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Water repellency in the rhizosphere of maize: measurements and modelling

Mutez Ahmed, Eva Kroener, and Andrea Carminati
Division of Soil Hydrology, Georg-August University of Goettingen, Goettingen, Germany (mahmed@uni-goettingen.de)

Although maize roots have been extensively studied, there is limited information on the effect of root exudates on the hydraulic properties of maize rhizosphere. Recent experiments suggested that the mucilaginous fraction of root exudates may cause water repellency of the rhizosphere. Our objectives were: 1) to investigate whether maize rhizosphere turns hydrophobic after drying and subsequent rewetting; 2) to develop a new method to collect root mucilage and test whether maize mucilage is hydrophobic; and 3) to find a quantitative relation between rhizosphere rewetting, particle size, soil matric potential and mucilage concentration.

Maize plants were grown in aluminum containers filled with a sandy soil. When the plants were three-weeks-old, the soil was let dry and then it was irrigated. The soil water content during irrigation was imaged using neutron radiography. In a parallel experiment, ten maize plants were grown in sandy soil for five weeks. Mucilage was collected from young brace roots using a new developed method. Mucilage was placed on glass slides and let dry. The contact angle was measured with the sessile drop method for varying mucilage concentration. Additionally, we used neutron radiography to perform capillary rise experiments in soils of varying particle size mixed with maize mucilage. We then used a pore-network model in which mucilage was randomly distributed in a cubic lattice. The general idea was that rewetting of a pore is impeded when the concentration of mucilage on the pore surface (g cm-2) is higher than a given threshold value. The threshold value depended on soil matric potential, pore radius and contact angle. Then, we randomly distributed mucilage in the pore network and we calculated the percolation of water across a cubic lattice for varying soil particle size, mucilage concentration and matric potential.

Our results showed that: 1) the rhizosphere of maize stayed temporarily dry after irrigation; 2) mucilage became water repellent after drying. Mucilage contact angle increased with mucilage surface concentration (gram of dry mucilage per surface area); 3) Water could easily cross the rhizosphere when the mucilage concentration was below a given threshold. In contrast, above a critical mucilage concentration water could not flow through the rhizosphere. The critical mucilage concentration decreased with increasing particle size and decreasing matric potential.

These results show the importance of mucilage exudation for the water fluxes across the root-soil interface. Our percolation model predicts at what mucilage concentration the rhizosphere turns hydrophobic depending on soil texture and matric potential. Further studies are needed to extend these results to varying soil conditions and to upscale them to the entire root system.