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Rewetting Rate of Dry Rhizosphere Limited by Mucilage Viscosity and Mucilage Hydrophobicity

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During root water uptake from dry soils, the highly nonlinear relation between hydraulic conductivity and water content as well as the radial root geometry result in steep water potential gradients close to the root surface. The hydraulic properties of the rhizosphere – the interface between root and soil – are one of the most important and least understood components in controlling root water uptake.

Previous research using young lupine plants revealed that after irrigation it took 1-2 days for the water content of the dry rhizosphere to increase. How can this delay be explained?

Our hypotheses are that: a) mucilage – a polymeric plant exudate – alters rhizosphere hydraulic properties, b) its hydrophobic moieties make the rhizosphere water repellent when dry, c) mucilage is a highly viscous, gelatinous material, the dryer it gets the more viscous it becomes, d) mucilage viscosity reduces rhizosphere hydraulic conductivity.

To test our hypotheses we used mucilage extracted from chia seed as an analogue for root mucilage. We measured: 1) the contact angle between water and pure dry and wet mucilage, dry soil treated with various concentrations of mucilage, 2) mucilage viscosity as function of concentration and shear rate, 3) saturated hydraulic conductivity as function of mucilage concentration, 4) swelling of dry mucilage in water. Finally, to mimic flow of water across the rhizosphere, we measured the capillary rise in soils treated with different mucilage concentrations.

The results showed that: 1) dry mucilage has a contact angle $> 90^\circ$ while it loses its water repellency when it gets wet, 2) viscosity and saturated hydraulic conductivity can change several orders of magnitude with a small change in mucilage concentration, 3) 1g of dry mucilage absorbs 300g water in its fully swollen state, 4) the swelling rate of mucilage showed an exponential behavior with half time of 5 hours. Capillary rise became slower in soils with higher mucilage concentration, while the final water holding capacity increased with mucilage concentration.

We conclude that the slow rewetting of the rhizosphere is initially caused by the high contact angle. As the mucilage swells it occupies the pore space and controls the water flow due to its high viscosity. These studies show the high potential of root exudates to control the rhizosphere water dynamics.