root cross section area was recorded only for the clone 30-

2/95 in Cd^{-7} conditions (Graf. 1). This reduction was caused by the reduction of the central cylinder cross section area as well as the reduction of the number of layers of parenchyma cells in the cortex (Graf, 2, 4).

In Cd^{-7} conditions, clone B-81 showed low increase in the root cross section area and the number of parenchyma cells in the cortex (Graf, 1, 4). The central cylinder cross section area was 8% lower compared to the control sample (Graf. 3). The low reduction of the root cross section area, the reduction of the number of layers of cortex parenchyma cells and the increase of the central cylinder cross section area of the clone B-81 were recorded in Cd^{-5} conditions. As the consequence, the percentage of central cylinder in the root was higher, compared to the control plants (Graf. 3). The B-81 clone also showed the significant reduction of the vessels lumen both in Cd^{-5} and Cd^{-7} conditions (Graf. 5). Cadmium concentrations did not have significant effect on the root structural characteristics of the I-214 clone. In conditions with higher cadmium concentrations, the xylem and phloem bands in vascular bundles were more numerous (Fig. 1).

The results of the measurements of the root cross section area indicated that those changes could have been caused by the changes in the number and/or cross section area of cortex parenchyma cells, or by the effect of cadmium on earlier differentiation of central cylinder elements. Those results could be connected with the effect of cadmium on earlier differentiation of tissues in the apical part of the root (Lunačkova et al., 2003/04).

Beside an increase of resistance to radial water transport in the root through an increase of the root thickness, higher heavy metal concentrations induce higher root lignification, and thus lower the permeability of cell walls for water transport (Barcelo and Poschenreider, 1990).

The concentration of cadmium in plant organs is determined by its concentration in the soil. The ability of plant to accumulate cadmium is clone specific (Tab. 1). The highest cadmium concentration was recorded in the roots, for all examined clones. Clone I-214 showed the highest ability to accumulate cadmium in the root. Clones 30-2/95 and I-214 had higher cadmium concentration in the leaves than in the stem, while for clone B-81 it was opposite. Cadmium concentration in the soil is positively correlated with the intensity of its absorption and transportation to aboveground organs (Verkleij and Schat, 1990).

The absence of structural changes in the presence of cadmium was previously recorded for *Phragmites australis*, a species with a high detoxification potential. The presence of cadmium causes deposition of lignin and significant stimulation of root antioxidative system (Ederli et al., 2004).

On the basis of presented results, clone I-214 could be singled out as the clone that did not show structural modifications of the root in the presence of cadmium, although it had the highest accumulation of this metal in the root.

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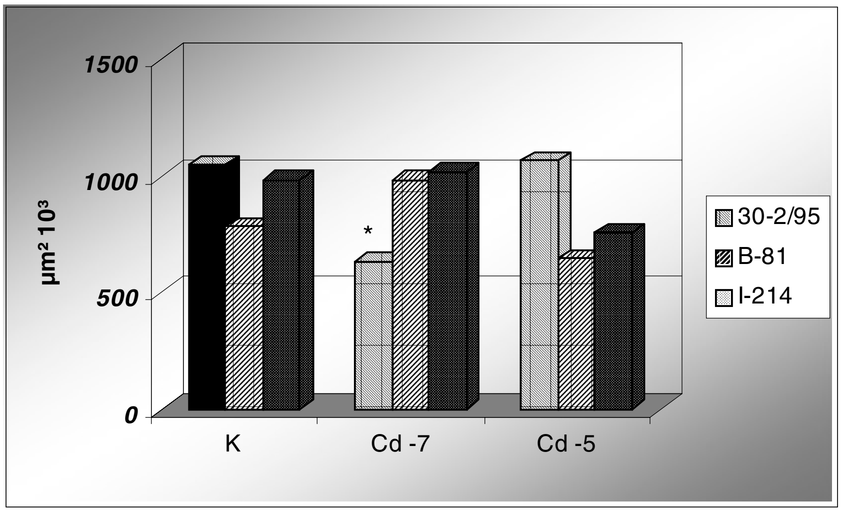
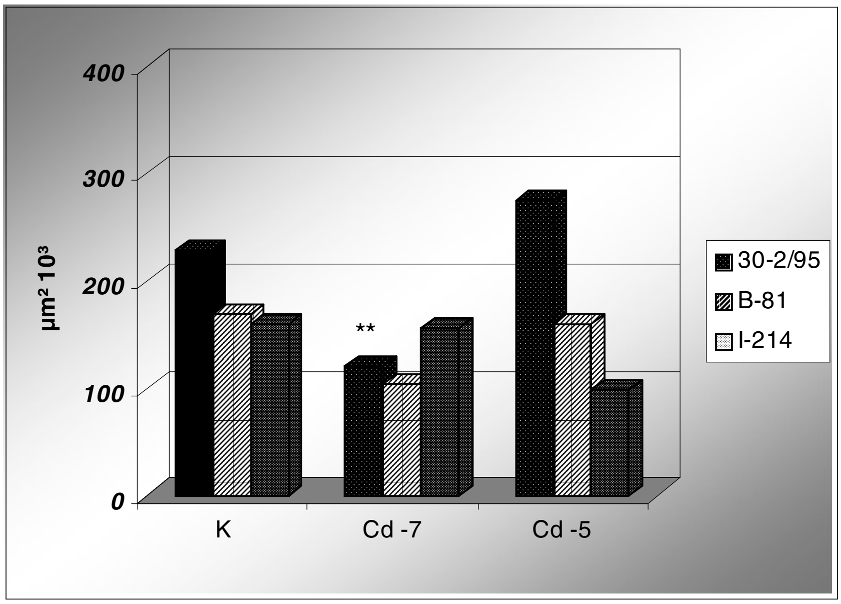
Table 1. Cadmium accumulation in leaves, stem and roots in different poplar clones (ppm)

