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How rhizosphere may affect nutrient uptake under drying soil condition?

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To be taken up by the roots, nutrients in soil solution should be transported towards the roots. The main mechanisms of transport are mass flow and diffusion which both are strongly affected by soil water content (limited). Increasing evidences have been suggesting that plants actively modify their surrounding soil so called the rhizosphere to improve their access to water and nutrients. Although the rhizosphere effects on nutrient availability have been focused of several studies from biological and chemical point of view, its effect on diffusion properties of nutrient has not been yet explored. In this study, we investigated on the effect of mucilage a gel like components released by roots on the diffusive transport of nutrient in soil.

A Phosphor-Imaging technique was used to study diffusion of radionuclides of 33P and 137Cs in the rhizospheric soil. As an analogy of rhizospheric soil, a quartz sand was mixed by mucilage extracted from chia seeds. The soil was packed into contraries with size of 5×2×1 cm which was portioned in two parts. The first half of the container was filled with soil mixed with mucilage and equilibrated at different water potential with nutrient solution (containing 33P and 137Cs). The other half was filled with soil mixed with mucilage and equilibrated at the same water potential with water. Same setup was prepared for soil without mucilage. The radionuclides diffused from one half of the soil container into the other half without solutes following the concentration gradient. Repeated Phosphor-Imaging made this process visible and was used to quantitatively obtain profiles of radionuclide concentration with time by help of image processing. A diffusion equation with adsorption term allowed us to estimate diffusion coefficients of the two ions.

The results showed that diffusion of these two ions strongly depended on soil water potential. The higher was the soil water potential the greater was the diffusion coefficient. Comparing the diffusion coefficient obtained from rhizospheric soil and bulk soil showed that at the same water potential the diffusion coefficient was greater in the presence of mucilage. These differences were more pronounced at low water potential occurring at dry condition.

In simple scenario the effect of mucilage on concentration of nutrients during a drying and rewetting cycles was evaluated by solving a diffusion-convection equation in soil. The results showed that in the case of mucilage a higher concentration of nutrients can be expected at the root surface during early stages of a soil drying cycle. This will help plant to access and extract more nutrient. As soil dries the concentration of nutrients dragged by mass flow towards the root surface tends to increase and may induce a salinity stress. Our results showed that presence of mucilage by avoiding the big drop in diffusion coefficient as soil dries delayed an expected buildup of concentration at the root surface. We conclude that the presence of mucilage in the rhizosphere of plant plays an important role in sustaining the transport of nutrient into the roots particularly at drying condition.