Root water uptake and its pathways across the root: quantification at the cellular scale

Mohsen Zarebanadkouki*[1], Pavel Trtik[2], Faisal Hayat[1], Andrea Carminati[1], Anders Kaestner[2]

[1] Chair of Soil Physics, University of Bayreuth, Germany

[2] Laboratory for Neutron Scattering and Imaging, Paul Scherrer Institute, Villigen, Switzerland

Email: Mohsen.zarebanadkouki@uni-bayreuth.de

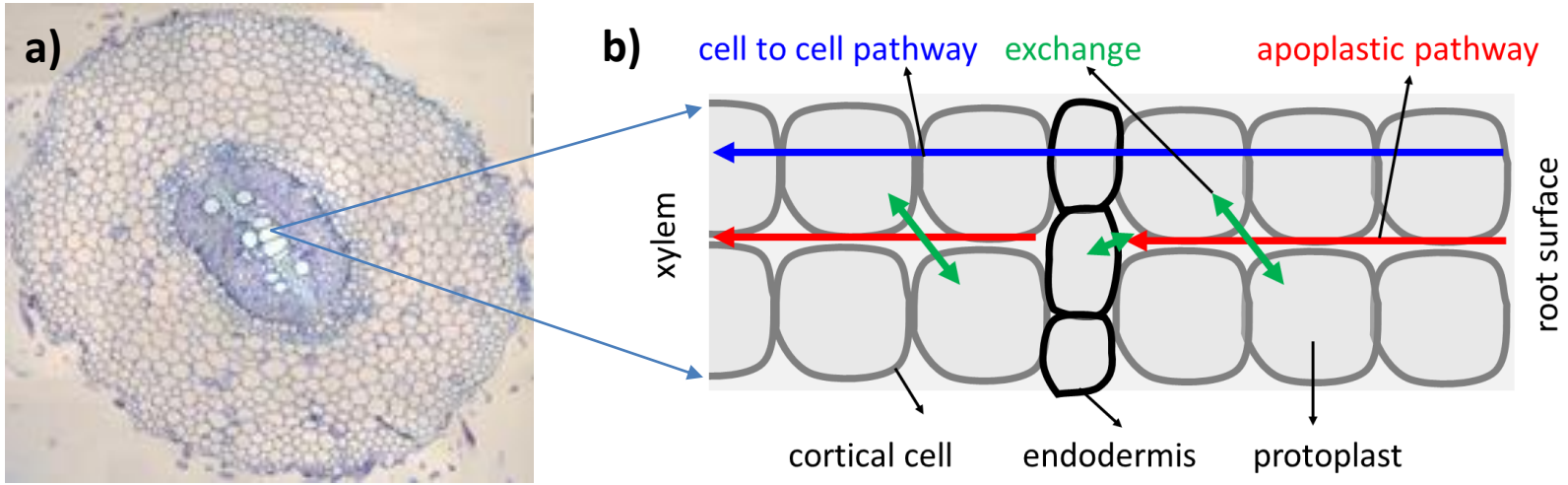
UNIVERSITÄT BAYREUTH

PAUL SCHERRER INSTITUT PSI

Motivation

Question: Where does water move across the root tissue (apoplastic or cell-to-cell pathways)?

Challenge: The answerer requires *in situ* measurement of water flux at the cellular scale.

