CT-assisted analysis of biopores and their influence on root growth and root dynamics

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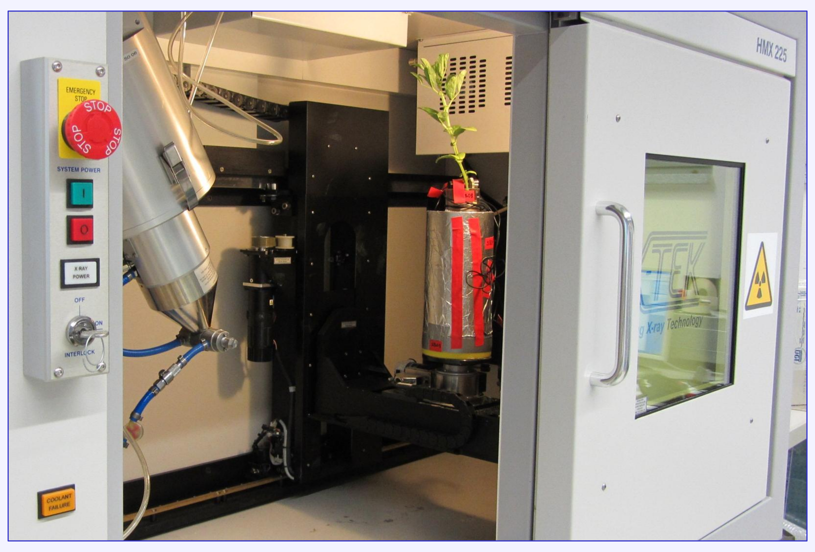
1 Introduction

Biopores (BP) are large continuous pores, developed and maintained by roots or earthworms and other soil fauna (1). Their physical and chemical properties may be totally different from those of the bulk soil (2). In particular in dense subsoil BP may enable preferential root growth because of lower physical resistance (3), better oxygen and altered nutrient availability, together with a higher microbial activity (2). It is likely that spatial extension, orientation and branching patterns of roots are influenced by the features of BP (i.e. size, tortuosity and topology) resulting in a modified root system architecture. The aim of this work is the spatial characterization and analysis of the BP in undisturbed soil samples, using X-ray microtomography (X-ray CT), as well as the chemical analysis of soil samples, taken from the pore walls and their vicinity, compared to those from the bulk soil, achieved by X-ray fluorescence analysis (XRF). Moreover, the influence of the BP on the shape of the rootsystem and its growing patterns is observed in comparison to homogenized samples without BP.

2 Experimental Setup

- ***Vicia faba*** **L.** grown in climate chamber for 21 days
- Soil cylinders (h=25 cm; Ø =11 cm) composed of acryl glass
- **Undisturbed field samples** (n=6; 40-65 cm; δ=1,47 g/cm³) and **homogenized** samples consisting of the same material (n=2)
- Controlled **matric potential (2 tensiometers per sample)**
- **Total Evapotranspiration** is measured by weighing cells
- X-ray CT visualization of **BP** and **root growth**
- **Soil** and **rooting traits : soil content of P and K, root diameter classes**



