Chemical imaging of dissolved phosphorus reveals complex P dynamics in the rhizosphere of *Brassica napus*

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Due to the important and often limiting role of phosphorus (P) for plant growth substantial research has been conducted to understand the rhizosphere processes involved in plant P acquisition. Major mechanisms of P solubilisation such as proton and carboxylate exudation and enzymatic decomposition of organic, P containing substances are well known. However, spatial allocation of P dynamics in the rhizosphere, especially in the vicinity of soil-grown roots, remains experimentally challenging. The aim of this study was to develop a system capable of localised sampling of dissolved P which allows for P distribution monitoring at a sub-mm scale.
Existing diffusive gradients in thin films (DGT) methodologies for sub-mm chemical imaging in aquatic sediments were adapted for their use in the soil and rhizosphere environment. DGT gels were deployed onto *Brassica napus* roots grown in a low-P Eutric Cambisol in rhizotrons for sampling of dissolved P. After drying the gels were analysed for P using Laser-Ablation-Inductively-Coupled-Plasma-Spectrometry (LA-ICP-MS). By these means we were able to map the dissolved P in the *B. napus* rhizosphere.
The resulting images of the P distribution in the rhizosphere were overlaid by photographic images of the roots under investigation. This allowed the allocation of localised changes in P concentration to specific root zones. We observed complex patterns of P distribution in the rhizophere of the studied roots. As expected, P depletion zones were found alongside the roots. Using mathematical modeling, zones of elevated P concentrations within the depletion zones could be attributed to efflux of P from plant roots. The simulations further showed that DGT measured P efflux from roots was linearly correlated with the P efflux rate. Large increases of the P concentration around the very root tips were also observed. These features could either be caused by mobilisation of P from the soil solid phase or by P exudation or loss at the root tip.
This study is the first visualisation and quantification of dissolved P in rhizosphere soil at the sub-mm scale. Our results contribute to the current understanding of P dynamics in close proximity to plant roots. Apart from further enhancing our understanding of solute dynamics, chemical imaging in the rhizosphere could be applied to select crop cultivars based on their P acquisition efficiency in plant breeding programs. Moreover, chemical imaging can be used for the validation of mathematical models of nutrient uptake and use efficiency. The method presented here is not restricted to P but should in principle be applicable to all solutes that can be sampled by DGT and analysed by LA-ICP-MS.