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Lead Movement in Poplar Adventitious Roots*

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Abstract. Lead was detected and located in definite regions of the *Populus* adventitious roots with the light microscope. Incubations of 24, 48, and 72 h in solutions of $Pb(NO_3)_2$ resulted in clear sequences of microscopic images. Interpretation of these images allows the construction of a scheme for lead transport pathways in roots.

Many studies (*e.g.* KOEPPE 1977, GARLAND and WILKINS 1981, PRZYMUSIŃSKI and WOŹNY 1985) have shown that lead (Pb) is taken up by the roots of plants growing in lead-containing substrates. Only few of these studies emphasize the participation of particular root tissues in lead movement (MALONE *et al.* 1974, LANE and MARTIN 1977, SIGHARDT 1981, 1984). The present study addresses the question of the specific routes of Pb transport through roots. The method involved locating this element in root tissues after different time periods of treatment with lead salt. The temporal changes in the location of Pb would thus indicate routes through which the absorbed Pb moved within the roots.

MATERIAL AND METHODS

Experiments were conducted on adventitious roots of the *Populus* hybrid labelled PK–136. The plants were grown in pots from cuttings taken at the Institute of Dendrology of the Polish Academy of Sciences in Kórnik.

After taking the plants out of the ground and washing the roots, they were placed in distilled water (control) or in an aqueous solution of $Pb(NO_3)_2$ in the concentration of 0.5 mmol Pb dm^{-3}. The plants were maintained under continous, fluorescent illumination of 200 W m^{-2} at 20 °C with a relative humidity of about 60 %. After 24–, 48–, and 72–h incubation of the roots in the solution of $Pb(NO_3)_2$, root tips, their parts derived from half their length (*i.e.* about 6 cm from the tip) and the base of the roots, (*i.e.* those next to a shoot) were fixed in FAA. For each experimental time

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30 roots (in 3 repeats for 10 roots) were tested. After the material had been embedded in paraplast, a rotary microtome was used to slice 12 μm-thick sections. Black deposits of lead sulfide (PbS) were detected with the light microscope because the roots were soaked in a saturated aqueous solution of H_2S for 20 min. Photographs were taken in an Amplival (Zeiss) microscope with an attached automatic device for controlling the exposure time and with a special head.

RESULTS AND DISCUSSION

After 24-h incubation in a solution of lead nitrate, the black deposits of PbS were best visible in the apical meristem of the root and in the adjacent cap cells (region signed 1 in Fig. 1A). When the incubation was prolonged for 48 or 72 h the amount of lead accumulated in this region increased. Only after 48-h contact of the roots with Pb, the black deposits were markedly visible in the apical cap cells. No traces of lead were detectable in the cells of the middle part of the meristem (region signed 2 in Fig. 1A) or in the procambial cells of the adventitious roots after 24- and 48-h incubation in $Pb(NO_3)_2$. Small amounts of deposits were found in these cells of the *Populus* roots as soon as 72 h had passed after placing the roots in the solution of lead nitrate. As early as after 24 h, lead was, in turn, detected in the lateral parts of the meristem base (region signed 3 in Fig. 1A) and in the cortex cells. The number of cells which contained Pb deposits increased as the duration of contact with the available solution became longer (Fig. 1A, B). Descriptions of the occurrence of Pb in root caps and some meristem parts have also been provided for other plant species (PRZYMUSIŃSKI and WOŹNY 1985, WIERZBICKA 1987, WOŹNY 1987, IDZIKOWSKA 1988, KSIĄŻEK – unpublished data). LANE and MARTIN (1977) stated that lead was detectable within the root cap after only a short period of incubation in lead compounds. As early as after 24-h incubation of the roots in $Pb(NO_3)_2$, large amounts of black lead deposits were commonly encountered in the hairs and other epidermal cells of the root hair region which take up water and dissolved substances. Thus, it appears to be that *via* the latter cell types (Fig. 2A, B) Pb enters the interior of the roots. This also receives confirmation from the results obtained by other workers (among others, GLATER and HERNANDEZ 1972, SIGHARDT 1984). The Pb is next transported radially deep into the root. As can be seen in longitudinal sections of the *Populus* root tips (Fig. 1A and B) and in cross-sections of the root hairs region incubated in the solution of $Pb(NO_3)_2$ for 24 h (Fig. 2C), the endodermal cell walls are black. Undoubtedly, the endodermis serves as a barrier to the radial transport of Pb from the cells of the primary cortex into the central cylinder. The endodermis functioning as a barrier to the radial transport of this element through roots has also been described for many other species (TANTON and CROWDY 1971, LANE and MARTIN 1977, SIGHARDT 1981, 1984).