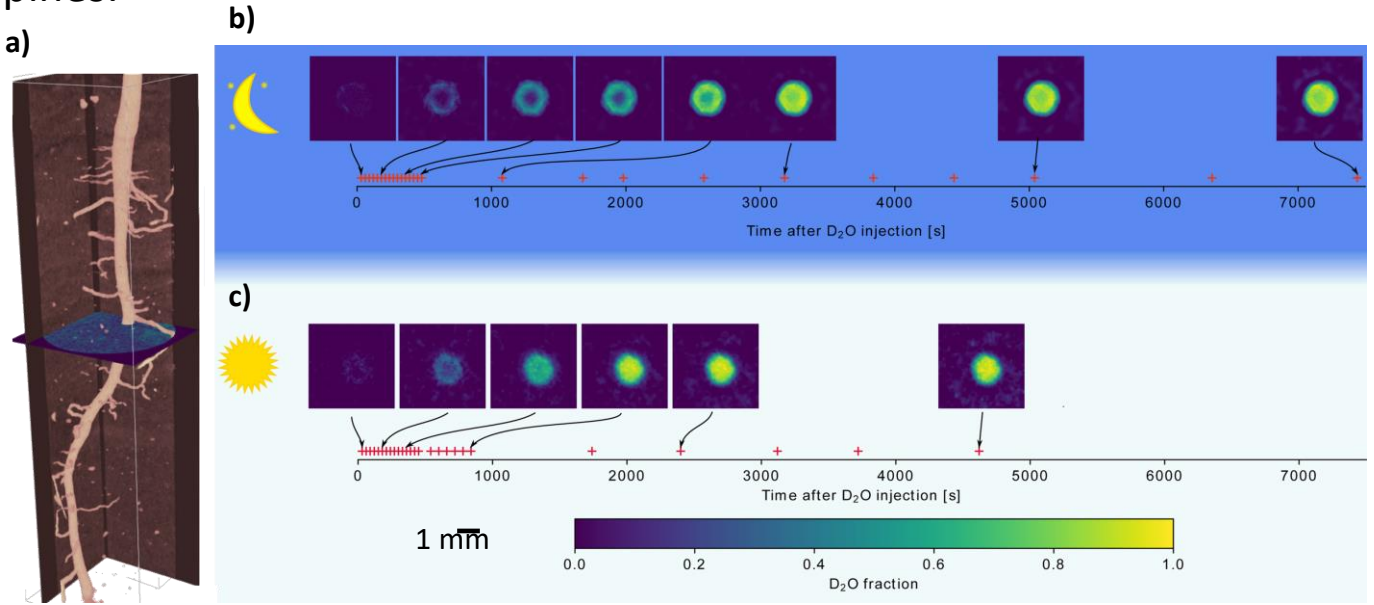


Objective: To develop a method enabling us to measure water fluxes at cellular scale.

Materials and Methods

1) We combined rapid neutron tomography (a resolution of 45 µm and 30 s) with injection of deuterated water (D_2O) in soil to visualize the transport of water across the root tissue.

Plant: 12 days old lupines.



Reconstructed tomograms showing:

a) 3D root system of lupine, b) D_2O transport during night, c) during day.

Materials and Methods

2) A cell-scaled diffusion-convection equation was used to inversely simulate D_2O transport.

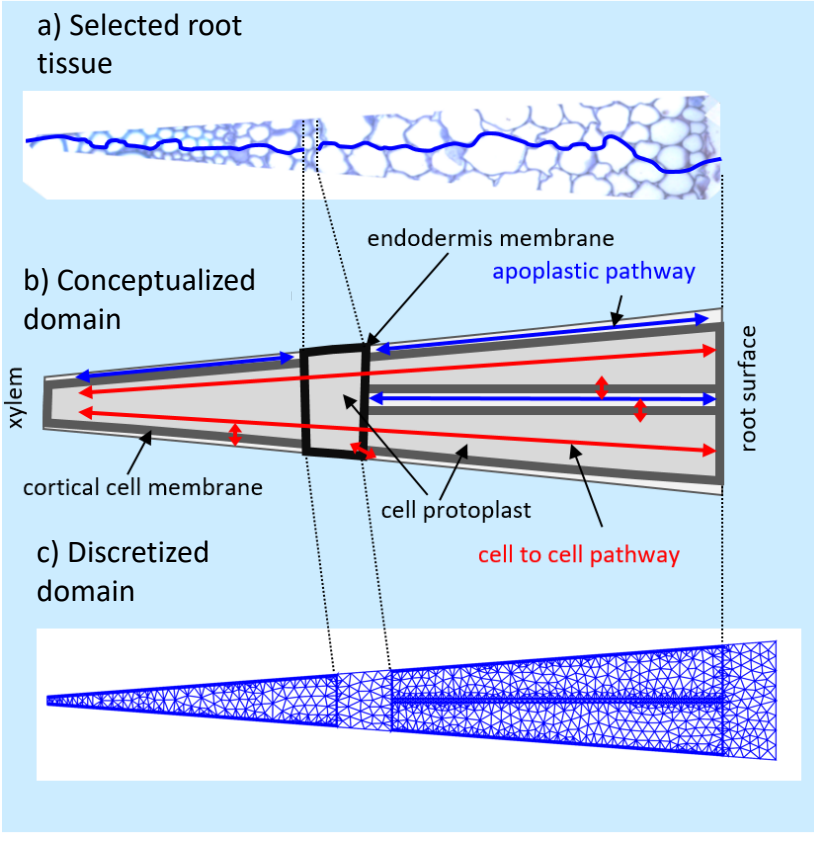
$$\theta \frac{\partial C}{\partial t} = \nabla(D\Delta C) - \nabla(qc)$$

