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Coupled model of root water uptake, mucilage exudation and degradation

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Although the fact that root mucilage plays a prominent role in soil-plant water relations is becoming more and more accepted, many aspects of how mucilage distribution and root water uptake interact with each other remain unexplored. First, it is not clear how long mucilage persists in soil. Furthermore, the effects of water content and root water uptake (i.e. convective fluxes) on the diffusion of mucilage from the root surface into the soil are not included in current models of water uptake.

The aims of this study were: i) to measure the effect of soil moisture on mucilage decomposition; ii) to develop a coupled model of root water uptake and mucilage diffusion and degradation during root growth. C4 root mucilage from maize was added as single pulses to a C3 soil of two different moisture levels. We have then employed the Richards Equation for water flow and an advection-dispersion equation to describe the dynamic distribution of mucilage in a single-root model.

Most of the mucilage was decomposed under optimum water supply. Drought significantly suppressed mucilage mineralization. Opposed to classical solute transport models the water flow in the rhizosphere was affected by the local concentration of mucilage. Namely a higher concentration of mucilage results in (a) an increase in equilibrium water retention curve, (b) a reduction of hydraulic conductivity at a given water content and (c) a non-equilibrium water retention curve caused by swelling and shrinking dynamics of mucilage in the pore space. The dispersion coefficient, on the other hand, depends on the water content. The parameters of mucilage diffusion have been fitted to observations on real plants.

The model shows that mucilage exuded in wet soils diffuses far from the roots and it is rapidly degraded. On the contrary, mucilage of plants growing in dry soil is not easily degradable and it remains at higher concentrations in a narrow region around the roots, resulting in a marked increase in water content towards the roots as well as to the formation of stable rhizosheath observed in dry soils. This model shows how feedbacks between root water uptake and root exudation result in adaptation mechanisms of plants to drought.