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Micro- to Nano-scale Soil and Rhizosphere Processes Analyzed Using Multiple Beamlines at the Sirius Synchrotron

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Determining mechanisms that regulate plant-nutrient behavior in agricultural soils is often confounded by interactions between physical, chemical, and biological processes within these multicomponent, heterogeneous, and hierarchical systems. This presentation will focus on strategies and examples of addressing these complexities by using complementary techniques at multiple Sirius beamlines. For example, we hypothesize that diffusion and reaction of fertilizer phosphate inside soil microaggregates contributes to slowly reversible phosphate binding ("fixation"), which diminishes plant availability of this macronutrient. Micro and nanoscale imaging results from three beamlines were used to evaluate the 3D internal physical structure of soil microaggregates (CATERETÊ coherent diffraction imaging beamline), 3D spatial distributions of soil-matrix elements (CARNAÚBA coherent X-ray nanoprobe beamline), and the presence of biological components (IMBUIA infrared microprobe beamline). Results revealed accumulations of physical structures of high electron density that at least partially coincide with hotspots of iron and other metals, as well as structures of low electron density that are possibly of biological origin. We will also illustrate how a combination of chemical imaging around a living wheat root at CARNAÚBA and root-structural imaging at the MOGNO X-ray computed tomography beamline reveal root-induced chemical changes in the rhizosphere over time. Initial results show highly reproducible spatial structures of soil matrix elements in the rhizosphere over time and well-defined imaging of roots and root hairs. Integrating multimodal analyses from beamlines with unique capabilities to probe different aspects of a soil matrix is essential for determining how coupled processes affect agricultural nutrient behavior in such complex systems.

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