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Effect of soil water content on spatial distribution of root exudates and mucilage in the rhizosphere

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Water and nutrients are expected to become the major factors limiting food production. Plant roots employ various mechanisms to increase the access to these limited soil resources. Low molecular root exudates released into the rhizosphere increase nutrient availability, while mucilage improves water availability under low moisture conditions. However, studies on the spatial distribution and quantification of exudates in soil are scarce. Our aim was therefore to quantify and visualize root exudates and mucilage distribution around growing roots using neutron radiography and 14C imaging at different levels of water stress.

Maize plants were grown in rhizotrons filled with a silty soil and were exposed to varying soil conditions, from optimal to dry. Mucilage distribution around the roots was estimated from the profiles of water content in the rhizosphere – note that mucilage increases the soil water content. The profiles of water content around different root types and root ages were measured with neutron radiography. Rhizosphere extension was approx. 0.7 mm and did not differ between wet and dry treatments. However, water content (i.e. mucilage concentration) in the rhizosphere of plants grown in dry soils was higher than for plants grown under optimal conditions. This effect was particularly pronounced near the tips of lateral roots. The higher water contents near the root are explained as the water retained by mucilage.

14C imaging of root after $14CO_2$ labeling of shoots (Pausch and Kuzyakov 2011) was used to estimate the distribution of all rhizodeposits. Two days after labelling, 14C distribution was measured using phosphor-imaging. To quantify 14C in the rhizosphere a calibration was carried out by adding given amounts of 14C-glucose to soil. Plants grown in wet soil transported a higher percentage of 14C to the roots (14Croot/14Cshoot), compared to plants grown under dry conditions (46 vs. 36 %). However, the percentage of 14C allocated from roots to rhizosphere (14Crhizosphere/14Croot) was double in plants grown under dry conditions (0.43 vs. 0.75 %). Plants grown in wet soils showed a faster root growth (1.4 cm d-1) compared to plants in dry soil (1 cm d-1). Compared to the results with neutron radiography, rhizosphere extension of 14C was generally higher and strongly depended on root type: it was 2 mm for main roots and 1 mm for lateral roots. This indicates that low molecular exudates diffuse further into the soil than mucilage. As for mucilage, concentration of 14C was higher in the rhizosphere of plants grown under dry conditions. This observation can be explained by: (a) higher allocation of 14C from roots to rhizosphere in dry soils, (b) a fast diffusion of exudates in wet soils, and (c) faster root growth in wet soils, which results in lower exudation per root length.

In summary, the combination of neutron radiography and 14C imaging was successfully used to visualize and to quantify the distribution of mucilage and root exudates in the rhizosphere of plants grown in soil. The high concentration of root exudates in rhizosphere under dry conditions might be strategy of plants to increase their water and nutrient availability unfavorable conditions.