3 Results – Imaging of BP and root growth

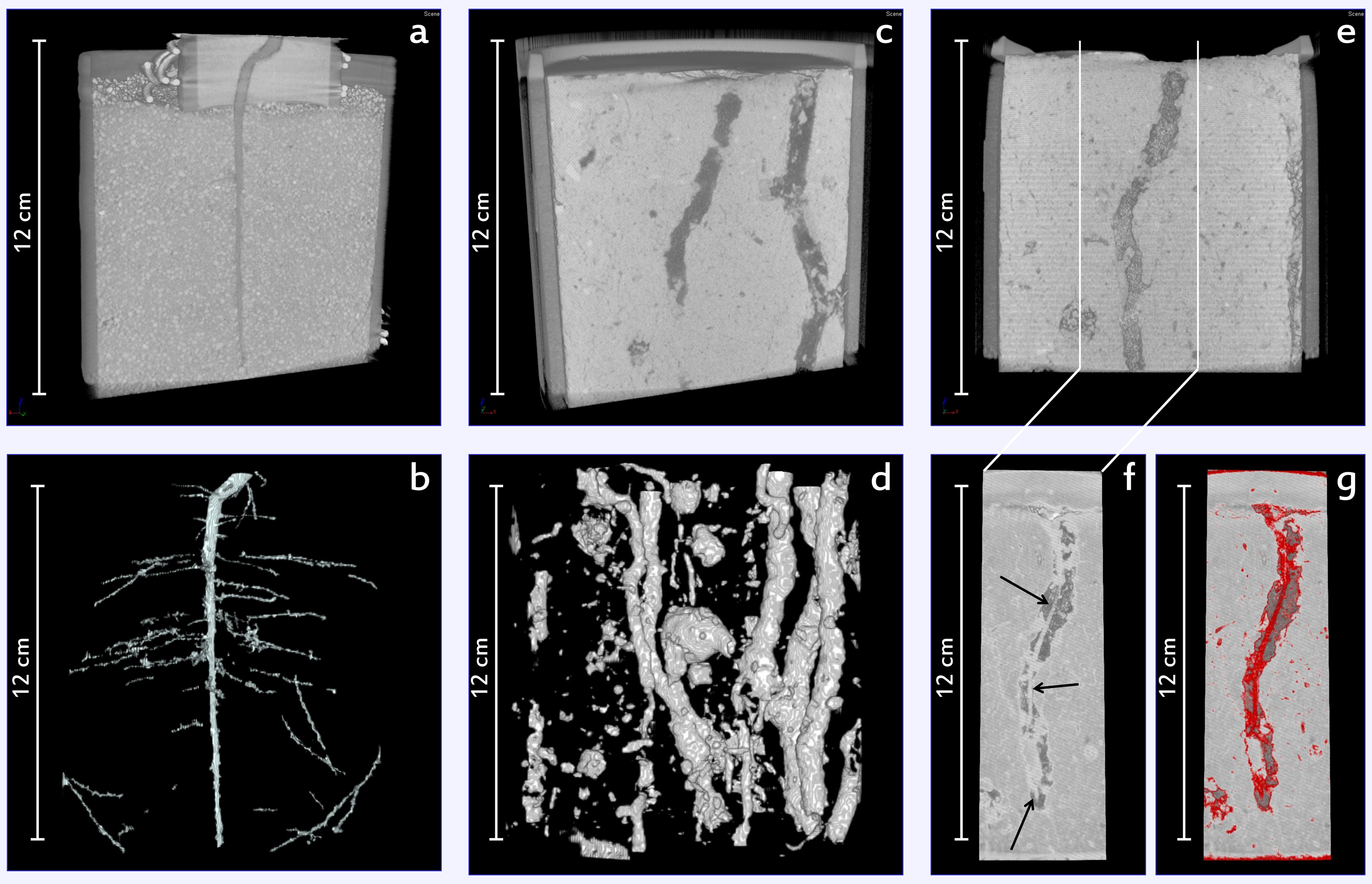


Figure 1a-g: Examples of raw images and 3D-segmentations derived from X-ray tomographies (upper part of the soil cylinders): a) homogenized soil sample with visible roots 21 days after planting (DAP); b) segmented root system from a); c) BP in undisturbed field sample; d) segmented BP from c); e) BP in undisturbed field sample before plant growth; f) new tap root of Vicia faba growing in a BP of an undisturbed field sample (21 DAP); g) coloring by greyvalue thresholding from f);

Analysis of the X-ray tomographies was done in analogy to Kaestner et al. (4). A nonlinear diffusion filter (5) was used for the reduction of image noise while edges between roots, pores and soil were preserved. To remove disturbing structures, smaller than roots, a greyscale opening was performed additionally. Due to high bulk density, soil type and large sample size, artifacts occurred and the resolution of the X-ray tomographies was not high enough to retrieve all roots. In the homogenized samples, roots could be segmented by an iterative region growing algorithm. For roots growing in BP, other segmentation methods have to be applied. Fig. 1g) shows a greyvalue thresholding for the taproot (red) growing in a BP of one example of the undisturbed field samples. The color distribution indicates, that some other structures like cracks, pore walls and small voids are misclassified as roots, resulting in difficulties during segmentation of the roots.

