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Distribution of root exudates and mucilage in the rhizosphere: combining 14C imaging with neutron radiography

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Water and nutrients will be the major factors limiting food production in future. Plant roots employ various mechanisms to increase the access to limited soil resources. Low molecular weight organic substances released by roots into the rhizosphere increase nutrient availability by interactions with microorganisms, while mucilage improves water availability under low moisture conditions. Though composition and quality of these substances have intensively been investigated, studies on the spatial distribution and quantification of exudates in soil are scarce. Our aim was to quantify and visualize root exudates and mucilage distribution around growing roots using neutron radiography and 14C imaging depending on drought stress. Plants were grown in rhizotrons well suited for neutron radiography and 14C imaging. Plants were exposed to various soil water contents experiencing different levels of drought stress. The water content in the rhizosphere was imaged during several drying/wetting cycles by neutron radiography. The radiographs taken a few hours after irrigation showed a wet region around the root tips showing the allocation and distribution of mucilage. The increased water content in the rhizosphere of the young root segments was related to mucilage concentrations by parameterization described in Kroener et al. (2014).

In parallel 14C imaging of root after $14CO_2$ labeling of shoots (Pausch and Kuzyakov 2011) showed distribution of rhizodeposits including mucilage. Three days after setting the water content, plants were labeled in $14CO_2$ atmosphere. Two days later 14C distribution in soil was imaged by placing a phosphor-imaging plate on the rhizobox. To quantify rhizodeposition, 14C activity on the image was related to the absolute 14C activity in the soil and root after destructive sampling. By comparing the amounts of mucilage (neutron radiography) with the amount of total root derived C (14C imaging), we were able to differentiate between mucilage and root exudates. We found that mucilage and 14C concentrations were higher around the young root segments. Mucilage concentration was particularly high in the most apical 3-5 cm of the roots.

Drought stress increased 14C exudation relative to C fixation and led to higher mucilage concentrations around roots. However, it remains unclear, whether the lower mucilage concentration around roots grown at higher soil moisture was caused by the faster diffusion of mucilage in wet soils. Therefore, a second experiment was focused on diffusion of mucilage in soil at varying water contents. The diffusion of mucilage in soil was not very sensitive to soil water content. We conclude that mucilage release was higher for plants exposed to drought stress.

In summary, the combination of neutron radiography and 14C imaging can successfully be used to visualize and to quantify the distribution of mucilage and root exudates in the rhizosphere of plants grown in soil.

References

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