Dynamic Imaging of Root and Rhizosphere Processes

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Attenuation-based neutron radiography and computed tomography are currently utilized for the study of plant-soil interactions *in situ*. Results with various woody plants, maize and switchgrass indicate significant variability in water dynamics across the soil-rhizosphere-root pathway, including root water uptake and hydraulic redistribution, hysteresis in water release curves and soil wettability. Measured water extraction rates by cottonwood roots ranged from 0.003 to 0.02 g cm^{-2} root surface h^{-1}, with rates declining for larger roots. Across species, root rhizosphere development increases with root size, stabilizing as roots reach ~2 mm in diameter. Analysis leveraged development of a novel image analysis software to identify and segment roots, and analyze root, rhizosphere, and soil water dynamics. Neutron radiography and paired laboratory measurements have also indicated significant root and mycorrhizal impacts to the soil hydraulic parameters, including hydraulic conductivity and residual water content, and the impacts were more pronounced in sandy soil as compared with silt-loam. While bulk water dynamics are readily visible using neutron radiography, alternate or novel techniques are needed to assess higher resolution water dynamics (e.g., <50 um), symbiotic root-microbial relationships, development of gaps across the rhizosphere that can isolate the root from the soil, and critically, nutrient, ion or exudate uptake or release dynamics.