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Water uptake patterns and root system architecture of Zea mays in a natural soil under influence of drought stress monitored by MRI

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The interface between roots and soil plays a key role in water transport in the Soil-Plant-Atmosphere-Continuum (SPAC). The transport which changes with the degree of dehydration is influenced by both the hydraulic conductivity of roots and the soil. One important factor in plant growth is the amount of available water in the soil, which correlates directly with soil texture. Water uptake of plant roots and water uptake patterns in soil can be monitored using non-invasive 1H Nuclear Magnetic Resonance Imaging (MRI). In a preceding study the effect of root water uptake and uniform desiccation patterns under drought conditions were observed for Ricinus communis grown in a model medium (Pohlmeier et al. 2008).
Continuing these studies, the new aspect is the determination of water uptake patterns and root system architecture in a natural soil. The general challenge of MRI in soils are the inherent fast relaxation times T2* and T2 of the soil matrix. With the use of conventional sequences only water in macropores can be determined. The loss of sensitivity can be overcome by MRI sequences with sufficiently short detection times. In this work we employed and assessed two methods: SPI (Single Point Imaging) detects the T2* relaxation with a dead time of < 0.05 ms and SE3D (Spin Echo 3D) probes T2,eff with an echo time of about 0.8 ms. Zea mays, planted in a cylindrical container filled with a natural soil was completely sealed after 4 weeks of growth to avoid evaporation, so water loss took place via transpiration only. The water content of the soil was determined gravimetrically and by means of MRI each 2nd day over a period of 14 days. Furthermore a SEMS (Spin Echo Multi Slice) sequence was used to visualize the growth of root system architecture.

This study shows that SPI3D and SE3D are feasible for the determination of water content in a natural soil up to a certain detection limit. We observed quite uniform water uptake patterns during drying of the soil until water content was less than 0.15 cm̃3/cm̃3, which is the detection limit of both sequences for the used soil material. Accordingly, this indicates an always sufficiently high hydraulic conductivity of the soil to sustain water supply for the plant. The growth of the root system architecture could reliably been visualized with SEMS sequence where the best differentiation between soil and roots is obtained by the choice of long echo time and small voxel size. During the whole drought period we observed an increase in root growth what is an effect of the high water supply.

Pohlmeier, A., Oros-Peusquens, A., et al. (2008) " Changes in Soil Water Content Resulting from Ricinus Root Uptake Monitored by Magnetic Resonance Imaging" Vadose Zone J. 7: 1010-1017.