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Water percolation through the root-soil interface

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Plant roots exude a significant fraction of the carbon assimilated via photosynthesis into the soil. The mucilaginous fraction of root exudates affects the hydraulic properties of the soil near the roots, the so called rhizosphere, in a remarkable and dynamic way. After drying, mucilage becomes hydrophobic and limits the rewetting of the rhizosphere. Here, we aim to find a quantitative relation between rhizosphere rewetting, particle size, soil matric potential and mucilage concentration. We used a pore-network model in which mucilage was randomly distributed in a cubic lattice. The general idea was that the mucilage concentration per solid soil surface increases the contact angle between the liquid and solid phases consequently limiting the rewetting of pores covered with dry mucilage. We used the Young-Laplace equation to calculate the mucilage concentration at which pores are not wettable for varying particle sizes and matric potentials. Then, we simulated the percolation of water across a cubic lattice. Our simulations predicted that above a critical mucilage concentration water could not flow through the porous medium. The critical mucilage concentration decreased with increasing particle size and decreasing matric potential. The model was compared with experiments of capillary rise in soils of different particle size and mucilage concentration. The experiments confirmed the percolation behaviour of the rhizosphere rewetting. Mucilage turned hydrophobic at concentrations above 0.1 mg/cm^2. The critical mucilage concentration at matric potential of -2.5 hPa was ca. 1% [g/g] for fine sand and 0.1 % [g/g] for coarse sand. Our conceptual model is a first step towards a better understanding of the water dynamics in the rhizosphere during rewetting and it can be used to predict in what soil textures rhizosphere water repellency becomes a critical issue for root water uptake.