Plant-Sediment Interactions in Salt Marshes – An Optode Imaging Study of O₂, pH and CO₂ Gradients in the Rhizosphere

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Abstract:

In many wetland plants, belowground transport of O₂ via aerenchyma tissue and subsequent O₂ loss across root surfaces generates small oxic root zones at depth in the rhizosphere with important consequences for carbon and nutrient cycling. This study demonstrates how roots of the intertidal salt-marsh plant Spartina anglica affect not only O₂, but also pH and CO₂ dynamics, resulting in distinct gradients of O₂, pH and CO₂ in the rhizosphere. A novel planar optode System (VisiSens TD, PreSens GmbH) was used for taking high-resolution 2D-images of the O₂, pH and CO₂ distribution around roots during alternating light-dark cycles. Belowground sediment oxygenation was detected in the immediate vicinity of the roots, resulting in oxic root zones with a 1.7 mm radius from the root surface. CO₂ accumulated around the roots, reaching a concentration up to threefold higher than the background concentration, and generally affected a larger area within a radius for 12.6 mm from the root surface. This contributed to a lowering of pH by 0.6 units around the roots. The O₂, pH and CO₂ distribution was recorded on the same individual roots over diurnal light cycles in order to investigate the interlinkage between sediment oxygenation and CO₂ and pH patterns. In the rhizosphere, oxic root zones showed higher oxygen concentrations during illumination of the aboveground biomass. In darkness, intraspecific differences were observed, where some plants maintained oxic root zones in darkness, while others did not. However, the temporal variation in sediment oxygenation was not reflected in the temporal variations of pH and CO₂ around the roots, which were unaffected by changing light conditions at all times. This demonstrates that plant-mediated sediment oxygenation fueling microbial decomposition and chemical oxidation has limited impact on the dynamics of pH and CO₂ in S. anglica rhizospheres, which may in turn be controlled by other processes such as root respiration and root exudation.

Keywords: salt marsh, planar optode, sediment oxygenation, plant-soil interactions, soil chemistry, roots, Spartina, imaging methods