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Imaging water flow in soils and roots

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Plants need continuous and adequate supply of water from soils. How do plant roots can sustain the water demand set by transpiration, in particular when water becomes limited and heterogeneously distributed? This is a central question in hydrology and agriculture, in particular in times of climate change, when precipitation is expected to become more irregular and rare.

Our understanding of plant-soil water relations suffers from the lack of experimental methods to directly measure root water uptake in-situ. Nowadays, advances in imaging techniques such as X-ray CT, NMR, and neutron radiography and tomography offer new possibilities to image root and water distribution in soils. In particular, neutron radiography of water distribution near roots of transpiring plants revealed an unexpected behavior of the soil near roots, the so called rhizosphere (Carminati et al., 2010). In contrast to the existing theory, rhizosphere was wetter than the adjacent bulk soil during drying. Interestingly, after irrigation the rhizosphere remained markedly dry. The consequence of such unexpected properties of the rhizosphere are not known and need complementary experiments. In particular, a method to measure the fluxes of water from soil to roots is needed.

Here we present a new method to directly image water flow across the root-soil interface and along roots. We used neutron radiography to trace the transport of heavy water (D_2O) from soil to roots of transpiring plants. The flow rate of D_2O into the roots was modeled with a diffusion-convection equation. Comparison between model and observations gave: 1) the permeability of roots and 2) the local root water uptake. The model was validated by independent measurements of flow along roots.

With this new method we measured for the first time the water flow across the soil-root interface. Our results were based on two-dimensional images, from which we extrapolated the profile of D_2O across the roots. The estimations, as well as the validation of the model, would be much more accurate if three-dimensional images of D_2O transport into roots were available. The half time of D_2O flow into roots was in the order of 2-3 minutes. Our next objective/wish is to monitor D_2O transport in soil and roots at high resolution in three-dimensions by means of neutron tomography. Such results will bring new insights on how water enters the roots.

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