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Water fluxes in root-soil-systems investigated by Magnetic resonance imaging

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Water flux through soils is one of the most important control function with respect to the water supply for root and plant growth. The understanding of these processes bases generally on the interplay between experimental investigations and the development of theory and numerical models. In recent time detailed 3D models have been developed, but experimental information is mainly available from two-dimensional rhizotrons or only with coarse resolution from water content measurements by means of TDR probes and tensiometers. An emerging powerful tool for high resolution, non-invasive imaging of water content and fluxes in soils in saturated and unsaturated state is Nuclear Magnetic Resonance Imaging (MRI)[1,2]. With respect to water fluxes the slow flow velocities do not allow the direct monitoring by MRI flow imaging so indirect methods like transport of contrast agents should be applied. Therefore we have chosen Gd-DTPA [3], a negatively charged paramagnetic Gd-complex, as tracer for the investigation of water fluxes during i) infiltration and ii) injection experiments of unsaturated model soil with maize and lupin plants. The contrast of the NMR measurements was optimised using high resolution T1 weighted spin echo sequences.
With respect to the infiltration experiment we observed that during rapid infiltration from the bottom the plume moved homogeneously into the bulk soil, but leaves out the immediate surrounding of the maize roots. After this initial period a continuously increasing enrichment of tracer in this region is monitored, but no uptake by the plant within one hour. Continuing these studies injection experiments have been performed where the tracer was placed in a small volume in the direct vicinity of the roots, and the entire water content changed only minimal even under quite dry conditions. For a well developed lupin root system we observed diffusive spreading followed by a very slow transporte of the plume to the root system over a period of two days. The important difference to the short term experiment is the observation of tracer uptake followed by an upward transport in the inner root tissues. This could also be proved by a following chemical analysis showing decreasing Gd content from the roots over the shoot to the leaves. In parallel a high resolution 3d image of the root system architecture was performed, in order to compare the experimentally observed motion of the plume with detailed 3D model calculations of water uptake and tracer transport.

References:
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