For simulation we conceptualized the complex structure of the root tissue as shown here. Then the flow domain and cellular scale hydraulic information were combined to build a finite element model.

a) The fraction of the root tissue used to set-up pathways across root tissue.

b) Schematic of the flow domain across the root tissue

c) Discretization of the flow domain into 2000 finite elements.

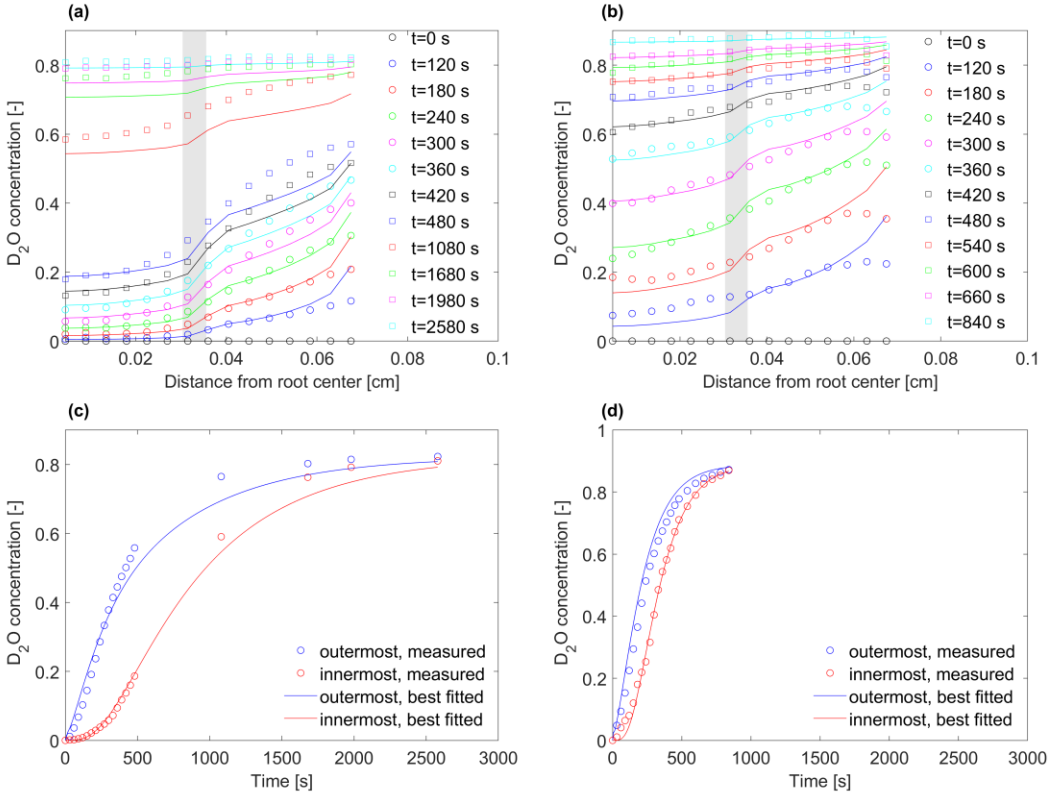


Results

We quantified the reconstructed neutron tomograms to calculate profile of D2O concentration across the root tissue during night (a,c) and day (b,d).

