Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.34288

Nd Isotopes and REE Systematics Constrain Direct Foliar Uptake of Atmospheric Dust in Terrestrial Plants

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Atmospheric mineral dust is a major vector of bioessential elements, but its direct assimilation by terrestrial vegetation has not been quantitatively demonstrated. Here, we use Rare Earth Element (REE) systematics and Nd isotope tracers to demonstrate and quantify direct foliar acquisition of dust-derived nutrients in terrestrial plants.

We applied controlled laboratory experiments and replicated Mediterranean field manipulations simulating natural dust deposition. Foliar dust application significantly increased plant macro- and micronutrient concentrations. REE patterns, particularly LREE/HREE ratios, reveal systematic fractionation consistent with preferential incorporation of light REE into plant biochemical pathways (Fig. 1). These geochemical fingerprints, together with εNd isotope signatures, provide unambiguous source attribution of foliar-derived elements.

Using Nd isotopic binary mass-balance calculations, we show that—depending on dust composition—plants can derive up to ~80% of specific elemental components of their ionome directly from foliar dust uptake. Dissolution experiments further indicate that the mildly acidic, organic-acid-rich leaf surface microenvironment enhances mineral dissolution, enabling rapid nutrient release and assimilation directly on the foliage.

These findings identify foliar dust uptake as a major and previously under-quantified pathway in terrestrial nutrient cycling. Incorporating this mechanism into biogeochemical and ecosystem models is critical, particularly under future climate scenarios expected to alter dust fluxes and atmospheric transport patterns.

