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The rhizosphere physical network

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That the properties of the rhizosphere are different from those of the adjacent bulk soil is known since long time. What is missing is a mechanistic and predictive description of how roots and microorganisms engineer the properties of the soil where they live. In this paper we review recent progresses explaining: 1) the biophysical mechanisms of such interactions, 2) their impact on the hydraulic properties of the rhizosphere, and 3) the implications for plant and microbial growth.

Concept: three key physical properties of mucilage, namely viscosity, surface tension and water adsorption, affect the retention and spatial configuration of water in the rhizosphere. Mucilage adsorbs water, reduces its surface tension and increases its viscosity. As soils dry, mucilage becomes increasingly viscous, so that viscosity, rather than surface tension, determines the spatial configuration of the liquid phase, which is elegantly described by the Ohnesorge number. A consequence is the formation of long filaments (at low mucilage concentrations) and two-dimensional structures that span throughout the porous medium, such as hollow cylinders (at high mucilage concentrations).

The spatial configuration of water impacts the retention and transport properties of the rhizosphere. During drying, mucilage polymers become increasingly viscous and do not move as fast as the receding water phase, thereby acting a network holding water and increasing the water retention capacity. This viscous network also increases the connectivity of the liquid phase, which might maintain water and solute transport in drying soils – i.e. the relative unsaturated conductivity drops more gradually compared to the case without mucilage. The spatial configuration is also likely to impact other processes such as reducing vapour diffusion (and evaporation) and wettability (as mucilage of some species was shown to turn hydrophobic).

An open question remains the generalization of this concept. There is increasing evidence of the large variability of mucilage properties among plant species, age and environmental conditions. The theoretical framework that we propose can account for such variability, allowing to predict the effects of mucilages with varying viscosity and surface tension. It can also be extended to other biofilms in soils, such as microbial EPS, which show similar physical properties to mucilage. In conclusion, by modifying the physical properties of the soil solution, plants and microorganisms create a network that mediates flow processes across the rhizosphere.