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Effect of different spatial P distributions on soil microbial P uptake, microbial community structure and plant nutrition

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Phosphorus (P) is an essential nutrient for plant growth, yet little is known about the spatial distribution of P in forest soils. Even more, no information is available concerning the effects of a homogenous vs. heterogeneous (i.e. a patchy) soil P distribution on root traits for plant P nutrition, microbial P acquisition and microbial community structure in the rhizosphere. Thus, two rhizotron experiments were conducted on a P-deficient forest soil to investigate competitive P uptake strategies of microbes and Fagus sylvatica [L.] roots depending on (i) spatial heterogeneity patterns (homogenous vs. patchy) of P distribution and (ii) P source and availability (Fe33PO4 vs. 33P-labelled microbial necromass).
F. sylvatica-bearing rhizoboxes were labelled either with Fe33PO4, a P source, which is difficult to mobilize yet native in that soil, or with 33P-labelled microbial necromass, which was rarely considered as primary P contributor to forest P nutrition, yet. Homogenous and heterogenous P patterns were created in both experiments, to study the effects of spatial P heterogeneity on plant-root and microbial P acquisition. P mobilization by microorganisms was tracked by an improved 33P-PLFA method, linking 33P incorporation in microbes with changes in microbial community structure in soils in situ.
The microbial P uptake was enhanced in rhizotrons with a P distribution pattern of high patchiness. Characteristic PLFAs indicated a massing of ectomycorrhizal fungi associated with beech-roots in P-rich patches of the Fe33PO4-experiment. These ectomycorrhizal fungi likely increased P mobilization from the hardly available Fe33PO4 in high P habitats. In contrast, habitats with low Fe33PO4 contents require a more complex microbial community structure without a dominant group to mobilize this hardly accessible P species. Therefore, hotspots with high concentrations of Fe33PO4 are likely to promote the efforts of fungal hyphae for P mobilization – an effect that decreases with lower Fe33PO4 content. Additionally, gram positive and gram negative bacteria exhibited a vastly higher P uptake from Fe33PO4 under increasingly patched P distributions. Yet, they form a smaller portion of the microbial community than in a homogenously P enriched rhizotron, suggesting filamentous organisms to benefit from the patchy Fe33PO4 distribution. Thus, only a heterogenous P distribution promotes P acquisition of forest microbial communities from low-bioavailable mineral P sources.
To relate the changes in distribution of plant P uptake from microbial necromass to the spatial distribution of enzymatic P acquisition we combined autoradiography with zymography. In combination, these two approaches opened the door to disentangle the dimensions of P nutrition within the rhizosphere in time and space. Beech and microbial nutrition with increasing patchiness of labelled microbial necromass were reflected by 33P and 15N uptake into the plant and microbial biomass.
These first advances into the previously unknown territory of spatial P distribution in forest soils will help to understand the mechanisms of microbial P cycling in soils.