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Root water uptake and root permeability measured by heavy water injection and neutron radiography

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Water uptake by plants is a major component of soil water balance. Physical properties of the root-soil interface and the hydraulic conductivity of roots are known to be important parameters controlling the water uptake rate. Despite the importance of these components, there is only a limited number of studies reporting their direct measurement. The lack of experimental data is largely due to technical problem of measuring water fluxes across soil and roots in-situ.
Objective of this study was to develop a method to map locations and temporal -dynamics of root water uptake of living plants. We combined neutron radiography with the tracer Deuterium Oxide (D_2O). D_2O has similar physical and chemical properties to normal water (H_2O) but it has a much lower neutron attenuation coefficient compared to normal water, which makes it well visible in neutron radiography.
We grew lupins in 30 x 15 x 1 cm containers filled with sandy soil. 16 days after planting, we locally injected D_2O in the soil next to various parts of the root system. We used time-series neutron radiography to image the D_2O redistribution after injection. D_2O injection at same locations during day and night was carried out for separating diffusion of D_2O in H_2O and convection processes due to net mass flow. The results showed that some minutes after D_2O injection, neutron attenuation inside the roots decreased due to D_2O entering the roots. The signal was used to estimate the diffusional permeability of roots as well as the net root water uptake. Afterwards, we observed that convective D_2O flow along the root till the plant shoot. No convective flow of D_2O was visible during the night measurement. We also observed that water uptake rate varied among roots: lower D_2O uptake by the tap root, and higher uptake by lateral roots. We conclude that neutron radiography combined with D_2O injection is a promising technique to investigate root permeability and water fluxes in soil and plants.