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Investigating the Molecular Mechanisms Controlling Biotic Weathering of Minerals by Fungi using TerraForms

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Potassium (K) is a critical nutrient for plants and plays a role in mitigating the effect of drought in several plant and microbial species. However, many environments are K limited because up to 98% of soil K is structurally bound in minerals, which is considered non-bioavailable. A sustainable pathway for increasing K bioavailability without the need for fertilizer is potassium-solubilizing microbes (KSM). However, there is a lack of understanding of the molecular processes governing K translocation from mineral to microbes and plants. Synchrotron based X-ray Absorption Spectroscopy (XAS) and X-ray Fluorescence Imaging (XRF) provide information on elemental speciation and complexation in heterogeneous samples. The Stanford Synchrotron Radiation Lightsource (SSRL) has several XAS and XRF beamlines that can accommodate a variety of samples and measure speciation from the micron to bulk spatial scales, permitting the characterization of elemental species within a spatial context, allowing the interrogation of molecular evolution across complex samples. Potassium XAS of biological and inorganic compounds are feature-rich within 15 eV of the absorption edge, meaning that chemical imaging of different forms of K is possible with a combination of μ-XRF imaging and XAS.

In this research, we used a combination of synthetic soil habitats (TerraForms), mass spectrometry imaging (MSI) and computational approaches at EMSL, with synchrotron μ-XRF imaging and XAS at SSRL to probe the molecular mechanisms controlling K uptake, storage and transport by the saprotrophic fungus *Fusarium sp. DS 682* and *Brachypodium distachyon* from a mineral source. K-rich minerals were embedded in the TerraForms, and conditions focused on carbon limitation. MSI of the TerraForms surface following 30 days of fungal growth indicated that *Fusarium sp. DS 682* spatially controls the exudation of specific organic acids. As a result of fungal exuded organic acid interaction with the K-rich minerals embedded in the TerraForm, a secondary clay mineral formed as ~10 μm mineral coatings. Importantly, K within clay interlayers in considered a readily bioavailable form of K, increasing the abundance of K that can be exchanged into solution K, which is accessible to plants. This multi-modal, multi-institutional approach lays the groundwork for K bioimaging in complex soil-microbe-plant systems.