Experimental report

14/08/2019

Proposal: **UGA-49** **Council:** 4/2018

Title: Tracking 3D water flow and root uptake in soil by means of ultrafastneutron tomography

Research area:

This proposal is a new proposal

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Samples: Wood

Instrument	Requested days	Allocated days	From	To
D50 T	3	3	21/09/2018	24/09/2018

Abstract:

Experimental Report

Scientific Background

Neutron tomography is an outstanding tool for analyzing soil water distributions in plant root systems enabling 3D studies on the hydraulic interaction between roots and soil during water uptake. Using deuterated water as tracer it is possible to visualize the uptake of water by plant roots as demonstrated in dynamic 2D measurements (e.g. Zarebanadkouki *et al.*, 2012). Until recently, insufficient time resolution of neutron tomography has been the major limitation for studying such dynamic hydraulic processes in three dimensions. However, recent development of fast neutron tomography now provides new possibilities to study root water uptake time-resolved in three dimensions (Tötzke et al. 2017). Here we report on the first measurement campaign dedicated to testing and establishing the necessary acquisition protocols for fast neutron tomography at the neutron instrument NeXT. Taking into consideration the superior flux of the ILL neutron source significant improvements of image quality and speed of tomographic acquisition appear possible with respect to preliminary measurements at performed CONRAD instrument at HZB. Designed as pilot study we performed experiments appropriated for studying the influence of root systems on the water infiltration dynamics and for visualization of the local root uptake dynamics in maize and lupine root systems. Such experiments will promote a better understanding of root water uptake and can provide valuable data sets for numerical modelling approaches. Furthermore, optimization of imaging parameters and evaluation procedures are urgently needed to facilitate the broader application of ultra-fast neutron tomography by the scientific community.

Samples, imaging conditions and preliminary results

For first time fast neutron tomography was performed at the NeXT imaging station. This required special preparations such as the installation of a dedicated rotation stage with sufficient rotational speed, the adjustment of the acquisition software to realize the novel acquisition protocols as well as the provision of sufficient data memory and transfer capacity in order to handle the large amount of tomographic data. After successful installation and testing of the fast rotation stage several tomographic time series were performed on different plant samples: Three lupine and two maize plant samples were scanned after injection of D_2O at the bottom of the container. Experiments with maize focused on the local root water uptake. We illuminated the plants during daytime measurements while no illumination was applied during nighttime experiments. The spatiotemporal resolution was 1 min/tomography and 50 µm/pix, which is appropriate to capture both dynamic of root uptake and the fine details of the maize root system. The experiments with lupine plants had a different focus: capturing the infiltration dynamics of the soil column in particular on the exchange of H_2O by D_2O in the immediate vicinity of roots. Compared to root water uptake these processes are considerably faster. Therefore, higher acquisition speed was necessary: 10 s/tomogram, 100 µm/pix. Finally, we performed an infiltration experiment with a soil column at an acquisition speed of 1.5 s/180° or 3s/360° tomography. To our best knowledge, this is the highest temporal resolution for neutron tomography achieved so far. Fig.1 shows a 3D rendering of the root system root system 30 s (at left), 60 s (at center), and 90 s after injection of D_20 at the bottom of the soil column. D_2O enters the plant container quickly through the porous bottom plate, forming a water front at the bottom region of the soil column (see Figure 4 at t = 9s). As D2O invades the pore system of the soil matrix it displaces present light water (H2O), pushing it upwards in the soil column until the water front arrives at the hydraulic barrier where it accumulates and shows at its upper border a sharp boundary (t = 90 s). The results presented here will be subject of a regular research article (already submitted in June 2019).

