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Quantitative measurements of root water uptake and root hydraulic conductivities

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How is root water uptake distributed along the root system and what root properties control this distribution? Here we present a method to: 1) measure root water uptake and 2) inversely estimate the root hydraulic conductivities. The experimental method consists in using neutron radiography to trace deuterated water (D2O) in soil and roots. The method was applied to lupines grown aluminium containers filled with a sandy soil. When the lupines were 4 weeks old, D2O was locally injected in a selected soil regions and its transport was monitored in soil and roots using time-series neutron radiography. By image processing, we quantified the concentration of D2O in soil and roots. We simulated the transport of D2O into roots using a diffusion-convection numerical model. The diffusivity of the roots tissue was inversely estimated by simulating the transport of D2O into the roots during night. The convective fluxes (i.e. root water uptake) were inversely estimating by fitting the experiments during day, when plants were transpiring, and assuming that root diffusivity did not change. The results showed that root water uptake was not uniform along the roots. Water uptake was higher at the proximal parts of the lateral roots and it decreased by a factor of 10 towards the distal parts.

We used the data of water fluxes to inversely estimate the profile of hydraulic conductivities along the roots of transpiring plants growing in soil. The water fluxes in the lupine roots were simulated using the Hydraulic Tree Model by Doussan et al. (1998). The fitting parameters to be adjusted were the radial and axial hydraulic conductivities of the roots. The results showed that by using the root architectural model of Doussan et al. (1998) and detailed information of water fluxes into different root segments we could estimate the profile of hydraulic conductivities along the roots. We also found that: 1) in a tap-rooted plant like lupine water is mostly taken up by lateral roots; (2) water uptake by laterals decreased towards the root tips due to a dissipation of water potential along the root and it had a maximum at a distance of 10 cm from the root tip; (3) water uptake by the taproot was higher in the distal segments and was negligible in the proximal parts, which had a low radial conductivity.

The method introduced here enabled us to reconstruct the water fluxes and the profile of hydraulic conductivities of a root system. This method can help to better understand root development and function in response to varying soil conditions. The method can also be used to calibrate and test existing models of root water uptake.