Clone	Treatment	Stem	Leaves	*Roots*
	0 (Control)	0.47	0.54	1.86
30-2/95	10^{-7}	2.56	4.67 **	33.67
	10^{-5}	7.08 *	11.0 **	204.8 **
	0	0.26	0.83	4.75
B-81	10^{-7}	5.09 **	3.61 **	34.69
	10^{-5}	16.8 **	5.0 **	258.9 **
	0	0.39	0.72	1.54
I-214	10^{-7}	2.60	4.3 *	72.07 *
	10^{-5}	5.00 **	6.75 **	338.6 **

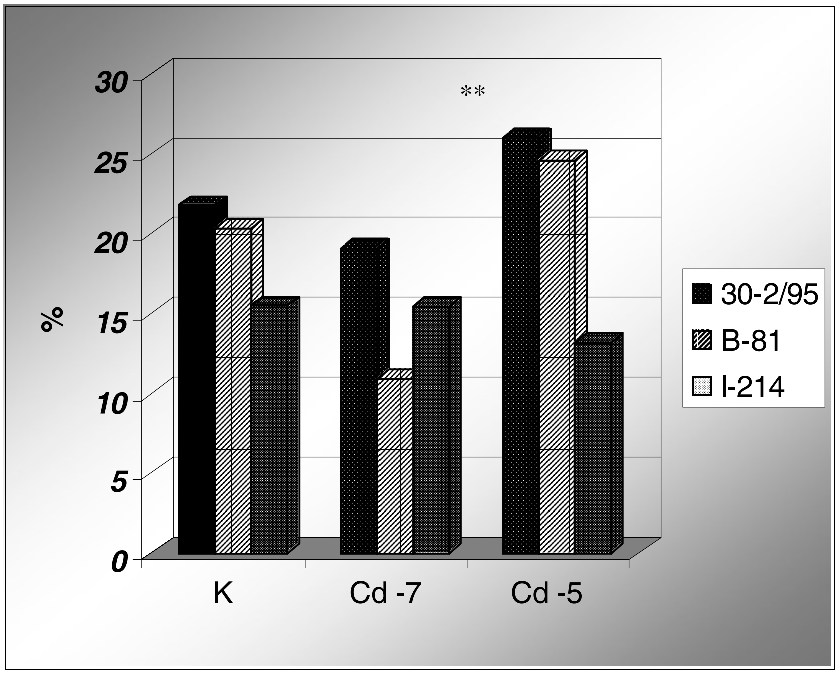
Means with * significantly at $p<0.05$; means with * *significantly at $p<0.01$



