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Evaluation of Microbial-mediated Moisture Retention in Emulated Soil Micromodels

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Pore-scale water content controls the function of soil microbial communities by modulating the hydraulic connectivity of microbial communities and the flux of aqueous and gaseous substrates. In turn, soil bacteria regulate local moisture within porous structure through the secretion of extracellular polymeric substances (EPS). EPS promotes water retention as hydrogel in several ways: (i) by increasing the abundance of intra-aggregate micropores via soil aggregation, (ii) by swelling during wet soil conditions and remaining hydrated during dry soil conditions, and (iii) by altering soil surface wettability. The complex microbial process of soil moisture regulation can be understood by controlling the micro-structured environment systematically. Here we describe pore-scale changes in moisture distribution within emulated soil micromodels featuring systematically varied physical microstructures and surface water repellencies, loaded with well-defined pore solutions. Air infiltration into initially water-saturated soil microenvironments was recorded and quantified using microscopy. Experimental results showed that microstructure geometry was found to effect drying rate over a range of pore saturation values as well as control the spatial distribution of liquid and gas phases with unsaturated soil micromodels. EPS was cultured from stationary-phase Sinorhizobium meliloti bacteria, and was diluted to 0.25x, or concentrated via lyophilisation to 5x. The pristine EPS solution took twice as long to dry compared with pure water in identical micromodels. The 0.25x EPS solution took about four times slower than deionized water, and the 1x EPS solution took about eight times slower than deionized water. The influence of a relatively small amount of EPS is magnified by the porous structure to limit evaporation at pore throats. These results illustrate how natural microbial processes work within a complex soil microstructure to control the spatial distribution of water and limit the loss of soil moisture. We provide a systematical method to evaluate drying process within realistic soil microenvironments; we anticipate our approach may facilitate development of novel agriculture biotechnology to enable farmers to produce more crops using less water.

References

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