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Mucilage: The hydraulic bridge between roots and soil

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As plant roots take up water and the soil dries, water depletion is expected to occur in the soil near the roots, the so called rhizosphere. Ultimately, as the soil hydraulic conductivity drops and the soil cannot sustain the transpiration demand, roots shrink and lose contact to the soil. Both, water depletion in the rhizosphere and formation of air-filled gaps at the root-soil interface potentially limit the availability of water to plants. How can plants overcome these potential hydraulic barriers at the root-soil interface?
One strategy consists in the exudation of mucilage from the root tips. Mucilage is a polymeric gel that is capable of holding large volumes of water. When exuded into the soil, mucilage remains in the vicinity of roots thanks to its relatively high viscosity and reduced surface tension. As mucilage is mainly made of water, its slow penetration into the soil results in higher water content and hydraulic conductivity of the rhizosphere compared to the adjacent bulk soil. Recent measurements with a root pressure probe technique demonstrated that mucilage exudation facilitates the water flow in dry soils. Additionally, mucilage increases the adhesion of soil particles to the roots, reducing the formation of gaps at the root-soil interface. Based on these observations, it is very tempting to conclude that mucilage acts as an optimal hydraulic bridge across the root-soil interface.
However, as mucilage dries and ages, it turns hydrophobic. Consequently, the rhizosphere becomes water repellent and its rewetting time increases. Our former experiments showed that after irrigation subsequent to a drying cycle, the rhizosphere of lupines remained markedly dry for 2 days. Recently, we demonstrated that the rhizosphere water repellency is concomitant with a decrease in local water uptake of 4-8 times. We conclude that after drying and rewetting, the rhzisophere temporarily limits root water uptake.
In summary, the hydraulic properties of the root-soil interface changes over time and along the root system. Young, well hydrated mucilage optimally connects the roots to the soil and facilitates the uptake of water from relatively dry soils. However, as mucilage ages and dries, it reduces the rhizosphere wettability and the water flow to the roots. Such a dual behavior of the rhizosphere, rather than a contradiction, seems a plant strategy to adapt to the typically heterogeneous distribution of water in soils. For instance, in a soil profile with water stored in the sub soil, mucilage would facilitate the water uptake of young, deep root segments and it would avoid water loss from the root segments into the dry top soil.
These studies show that the root-soil interactions in the rhizosphere play a crucial role in regulating root water uptake. We believe that s better understanding and management of such interactions can bring a more efficient and sustainable use of water resources.