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Impact of plant species, substrate types and porosity on the fractionation of rare-earth elements in plants

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The distribution and content of rare-earth elements (REEs) were determined in two radish species (Raphanus sativus and Raphanus raphanistrum) that were grown under laboratory-controlled conditions, in three substrates consisting in illite for one and in smectite for the two others, the two latter being of the same type but with different porosities. The plants were split into two segments: the leaves and the stems+roots. The results indicate that both species pick up systematically higher amounts of REEs when grown in the illite substrate, considering that the smectite contains about 3 times more REEs.

In R. sativus, the REE concentration of the leaves and of the stems+roots, whatever the substrate, ranges from 1.4 to 1.9 [U+F06D]g/g. After normalization to the substrate in which they grew, the distribution patterns for the leaves of those from illite substrate are nearly flat, but irregular with a positive Eu anomaly. Those for the stems+roots are similar, but enriched in heavy REEs, also with a positive Eu anomaly. The REE concentrations of the leaves and the stems+roots of R. sativus grown in smectite are analytically similar at 1.6 and 1.4 [U+F06D]g/g, respectively. The REE distribution patterns for the two organs, normalized again to those of the substrate, are very similar, flat with a distinct Eu anomaly. The heavy REE of the stems+roots of R. sativus grown on illite are enriched relative to those of the leaves, and a distinct positive Eu anomaly is observed in both the leaves and stems+roots from species grown on both illite and smectite.

In the case of R. raphanistrum, the REE concentrations of the leaves and the stems+roots for those grown in the illite substrate were found to be significantly different at 11.0 and 6.6 [U+F06D]g/g, respectively. The REE distribution patterns for the two different plant organs normalized to those of the substrates were found to be quite similar, all being quite flat, with a more or less pronounced Ce negative anomaly, and a prominent positive Gd anomaly. When grown on smectite, the REE concentrations of the leaves and the stems+roots were about 7.2 and 6.3 [U+F06D]g/g, respectively. The REE distribution patterns for the leaves and the stems+roots normalized to the corresponding smectite substrate are very closely similar, each having a nearly flat pattern with a slight but not significant negative Ce anomaly and a similar positive Gd anomaly. When grown on the smectite substrate with a different porosity, the leaves and the stems+roots had significantly higher REE concentrations of 9.3 and 19.7 [U+F06D]g/g, respectively. Relative to the substrate REE pattern, the two organs had nearly identical flat REE distribution patterns, with a slight negative Ce anomaly and positive Gd and Er anomalies,

In summary, the REE take up is more plant species dependent than mineral composition dependent: R. raphanistrum takes up 3.5 to 6.7 times more REEs than R. sativus, depending on the substrate, its porosity and the considered plant segments. Increased substrate porosity favors the pick up of the REEs, but no particular uptake is observed in leaves relative to that in the combined stems and roots. The transfer of the REEs from minerals to plant organs does not appear to induce systematically identical patterns. The effect of the plant species in the elemental uptake suggests that the root exudates are different, with a varied control on the micro-organism activity in the rhizosphere and probably different microbial compounds. New questionings about the identification of the organic compounds that influence and control the process of elemental exchanges activated by the root exudates in the soils within the rhizosphere, are also raised.