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Chemical Imaging of Plant-Soil-Microbe Systems: Examples from SSRL

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The Structural Molecular Biology resource at SSRL develops, operates, and supports three dedicated XRF imaging beamlines that cover a range of spatial scales (μm to cm) and elements of biological importance. These beamlines can perform μ-XAS to characterize the oxidation state, or chemical species, at a single point within a sample. Chemical imaging using synchrotron XRF imaging lends itself to rhizosphere and phyllosphere research due to the ability to track transformations of key nutrients (P, S, K, Fe) and/or toxic heavy metals (As, Hg) in a complex and heterogenous sample.

Potassium is a critical nutrient for plants and microbes, playing important roles in osmoregulation, enzyme activation and mitigates the effect of drought. However, K is limited in most environments, even when K is supplied by fertilizer. In collaboration with SSRL, researchers from EMSL are using synthetic soil habitats (SSH) to visualize the organic and inorganic processes controlling fungal sourcing, transport, and transformation of K during C-limitation, including: (i) XRF imaging of fungal hyphae on SSH in the presence and absence of an inorganic K source to determine forms of bioavailable K and (ii) XAS and theoretical calculations to determine the K bonding environment in organic K compounds. Data indicate the importance of fungal exuded tartaric and citric acids, which are likely responsible for sensing K rich minerals and uptake/storage of K by fungi, respectively. Secondary clay mineral formation on the SSH provides insight into fungal mineral degradation over environmentally relevant scales. We applied potassium XRF imaging to an agriculturally relevant field example to observe changes in the spatial distribution of non- vs. readily bioavailable K within rice paddy soil treatments. Under anoxic, flooded conditions, there was a greater abundance of readily bioavailable K compared to non-flooded conditions. These differences may be a result of differing microbial processes under each condition.

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