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The development of the rhizosphere: simulation of root exudation for two contrasting exudates: citrate and mucilage

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Different types of root exudates and their effect on soil/rhizosphere properties have received a lot of attention. Since their influence of rhizosphere properties and processes depends on their concentration in the soil, the assessment of the spatial-temporal exudate concentration distribution around roots is of key importance for understanding the functioning of the rhizosphere. Different root systems have different root architectures. Different types of root exudates diffuse in the rhizosphere with different diffusion coefficient. Both of them are responsible for the dynamics of exudate concentration distribution in the rhizosphere. Hence, simulations of root exudation involving four kinds of plant root systems (Vicia faba, Lupinus albus, Triticum aestivum and Zea mays) and two kinds of root exudates (citrate and mucilage) were conducted. We consider a simplified root architecture where each root is represented by a straight line. Assuming that root tips move at a constant velocity and that mucilage transport is linear, concentration distributions can be obtained from a convolution of the analytical solution of the transport equation in a stationary flow field for an instantaneous point source injection with the spatial-temporal distribution of the source strength. By coupling the analytical equation with a root growth model that delivers the spatial-temporal source term, we simulated exudate concentration distributions for citrate and mucilage with MATLAB. From the simulation results, we inferred the following information about the rhizosphere: (a) the dynamics of the root architecture development is the main effect of exudate distribution in the root zone; (b) a steady rhizosphere with constant width is more likely to develop for individual roots when the diffusion coefficient is small. The simulations suggest that rhizosphere development depends in the following way on the root and exudate properties: the dynamics of the root architecture result in various development patterns of the rhizosphere. Meanwhile, Results improve our understanding of the impact of the spatial and temporal heterogeneity of exudate input on rhizosphere development for different root system types and substances. In future work, we will use the simulation tool to infer critical parameters that determine the spatial-temporal extent of the rhizosphere from experimental data.