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Simulating root exudation by reverse microdialysis

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The release of labile compounds by plant roots commonly referred to as root exudates, dramatically increases C concentrations in the rhizosphere. While it is well known that root exudation significantly affects soil physical and chemical properties as well as microbial activities at the soil microscale, studying such effects remains a challenge due to the sheer complexity of soils and plant root systems. Current methods for simulating root exudation are often unsatisfactory, since the injection of exudate solution into soil is punctual and severely changes the natural soil water balance. Here, we present a novel approach based on microdialysis enabling the controlled and gradual release of exudates with minimum disturbance of the soil and, simultaneously, allowing monitoring its consequences at these spots.

Microdialysis, a technique developed for neuroscience, has been successfully adapted to assess in situ soil nutrient fluxes in a non-invasive way. Briefly, microdialysis probes including a semi-permeable membrane are inserted into the soil and a perfusate (e.g. distilled water) is pumped through the probes. The concentration gradient between the soil solution and the perfusate induces the diffusion of compounds across the membrane, which can then be measured in the collected samples.

In this study, we used a 'reverse microdialysis' approach to simulate the release of low molecular weight compounds by plant roots into an undisturbed soil environment. In detail, we installed microdialysis membranes (10 mm length, 500 μm outer diameter, 20 kDa molecular weight cut-off) into undisturbed soil cores collected from a beech forest site in the vicinity of Vienna, Austria. Instead of distilled water, we used a perfusate containing an exudate mixture of acetate, succinate, fructose and glucose at concentrations previously reported for beech trees. We then simulated exudation for eight hours before switching back to a perfusate without exudate mixture. The dialysate of all soil cores was collected in hourly intervals, and concentrations of sugars and organic acids were measured by HPLC.

Our results show that transfer rates i.e. the percentage of perfusate compounds that were transferred across the membrane into the soil ranged between 5-37% at a flow rate of 2.5 ul/min. This was substantially lower compared to transfer rates of the same compounds into distilled water (80% at the same flow rate). Since the concentration of exudate compounds in the original soil solution was negligible, transfer rates must have been strongly influenced by soil properties rather than diffusional gradients. Moreover, transfer rates slightly decreased during the 8 hours pulse indicating a slow saturation effect. Concentrations of all compounds in the dialysate dropped down to initial levels within 4 hours after the pulse has ceased, indicating that all released compounds were rapidly removed from the soil solution. Our results thus demonstrate that reverse microdialysis is a powerful method to mimic root exudation, and future research efforts will be directed towards observing the soil microbiome surrounding the microdialysis membranes.