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Non-invasive analysis of root-soil interaction using three complementary imaging approaches

Sabina Haber-Pohlmeier (1), Christian Tötzke (2), Andreas Pohlmeier (3), Nicole Rudolph-Mohr (2), Nikolay Kardjilov (4), Eberhard Lehmann (5), and Sascha E. Oswald (2)

(1) RTWH Aachen, Aachen, Germany, (2) University of Potsdam, Institute of Earth and Environmental Science, Potsdam, Germany, (3) Forschungszentrum Jülich, Jülich, Germany, (4) Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany, (5) Paul Scherrer Institute, Villigen, Switzerland

Plant roots are known to modify physical, chemical and biological properties of the rhizosphere, thereby, altering conditions for water and nutrient uptake. We aim for capturing the dynamic processes occurring at the soil-root interface in situ. A combination of neutron (NI), magnetic resonance (MRI) and micro-focus X-ray tomography (CT) is applied to monitor the rhizosphere of young plants grown in sandy soil in cylindrical containers (diameter 3 cm). A novel transportable low field MRI system is operated directly at the neutron facility allowing for combined measurements of the very same sample capturing the same hydro-physiological state.

The combination of NI, MRI and CT provides three-dimensional access to the root system in respect to structure and hydraulics of the rhizosphere and the transport of dissolved marker substances. The high spatial resolution of neutron imaging and its sensitivity for water can be exploited for the 3D analysis of the root morphology and detailed mapping of three-dimensional water content at the root soil interface and the surrounding soil. MRI has the potential to yield complementary information about the mobility of water, which can be bound in small pores or in the polymeric network of root exudates (mucilage layer). We inject combined tracers (GdDPTA or D2O) to study water fluxes through soil, rhizosphere and roots. Additional CT measurements reveal mechanical impacts of roots on the local microstructure of soil, e.g. showing soil compaction or the formation of cracks. We co-register the NT, MRI and CT data to integrate the complementary information into an aligned 3D data set. This allows, e.g., for co-localization of compacted soil regions or cracks with the specific local soil hydraulics, which is needed to distinguish the contribution of root exudation from mechanical impacts when interpreting altered hydraulic properties of the rhizosphere. Differences between rhizosphere and bulk soil can be detected and interpreted in terms of root growth, root exudation, and root water uptake. Thus, we demonstrate that such a multi-imaging approach can be used as powerful tool contributing to a more comprehensive picture of the rhizosphere.