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Metal accumulation on the fine roots of *Rhizophora mangle* L.

Introduction

The impact of heavy metal exposure on mangrove plants has been considered as minor or nonexistent (Peters *et al*., 1997). Most mangrove trees species have developed strategies to minimize high metal uptake, including metal exclusion through rhizosphere oxidation and preferential metal fixation within root tissues (Doyle & Otte, 1997; Ong Che, 1999). These attributes of mangroves have been proposed as a way to mitigate metal pollution in coastal areas (Lacerda *et al*., 2000).

The importance of fine (small diameter, non-ligninacious) roots on the dynamics of cycling of essential elements and the negative effects of elevated metal exposure on their functioning have been demonstrated in terrestrial forests (Nadelhoffer *et al*., 1985; Helmisaari *et al*., 1999). In mangrove ecosystems however, there are few data on the interaction between fine roots and their substrate, although they can make up a large portion of the mangrove belowground biomass. Particularly, no study has focused on the relative importance of fine roots on mangrove trees adaptability to high metal concentrations in intertidal sediments.

The preliminary results shown here suggest that the presence of large metal-rich mineral deposits (denominated iron plaques), generated by root oxygen transport and release via aerenchima, found on the fine roots of *Rhizophora mangle* L., can moderate the metal uptake by roots and induce a substantial metal accumulation at the root-sediment interface.

Iron plaque extraction and metal analysis

Roots of various trees from a *R. mangle* forest at Sepetiba Bay, SE Brazil, were sampled during low tide by means of stainless steel spades. Root samples were carefully washed with estuarine water and distilled water to remove sediments. Fine (< 2 mm diameter) roots were separated and divided into 1.0 g fresh weight sub-samples for iron plaque extraction, and total acidic digestion for trace metal analysis. The cold DCB (sodium ditionithe-sodium citrate-sodium bicarbonate) method (Taylor & Crowder, 1983) was used for iron plaque extraction. Untreated and DCB-washed roots were digested in concentrated HNO_3 and the concentrations of Fe, Mn, and Zn determined by atomic absorption spectrophotometry. Metal concentrations in iron plaques were estimated as the difference between untreated and DCB-washed roots concentrations (Koch & Mendelssohn, 1989). One-way ANOVA was used to compare results of untreated and DCB-washed roots concentrations. Fe and Mn concentrations were log-transformed prior to the statistical analysis to satisfy parametric assumptions.

Metal accumulation by fine roots

Metal concentrations accumulated by fine roots of *R. mangle* are presented in Figure 1. Significant differences were found between untreated and DCB-washed roots mean concentrations for Fe (13,340 vs. 967 µg g^{-1}; $p < 0.001$), Mn (556 vs. 53 µg g^{-1}; $p < 0.001$), and Zn (138 vs. 79 µg g^{-1}; $p < 0.05$), with much higher concentrations of all metals in untreated roots. An estimation of iron plaque concentrations of Fe, Mn, and Zn gave values of the order of 12,370, 500, and 59 µg g^{-1}, respectively. Thus, iron plaques contribute about 92%, 90%, and 42% of the total concentrations of Fe, Mn, and Zn found in fine, roots of mangrove trees.

Although conventional studies on metal uptake and storage within mangrove vegetation (Silva *et al*., 1990; Zheng *et al.*, 1997) did not evaluate the contribution of iron plaques to quantify metal accumulation by roots, this may be necessary to an accurate estimation of metal concentrations within mangrove roots biomass and derived data, such as root concentration factors in relation to the substrate, and the metal translocation factors between below ground and above ground organs.

Iron plaques occurring in *R. mangle* fine, , nutritive roots in the study site can contribute to moderate the uptake of essential, but potentially toxic metals such as Fe, Mn, and Zn by *R. mangle* trees, by retaining them under insoluble forms outside root tissues. Lacerda *et al.* (1993) showed that total Fe and Zn concentrations in sediments colonized by *R. mangle* in the same site studied here were about 36,000 µg g^{-1}, and 190 µg g^{-1}, respectively. A comparison between the sediment metal content and those in the iron-plaques indicates that the oxidizing activity of *R. mangle* fine roots may concentrate on its surface a considerable amount of the metals stored within the surrounding sediments. This ability may be a key adaptive strategy of mangrove plants to colonize metal-rich sediments, in particular at polluted sites. Moreover, root-induced formation of oxy-hydroxides may retain metals within the sediment through strong bounds and decrease metal uptake by plants and transfer via detritus of above-ground plant tissues. This mechanism has an enormous potential to minimize and control metal pollution in tropical and sub-tropical coasts, particularly in developing countries where the availability of financial resources for conventional pollution treatment and control, by expensive technological processes, may prove to be unsustainable.

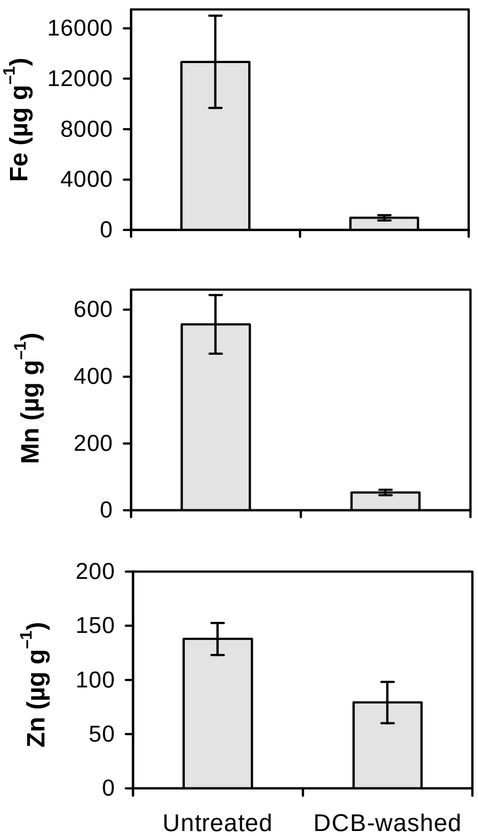

Figure 1. Metal concentrations in untreated and DCB-washed fine roots of *R. mangle*. Columns indicate means (± one standard error) of five replicates.

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