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Quantitative imaging of root water uptake in soils: approaching the cellular scale

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The pathways of water flow across the root tissue and the relative importance of the apoplastic and cell-to-cell pathways are still matter of debate, because of technical challenges in measuring water flux at the cell-scale. A method is proposed to quantify the local flow of water across the root tissue of plants growing in soil. The technique consists of (i) using an ultra-fast neutron tomography to monitor the transport of deuterated water (D_2O used as a tracer of normal water) in soil and roots, (ii) and quantifying the monitored transport of D_2O by inversely solving a diffusion-convection equation across the root tissue. The model includes root geometry and local distribution of hydraulic properties of both the cell membranes and the apoplast at the cellular scale. The results showed that in a 12 days-old lupin growing in soil, the radial flux [m s^{-1}] of water through the apoplastic pathway was 17 times greater than through the cell-to-cell pathway. Despite its little volumetric fraction, the overall contribution of the apoplast in water flow [m^3 s^{-1}] across the cortex was 53% of the total water flow. The main resistance of the water flow across the root tissue was at the endodermis, where the apoplast was blocked. The techniques proposed here allow for in-situ quantification of the water fluxes across the root tissue of plants growing in soils.

Keywords: Apoplastic and cell-to-cell pathway, Composite transport model, Diffusional permeability of roots, Hydraulic permeability of root, Root water uptake, Neutron imaging, Neutron tomography.