A faster D_2O transport during daytime than nighttime.

A steep drop in D2O concentration at the endodermis (position is shown with gray band).



Results

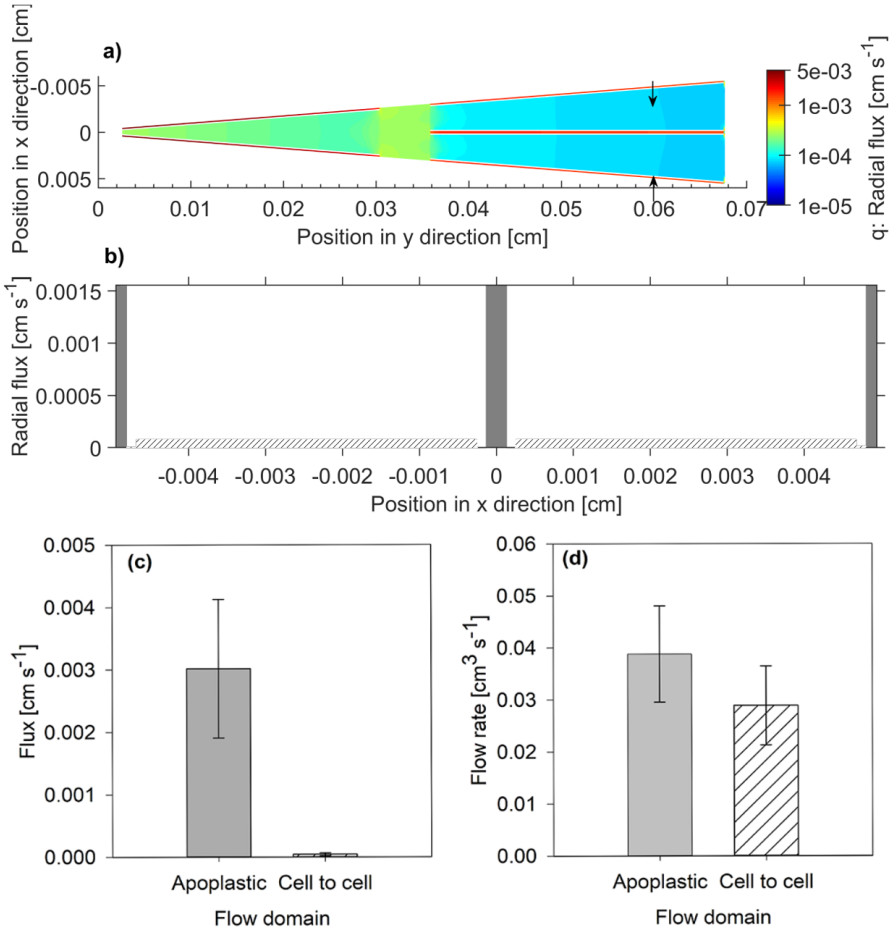
The solution of the inverse problem gave the spatial distribution of water flux :

a) Color mapped distribution of radial flux across the root tissue.

b) A transverse profile of radial flux in the cortex at a distance of 0.06 cm from the root center (position indicated by two arrows in subplot a).

c) Average flux across the apoplastic and cell-to-cell pathways.

d) The total flow of water across each pathway.



Take Home Massage

1) Water flux in the apoplast was **17** times greater than in the cell-to-cell pathway.
2) The overall contribution of the apoplast in water flow across the cortex is, despite its small volume of 5%, as large as **57%** of the total water flow.
3) The proposed method allows to non-invasively quantify the fluxes of water across the root tissue and the relative importance of their pathways.

www.nature.com/scientificreports

SCIENTIFIC REPORTS
nature research

Root water uptake and its pathways across the root: quantification at the cellular scale

Mohsen Zarebanadkouki[1], Pavel Trtik[2], Faisal Hayat[1], Andrea Carminati[1] & Anders Kaestner[2]