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Bioavailable concentrations of germanium and rare earth elements in soil as affected by low molecular weight organic acids and root exudates

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Availability of elements in soil to plant is generally dependent on the solubility and mobility of elements in soil solution which is controlled by soil, elemental properties and plant-soil interactions. Low molecular organic acids or other root exudates may increase mobility and availability of certain elements for plants as an effect of lowering pH in the rhizosphere and complexation. However, these processes take place in a larger volume in soil, therefore to understand their nature, it is also important to know in which layers of the soil what factors modify these processes. In this work the influence of citric acid and root exudates of white lupin (*Lupinus albus* L.) on bioavailable concentrations of germanium, lanthan, neodymium, gadolinium and erbium in soil solution and uptake in root and shoot of rape (*Brassica napus* L.), comfrey (*Symphytum officinale* L.), common millet (*Panicum milliaceum* L.) and oat (*Avena sativa* L.) was investigated. Two different pot experiments were conducted: (1) the mentioned plant species were treated with nutrient solutions containing various amount of citric acid; (2) white lupin was cultivated in mixed culture (0 % lupin, 33 % lupin) with oat (*Avena sativa* L.) and soil solution was obtained by plastic suction cups placed at various depths. As a result, addition of citric acid significantly increased germanium concentrations in plant tissue of comfrey and rape and increased translocation of germanium, lanthan, neodymium, gadolinium and erbium from root to shoot. The cultivation of white lupin in mixed culture with oat led to significantly higher concentrations of germanium and increasing concentrations of lanthan, neodymium, gadolinium and erbium in soil solution and aboveground plant tissue. In these pots concentrations of citric acid in soil solution were significantly higher than in the control.

The results show, that low molecular organic acids exuded by plant roots are of great importance for the mobilization of germanium, lanthan, neodymium, gadolinium and erbium in the rhizosphere and therefore the enhancement of bioavailability of the mentioned elements to plants. Based on the suction cup experiment we conclude that in vertical soil profile the bioavailable germanium is heavily affected by the activity of exudates, as the complexation processes of germanium take place at the root zone and below affected by the interplay of the infiltration of citric acid solutions and the actually produced exudates.

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