

Rare Earth Elements in the Soil-Plant Continuum: Pathways and Bioavailability

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Rare earth elements (REEs) are increasingly recognized as emerging contaminants because of their rising dispersion within ecosystems, driven by enhanced industrial extraction, agricultural applications, and natural geochemical processes.

The mobility and bioavailability of REEs in the soil-plant continuum are regulated by complex interactions involving soil chemistry, organic amendments, and competitive interactions with other elements [1]. In the rhizosphere, root exudates and microbial activity play a pivotal role in modulating the availability and uptake of REEs by plants. Moreover, REE speciation, primarily influenced by soil pH, cation exchange capacity, and organic matter content, determines the extent of REE uptake by plant roots and their subsequent translocation to other plant organs.

Once absorbed, REEs follow distinct translocation pathways within plant tissues, often exhibiting fractionation patterns, with light REEs (LREEs) and heavy REEs (HREEs) partitioning differently in roots, stems, and leaves. This intra-plant fractionation is governed by the chemical and physical properties of the REEs, including their affinity for cell wall pectins and cell membrane transporters, as well as their binding to organic acids in the vascular ap, which facilitates their mobility [2].

In plant physiology, REEs exhibit a biphasic effect known as hormesis. At low concentrations, they can enhance processes such as mineral nutrition, photosynthesis, and stress response; however higher concentrations induce toxicity, oxidative stress, and disruption of calcium-mediated signalling. These contrasting effects can significantly impact plant growth and development, underscoring the importance of establishing critical concentration thresholds of REEs in plants.

A comprehensive understanding of the mechanisms underlying REE mobility, bioavailability, and accumulation in plants is essential for evaluating the potential environmental risks associated with their presence. Such insights are critical for assessing risks to soil health, promoting sustainable land management, and safeguarding human food supply.

[1] Ribeiro, P.G., De Oliveira, C., Guerra, M.B.B., De Carvalho, T.S., Martins, G.C., et al. (2024), *Pollut. Rep.*, 10, 443–458.

[2] Yuan, M., Liu, C., Liu, W.-S., Guo, M.-N., Morel, J.L., et al. (2018), *J. Phytoremediation*, 20, 415–423.

