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Modeling water uptake by root system covered with mucilage at different degradation state

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For many years the rhizosphere which is the zone of soil in the vicinity of the roots and which is influenced by the roots is known as a unique soil environment with different physical, biological and chemical properties than those of the bulk soil. In recent studies, it has been shown that root exudates and especially mucilage alter the hydraulic properties of the rhizosphere, and that drying and wetting cycles of mucilage result in non-equilibrium dynamics in the rhizosphere, affecting water content distribution and root water uptake (RWU). Current models that integrate RWU with rhizosphere processes are limited to a simplified one root system with a homogeneous distribution of rhizosphere and root properties. In this work, we present a 3D model of water flow in the soil-plant continuum that takes in consideration root architecture and rhizosphere processes including the spatial and temporal variation in root and rhizosphere hydraulic properties, resulted from mucilage exudation and biodegradation.

In the new model mucilage concentration is distributed along the root system according to the exudation period and the biodegradation rate of mucilage described with a Monod-type equation. Mucilage considered being composed of miscible and immiscible components, each with contrasted microbial degradation preferences and rate, resulting in a different distribution of each of the component. The rhizosphere water holding capacity and hydraulic conductivity were set to be a function of the total mucilage concentration, and hydrophobicity (captured using non-equilibrium formulation) was set to be a function of the immiscible concentration. Several scenarios describing different degradation and exudation parameters were examined. The results show that the rhizosphere water content is positively related to the mucilage concentration and that the rhizosphere hydraulic conductivity is negatively related to mucilage concentration. We observed a complex relation between the concentration of the different mucilage components and the gradient required to sustain transpiration demand. In general, a higher concentration of mucilage lead to higher gradients, but as the concentration of the immiscible components was equalized, higher miscible concentration result in lower gradients. Overall, this work demonstrates that a combination of exudate rate and degradation contributes to determining the hydraulic properties of the rhizosphere and RWU. In future studies, this model can be used to assess the optimal spatial and temporal distribution of mucilage components and to design roots and bacteria to reach this optimum.