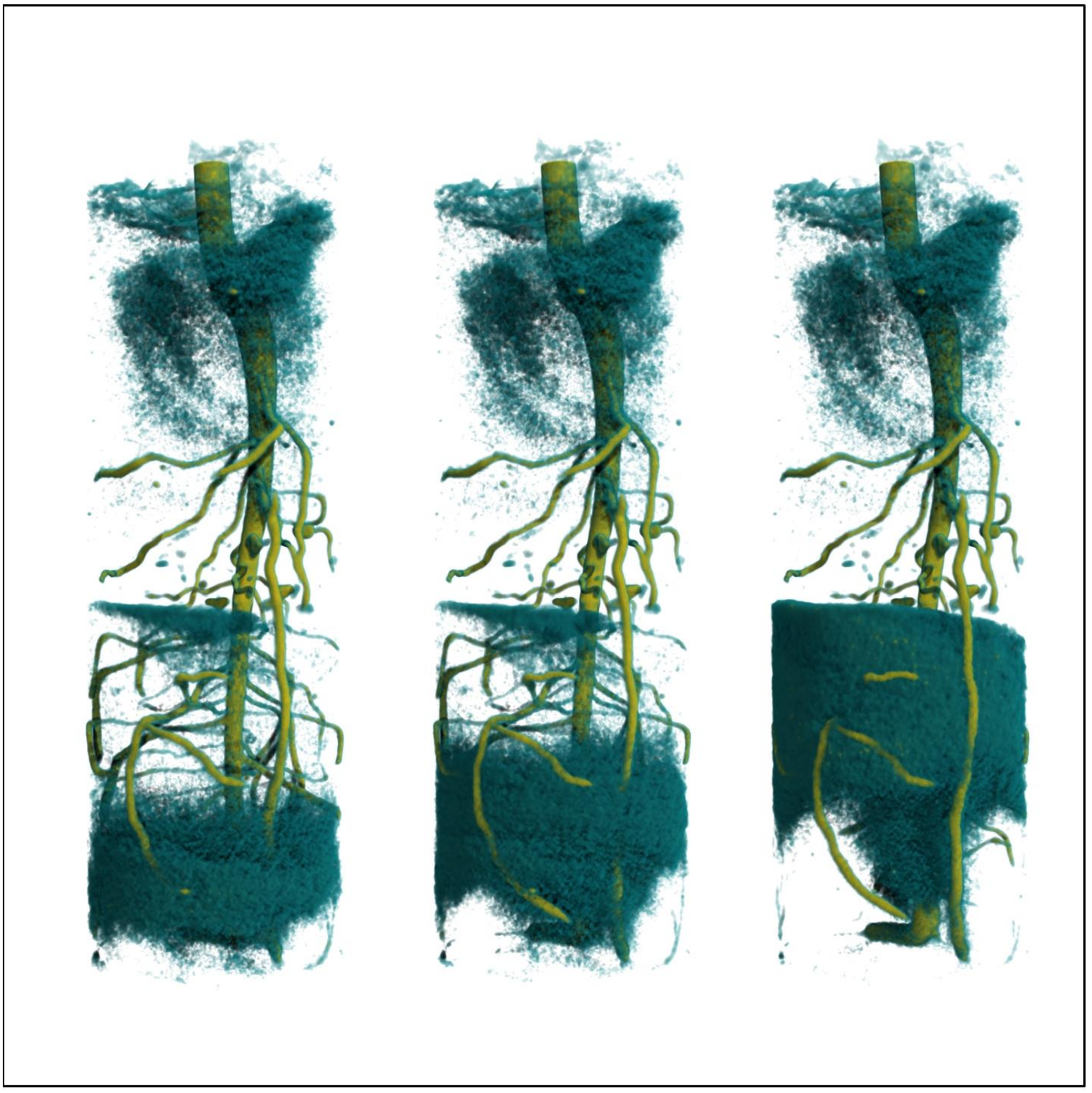

Fig. 1. Root system 30 s (at left), 60 s (at center), and 90 s after injection of $D_2 0$ at the bottom of the soil column. D_2O replaces the soil water already present before at the bottom compartment pushing upwards, where it agglomerates beneath the hydraulic barrier.

References

Zarebanadkouki M, Kim YX, Moradi AB, Vogel H-J, Kaestner A, Carminati A. 2012. *Quantification and Modeling of Local Root Water Uptake Using Neutron Radiography and Deuterated Water.* Vadose Zone Journal, 11.

Tötzke C, Kardjilov N, Manke I, Oswald SE. 2017. *Capturing 3D Water Flow in Rooted Soil by Ultra-fast Neutron Tomography*. Scientific Reports **7**, 6192