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Dynamics of Root Responses to Water Heterogeneity in Soil Using Neutron Radiography

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Heterogeneous water availability is a typical characteristic of soils in which plant roots grow. Water content in soil is spatially variable from one location to another because of the variable soil structure, distribution of organic materials, sand, clay, and pores. Water distribution in soil has also large temporal variability. Moreover, plant roots are not static and grow in a dynamic environment being forced to constantly interact with their surrounding. Despite the intrinsic heterogeneity of soil-plant water relations, we know little about the ways how plants respond to local environmental quality.

Our aim was to monitor root responses to water heterogeneity in soil and effects of water heterogeneity on root water uptake. To this end we used neutron radiography to non-invasive image root growth and soil water distribution.

Lupin plants were grown in 30*25*1 cm aluminum containers filled with natural sandy soil. To create the water heterogeneity, the root zone was partitioned to 9 compartments separated by 2 vertical and 2 horizontal capillary barriers, using coarse sand. Water has been equally injected in each compartment over two weeks. Afterwards, watering was stopped in the right side while the middle compartments (with tap root) and left ones (with lateral roots) were kept at constant wet condition by regular water injection. Daily changes in water content and root distribution in each compartment have been monitored by neutron radiography for 15 days.

Neutron radiography showed that the interactions between roots and the surrounding soil significantly varied over time and roots responded to soil water in terms of structural and morphological changes. Root growth in the drying compartment remained equal to that in the wet compartment, until the conditions became limiting. Actually, root growth in the dry parts was even higher than in the wet parts, in particular in terms of root cluster formation, as a response to phosphorus or water deficiency. In conclusion, our experiment showed that even in presence of a water source in one part of the root system, Lupin plants continued their root activity in dry parts to exploit soil water as much as possible. This root response was observed even in individual roots which crossed dry and wet compartments. These roots produced cluster roots only in the part exposed to the dry soil.