At a distance of 6 cm from the *Populus* adventitious root tip, *i.e.* halfway along the length of the roots under investigation, secondary growth of the roots was observable. The earliest presence of Pb was detected there after 24 h on the surface of the

cork cells and in the cell walls forming lenticels. After 48-h incubation, the black deposits were visible in the primary cortex parenchyma cells (Fig. 2D). A rather surprising result was obtained from the interpretation of images of root parts taken next to the shoot. After 48 h, Pb occurred there in large amounts in deposits which were only encountered in the central cylinder cells. Lead was not detected in the cortex parenchyma cells (Fig. 2E).

The temporal sequence or images of the distribution of Pb deposits in various regions of the *Populus* adventitious roots provided the basis for constructing a scheme of presumable pathways of lead transport and accumulation in the roots (Fig. 3). Lead enters the root tissues together with water from the external environment. As the root hairs region takes up the largest amount of water, most lead moves into the root through this region. After it has been taken up particularly by root hair cells Pb moves vertically and horizontally, probably within the primary cortex parenchyma cell walls. The endodermis functions as a barrier to the radial Pb transport near the root tips. However, Pb can enter the central cylinder region due to breaks in the continuity of the endodermis as a result of the formation of lateral roots and of the secondary growth. Lead found at the tip may either be taken up by the tip

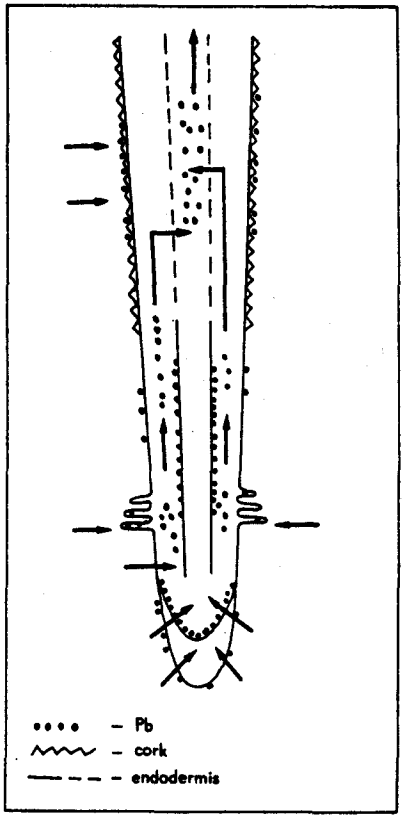

Fig. 3. Scheme of presumable Pb transport pathways in *Populus* adventitious roots.

itself or enters the tip along the route of basipetal transport of water and mineral salts, which is most likely to function in this root region.

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Figs. 1 and 2 at the end of the issue.

Fig. 1. Longitudinal sections of *Populus* adventitious root tips (× 150). – A: A root incubated in the solution of lead nitrate in the concentration 0.5 mmol Pb dm^{-1} for 24 h. No traces of Pb in the middle part of the meristem (region signed 2). Black Pb deposits visible in the adjacent cap cells (region signed 1) and in the lateral parts of the meristem base (region signed 3). B: A root incubated in the solution of lead nitrate (0.5 mmol Pb dm^{-1}, 48 h). Lead deposits additionally visible in the cortex cells (arrows). C: A root incubated in distilled H_2O (control).

Fig. 2. Longitudinal and cross-sections of *Populus* adventitious roots. – A, B: A root incubated in the solutions of lead nitrate (0.5 mmol Pb dm^{-1}, 24 h). Lead deposits visible in the interior of epidermal cells (A, × 180) and in root hairs – arrows (B, × 500). C: A root incubated in the solution of lead nitrate (0.5 mmol Pb dm^{-1}, 48 h). Pb visible in the endodermis – arrows (× 170). D: Cross-section halfway along the root length (at a distance of about 6 cm from the tip). A root incubated in the solution of lead nitrate (0.5 mmol Pb dm^{-1}, 48 h). Lead deposits visible in primary cortex parenchyma cells – arrow (× 160). E, F: Longitudinal sections of the base of the root next to the shoot (× 160). (E) A root incubated in the solution of lead nitrate (0.5 mmol Pb dm^{-1}, 48 h). Lead encountered only in central cylinder cells. (F) A root incubated in distilled water (control).