4 Results – Soil and rooting traits

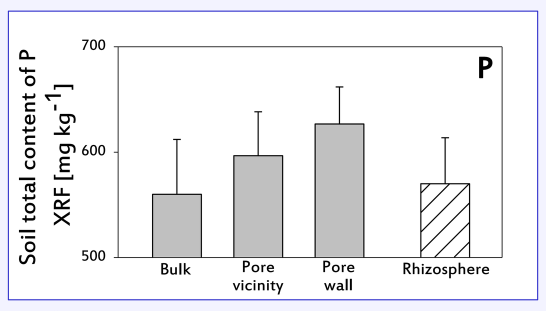


Figure 2: Soil total P content, measured by XRF in mg/kg

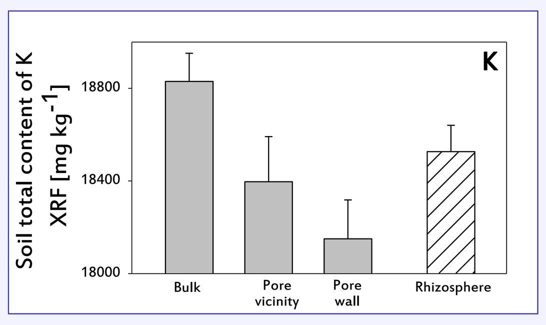


Figure 3: Soil total K content, measured by XRF in mg/kg

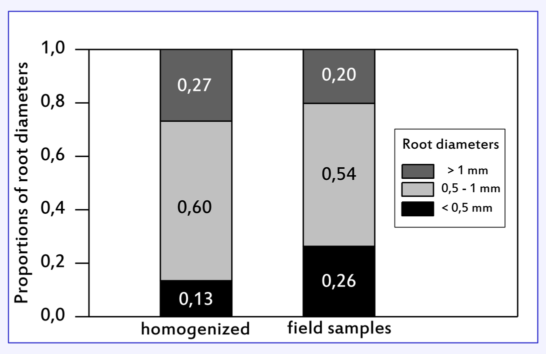


Figure 4: Proportions of root diameter classes for homogenized soil samples compared to field samples.

XRF analysis show distinct gradients from the pore wall to the bulk soil. For P, pore wall concentration is higher (Fig. 2), according to our expectations and results from Pankhurst et al (2). However, for K, pore walls show lower concentrations compared to bulk soil (Fig. 3). Independent of pore wall composition, rhizosphere soil shows depletion of K and no difference in P-concentration compared to bulk soil.

Destructive root sampling at the end of the experiment (roots were extracted by washing out, analysis was done with WinRHIZO (Regent Instruments)) showed marked differences in root diameter distributions. Roots growing in undisturbed field samples have a higher proportion of small root diameters (below 0,5 mm) compared to homogenized soil samples (Fig. 4).

5 Discussion and Outlook

It is well known, that the chemistry of pore walls is influenced by input of organic matter from roots and earthworms. P is enriched at the pore walls as it is bound in organic compounds, whereas the concentration of K decreases because of leaching and plant uptake due to high mobility of K^+ in organic matter. The rhizosphere shows depletion of K, reflecting low mobility in the bulk soil, while the concentration of P in the rhizosphere is similar to bulk soil.

Undisturbed field samples contain a higher amount of roots with small diameters, probably as they experience higher mechanical resistance during growth into the soil matrix with high bulk densities and high contents of silt and clay (68 and 28 % respectively). Further analysis will be conducted to quantify root-soil-contact in the BP and distribution of roots between BP and bulk soil matrix as well as nutrient uptake and the consequences for biomass production.

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