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Quantitative imaging of rhizosphere pH and CO_2 dynamics with planar optodes

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Abstract:

• *Background and Aims* Live imaging methods have become extremely important for the exploration of biological processes. In particular, non-invasive measurement techniques are key to unravelling organism-environment interactions in close-to-natural set-ups, e. g. in the highly heterogeneous and difficult-to-probe environment of plant roots: the rhizosphere. pH and CO_2 concentration are the main drivers of rhizosphere processes. Being able to monitor these parameters at high spatio-temporal resolution is of utmost importance for relevant interpretation of the underlying processes, especially in the complex environment of non-sterile plant-soil systems. This study introduces the application of easy-to-use planar optode systems in different set-ups to quantify plant root-soil interactions.
• *Methods* pH- and recently developed CO_2-sensors were applied to rhizobox systems to investigate roots with different functional traits, highlighting the potential of these tools. Continuous and highly resolved real-time measurements were made of the pH dynamics around *Triticum turgidum durum* (durum wheat) roots, *Cicer arietinum* (chickpea) roots and nodules, and CO_2 dynamics in the rhizosphere of *Viminaria juncea*.
• *Key Results* Wheat root tips acidified slightly, while their root hair zone alkalized their rhizosphere by more than 1 pH unit and the effect of irrigation on soil pH could be visualized as well. Chickpea roots and nodules acidified the surrounding soil during N_2 fixation and showed diurnal changes in acidification activity. A growing root of *V. juncea* exhibited a large zone of influence (mm) on soil CO_2 content and therefore on its bio-geochemical surrounding, all contributing to extreme complexity of the root-soil interactions.
• *Conclusions* This technique provides a unique tool for future root research applications and overcomes limitations of previous systems by creating quantitative maps without, for example, interpolation and time delays between single data points.

Keywords: *Triticum turgidum durum, Cicer arietinum, Viminaria juncea,* planar optodes, rhizosphere, quantitative imaging, pH dynamics, CO_2 dynamics