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Plant growth-promoting rhizobacteria (PGPR) enhance plant drought stress tolerance: physicochemical and hydrological changes in rhizospheric soil

Zheng, W., Bais, H. and Jin, Y.
Department of Plant and Soil Sciences, University of Delaware, Newark, Delaware, USA

Water is a key resource limiting agricultural production; the limitations will further intensify as agricultural activities expand to less fertile areas in order to meet the world's growing demands for food and fiber. Therefore, developing novel and sustainable solutions for plant growth under restricted water availability is essential to support the growing world population under the changing climate. Enhancement of plant drought stress tolerance by plant growth promoting rhizobacteria (PGPR) has been increasingly documented in the literature. However, most studies to date have focused on PGPR-root/plant interactions and plant responses to PGPR activities; very little is known about PGPR's role in mediating physiochemical and hydrological changes in the rhizospheric soil that may impact plant drought stress tolerance.

Our study seeks to systematically investigate the mechanisms and processes by which PGPR may change the physiochemical and hydrological properties of rhizosphere soil. In this study, we measured soil water retention characteristics, hydraulic conductivity, and water evaporation in soils with various textures (i.e., pure sand, sandy soil, and loam) as influenced by a model PGPR (a *Bacillus subtilis* strain UD1022 with proven effects on plant drought tolerance but unknown effects on soil properties and water retention) using the instrument Hyprop©. Preliminary results show that all PGPR-treated soils held more water, had reduced conductivity and reduced evaporation rate compared to their corresponding controls. While changes in evaporation behavior, i.e., the transition from Stage I to Stage II, due to PGPR addition, occurred in all soils. However, how and to what extent they differed varied with soil texture: PGPR prolonged Stage I (but at lower evaporation rate than control) in the pure sand while the bacteria shortened Stage I in the other two soils. These results indicate that PGPR affects evaporation by modifying soil capillarity and wettability that control liquid phase continuity and capillary forces that sustain Stage I evaporation. Scanning electron microscopy images show that PGPR promoted aggregation (hence broadened pore size distribution) in the pure sand due to EPS production and biofilm formation. On the other hand, modification of soil wettability by EPS/biofilm, thus water phase continuity and capillary driving forces, likely dominated the PGPR effects in sandy and loam soils. On-going research will quantify the PGPR's effects on soil contact angle, a measurement of hydrophobicity, and microbial extracellular polymeric substances (EPS) production to elucidate mechanisms of the effects. In addition, neutron tomography and radiography will be used for visual observation of water distribution involving plants in the testing soils as influenced by PGPR activities to provide additional insight and direct evidence on the processes involved.

Drought stress is a severe environmental constraint to agricultural production. While the development of drought tolerant crop varieties through genetic engineering and plant breeding is essential, it is a long drawn process. PGPR application in dry land agriculture to alleviate drought stresses in plants may play an important role in solving future food security issues. The overall goal of our study is to contribute to providing scientific basis for developing biotechnologies using rhizosphere beneficial microorganisms to ensure adequate food production for the growing world population under the changing climate.