in: Teller,A.;Mathy,P.et Jeffers,J.N.R.:1992
Responses of Forest Ecosystems to Environment Changes.-EC I.Europ.
Sympos. on Terrestr. Ecosystems,Florenz 1991,p.659-661 Elsevier
Essex.

CRITICAL CONCENTRATIONS OF LEAD AND CADMIUM FOR YOUNG BEECH TREES (FAGUS SYLVATICA L.)

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1. INTRODUCTION

For decades, the airborne heavy metal burden of forest soils in Central Europe has been increasing (10). The slowly decreasing input of some heavy metals due to decreased emissions in some countries of Western Europe did not improve the situation. Because metals cannot be decomposed, even a lowered input still leads to accumulation in the upper soil layers as well as in tree roots (9,11). Increasingly mobilized by acidification processes, these metals may have toxic effects on trees. Recently, Pb, Cd, Zn and Hg were shown to affect root growth of spruce seedlings (4), even despite of mycorrhizal fungal colonization (6). Several dose-response-experiments have been carried out by our group to evaluate the toxicity of root-applied Pb and Cd for young plants of Fagus sylvatica L. Different growth parameters, uptake of mineral nutrients and effects on transpiration were investigated.

2. MATERIALS AND METHODS

Seedlings as well as young trees of Fagus sylvatice L. were exposed to increasing concentrations of Pb and Cd in short and long term experiments in sand and soil culture. For the soil culture experiments, a homogenized soil ("Braunerde", upper mineral layer (A_h), pH(H_2O) 3.6) of a beech stand (Teutoburger Wald) near Bielefeld was contaminated with $Pb(NO_3)_2$ and $Cd(NO_3)_2$ solutions to equilibrium conditions. Soil concentrations of Pb and Cd were measured as plant available soil fractions, determined by ammonium-acetate extraction. The sand culture experiment with nutrient solution was carried out over three vegetation periods under open air conditions. At different times of the year Pb and Cd were applied to the roots as nitrates in water solution, singly or in combinations and at two pH levels (pH 3, pH 5). Root growth chambers (glass-faced boxes) were used to measure the root elongation rates of beech seedlings continuously over two months, depending on increasing soil concentrations of Pb, Cd and Pb plus Cd under laboratory conditions.

3. RESULTS AND DISCUSSION

Treatments of 20 ppm Pb and 1 ppm Cd (sand culture) at the pH 3 conditions resulted in a highly significant decrease of the dry weigths of stems and roots. At this pH level, stem diameter and leaf area were significantly reduced by the single as well as by the combined treatments. At pH 5, growth depressions were less severe: compared to the control plants, the decrease was significant only for the combined treatments, but not for the correspondent levels of the single metals. Stem diameter, dry weight of stems and roots and leaf area were reduced synergistically at pH 5 (7). Concentrations of 6.2 ppm Pb and 0.3 ppm Cd in the leaves (DW) were coincident with a significant reduction of the leaf area (7).

Apart from growth parameters, mineral nutrition was also affected. High accumulation of Pb and Cd in the roots was coincident with considerably lower levels of K, Ca, Mg and Mn than those found in the roots of control plants (2, 8). This decrease may be caused by harmful effects of Pb and Cd on the uptake mechanisms as well as by ion competition with the nutrient cations during root uptake (7, 8).

The leaves mostly contained less than 1 % of the Pb and Cd contents of the roots. Application of Pb and Cd in springtime (during the leaf development), but not when applied in summer or autumn, resulted in significantly lowered leaf concentrations of K, Ca, Mg, Fe, Mn and Zn, mostly amounting to less than 50 % of the contents in control plants. Symptoms . this multiple element deficiency were leaf margin necroses (K deficiency) and chlorotic yellowing of the leaves (mainly Mg deficiency) (7). Similar leaf symptons and element deficiencies (Ca and Mg) occurred in beech seedlings after 100 days of growth in Pb and Cd contaminated forest soil (7, 8).

In springtime, leaf development of metal-treated plants was delayed and autumnal tints appeared earlier than in control plants. Thus, even applications of only 20 ppm Pb and 1 ppm Cd resulted in a shortening of the vegetation period between 3 and 10 days (8).

High or low transpiration had no apparent effect on root absorption of Cd, but exposure of the roots of beech saplings to a $Cd(NO_3)_2$ solution reduced their rates of transpiration after very few days of treatment (5). A 20 % reduction of transpiration rates was measured in ten year old beech trees after three months of exposure to a forest soil containing 2.5 ppm plant available Cd (1).

The experiments with root growth chambers showed that root elongation rates and root biomass of beech seedlings were significantly reduced at soil concentrations (pH 3.6) of 44 ppm Pb or 7 ppm Cd by about 30 % after two months of exposure. At combined soil treatments with Pb plus Cd, however, similar growth depression effects occurred even at 24 ppm Pb and 2 ppm Cd, exhibiting synergistic effects (7, 8). A distinct reduction of root hair density started with 44 ppm Pb in the soil and increased at higher concentration levels of Pb. The root architecture was changed by Pb to a more compact and more branched system. A die-back of lateral roots was balanced by the formation of new second order laterals. Reduced ongation of primary roots of beech seedlings was found to recover again when growing from a highly (if max. 50 ppm Pb was not exceeded) into a lower Pb contaminated soil area (2).

Considering root elongation of seedlings as a rather sensitive parameter, plant available soil concentrations (NH_4-acetate-extractable) of 24 ppm Pb and 2 ppm Cd must be regarded as "critical" concerning depression of root growth. Effects on growth and mineral nutrition of young beech trees studied during three vegetation periods indicated that threshold concentrations in the long term aspect are even lower than 20 ppm Pb and 1 ppm Cd, especially when applied in combination.

The data indicate that present-day concentrations of Pb in many acid forest soils of Central Europe (9, 11) are sufficiently high to affect germination and growth of saplings. Furthermore, deficiencies of nutrient cations in the leaves of mature beech trees in acified stands of forest decline may not only be caused by leaching effects or poor soils (3), but also by effects of Pb and Cd in the rhizosphere. Levels of Cd actually may not yet have adverse effects on beech, but may be detrimental in the long run and in combination with other toxic elements. Especially Pb must be taken into account as a contributing factor to tree dieback at acidified beech stands.

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