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From rock-eating to vegetarian ecosystems — plant phosphorus acquisition strategies along a Chilean precipitation gradient

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Besides nitrogen, phosphorus (P) is the major limiting nutrient of terrestrial primary productivity, with major P stocks being bound in soils. Stocks, speciation, and bioavailability of soil P differ among ecosystem types and with rock weathering status, which are both driven by climatic conditions. Microorganisms and plants have developed a range of strategies to mobilize P from organic and inorganic sources, e.g. expression of extracellular phosphatases and excretion of low-molecular-weight organic acids (LMWOA). However, the impact of precipitation, vegetation type, and soil P speciation on plant P acquisition strategies is not well understood, yet.

A semi-desert-to-humid-temperate-rainforest ecosystem sequence was investigated. Soil samples were taken from three sampling sites, all developed on granodiorite, comprising a precipitation gradient (66 mm a^{-1} to 1469 mm a^{-1}) along the Chilean Coastal Cordillera. Small-scale gradients (mm) from single roots to bulk soil in three depths were sampled to examine changes in P speciation, enabling the identification of local P depletion by plant roots and differences in P-speciation between rhizosphere and non-rhizosphere soil. Phosphorus speciation was examined by X-ray absorption near edge structure analysis. LMWOA as biotic weathering agents, and acid phosphatase kinetics as proxy for organic P recycling, were quantified. The aim was to disentangle the impact and functions of roots and associated microorganisms on driving agents of P-cycling.

Rhizosphere P speciation in soil changed considerably along the precipitation gradient from mainly primary P minerals in the semi-desert ecosystem to a dominance of organic P species in the humid-temperate rainforest. Contents of organically bound P were higher in root proximity compared to bulk soil in the humid-temperate rainforest soils (320 mg kg^{-1} and 70 mg kg^{-1}, respectively) and in the topsoil of the Mediterranean woodland ecosystem (134 mg kg^{-1} and 62 mg kg^{-1}, respectively). In contrast, the rhizosphere soil was depleted in sesquioxide-adsorbed P in comparison to root-free bulk soil.

The content of LMWOA was correlated with inorganic P in soils of the semi-desert ecosystem, indicating intensive LMWOA exudation for biogenic P weathering of primary and secondary minerals. Under temperate rainforest LMWOA content, phosphatase activity, and microbial biomass carbon exhibited a negative correlation with secondary inorganic P forms but were positively linked to organic P species. We therefore conclude that P nutrition in this ecosystem relies less on weathering of P bearing minerals by LMWOA but is mainly based on organic P sources.

In terms of process understanding, these findings clearly show that LMWOA fundamentally change their role in the rhizosphere depending on the nutrient acquisition strategy of the respective ecosystem, which is affected by mean annual precipitation. While LMWOA facilitate biogenic weathering of P bearing minerals in the semi-desert, they mainly contribute to P recycling in the humid-temperate rainforest by preventing its precipitation and sorption. We conclude that P acquisition and cycling depends on the nutritional constrains of the given ecosystem: from biological weathering of inorganic P forms in the semi-desert driven by LMWOA and plant uptake to intensive P recycling from organic forms in the humid-temperate rainforest.