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Root and microbial respiration contribute to anoxic microsite formation in the rhizosphere

EMILY M LACROIX[1,2], GIULIA CERIOTTI[1], DANIEL GARRIDO-SANZ[1,3], SERGEY M BORISOV[4], JASMINE BERG[1], CHRISTOPH KEEL[1], PIETRO DE ANNA[1] AND MARCO KEILUWEIT[1]

[1]University of Lausanne
[2]Dartmouth College
[3]Autonomous University of Madrid
[4]Graz University of Technology

For decades, biogeochemists have speculated that roots are key drivers of anoxic microsites – anomalous volumes of oxygen depletion – in upland soils. Rhizosphere-associated anoxic microsites are hypothesized to regulate plant contaminant uptake, nutrient availability, and the fate of root-derived carbon. However, despite their potential importance, it remains unclear why, when, and where anoxic microsites form in the rhizosphere. Here, we pair planar optical oxygen sensors with microfluidic devices mimicking a soil structure to map the distribution of oxygen in a young wheat rhizosphere. We filled microfluidic devices with i) sterile; ii) wheat symbiont-inoculated, and iii) whole-soil community-inoculated nutrient solutions. As a result, we were able to determine root oxygen consumption vs. microbial oxygen consumption over space (i.e., at different root physiological features) and time (i.e., day/night cycles). We found that suboxic (<2% air saturation) conditions commonly establish at root tips and more rarely establish along more mature root segments, particularly in the presence of soil organic matter and complex microbial communities. Additionally, the distribution of oxygen, and thus root-induced anoxic microsites, depends on complex interactions among light/dark cycles, growth rate, and presence of microorganisms in the rhizosphere. This study provides real-time observations of the micron-scale oxygen dynamics around actively growing roots, thereby linking root physiology to anoxic microsite formation in the rhizosphere. Our work suggests a strong potential for root-driven anoxic microsite formation, prompting important questions about anoxic microsite impact on biogeochemical processes in natural rhizosphere soil.