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Rhizosphere biophysics and root water uptake

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The flow of water into the roots and the (putative) presence of a large resistance at the root-soil interface have attracted the attention of plant and soil scientists for decades. Such resistance has been attributed to a partial contact between roots and soil, large gradients in soil matric potential around the roots, or accumulation of solutes at the root surface creating a negative osmotic potential.

Our hypothesis is that roots are capable of altering the biophysical properties of the soil around the roots, the rhizosphere, facilitating root water uptake in dry soils. In particular, we expect that root hairs and mucilage optimally connect the roots to the soil maintaining the hydraulic continuity across the rhizosphere.

Using a pressure chamber apparatus we measured the relation between transpiration rate and the water potential difference between soil and leaf xylem during drying cycles in barley mutants with and without root hairs. The samples were grown in well structured soils. At low soil moistures and high transpiration rates, large drops in water potential developed around the roots. These drops in water potential recovered very slowly, even after transpiration was severely decreased. The drops in water potential were much bigger in barley mutants without root hairs. These mutants failed to sustain high transpiration rates in dry conditions.

To explain the nature of such drops in water potential across the rhizosphere we performed high resolution neutron tomography of the rhizosphere of the barleys with and without root hairs growing in the same soil described above. The tomograms suggested that the hydraulic contact between the soil structures was the highest resistance for the water flow in dry conditions. The tomograms also indicate that root hairs and mucilage improved the hydraulic contact between roots and soil structures. At high transpiration rates and low water contents, roots extracted water from the rhizosphere, while the bulk soil, due its low unsaturated conductivity, failed to compensate root water uptake.

We conclude that root hairs are functional to increase the contact area between the roots and the soil structures and mucilage maintains wet the soil region between root hairs. These observations demonstrate the importance of the biophysical processes in the rhizosphere in modulating root water uptake.