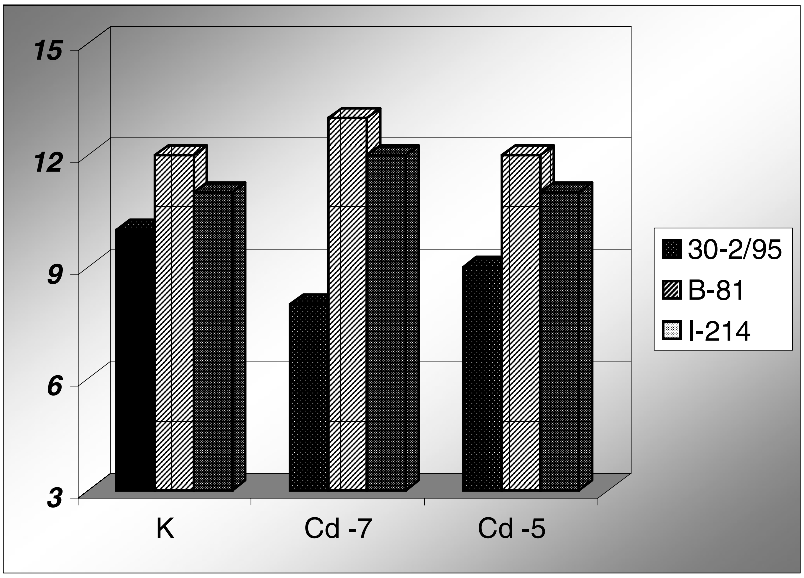
Graf 1. Root cross section area



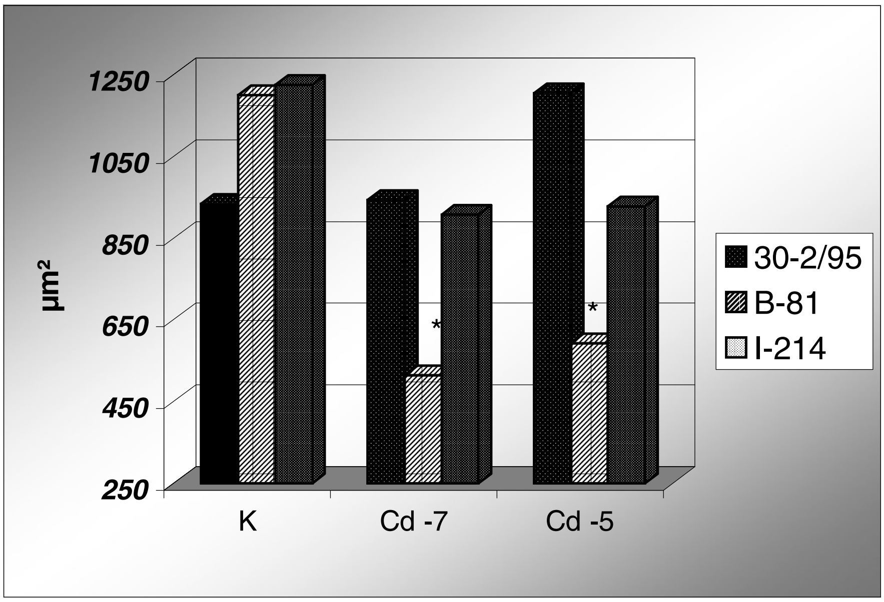
Graf. 2. Cross section area of vascular cylinder



Graf. 3. Percentage of vascular cylinder



Graf. 4. The number of layers of parenchyma cells in cortex



Graf. 5. The lumen of metaxylem vessels

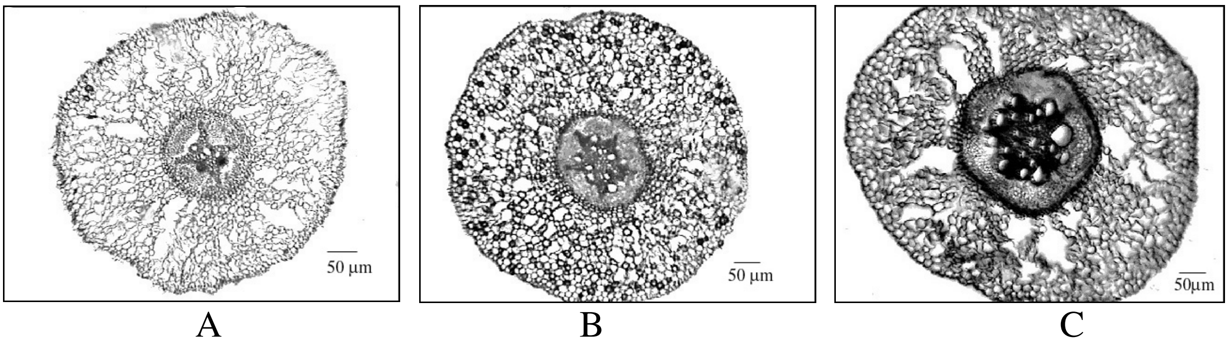


Fig. 1. Cross section of poplar root A) control, B) Cd $^{-7}$ tretmant and C) Cd $^{-5}$ tretmant