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The Development of the Rhizosphere during the Growth of a 3D Root Architecture-Simulating and Characterizing Spatio-temporal Patterns of Rhizodeposits around Growing Root Systems

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The rhizosphere refers to the soil area that is directly and actively influenced by root exudation and secretions. In terms of its spatio-temporal pattern, the rhizosphere is a not a fixed-size region, but consists of gradients in biological, chemical and physical properties that vary radially, longitudinally and temporally along the root. A better understanding of the rhizosphere in terms of root exudation and secretions dynamics and associated biogeochemical processes is critical for maintaining the health of plant growth and the composition of the organisms within the rhizosphere. Various types of organic substances are released by roots. Their crucial impact on rhizosphere properties and related functional processes depends on their spatio-temporal concentration distribution around roots. Further more, different plant species/genotypes have varying root architectures, and individual rhizodeposits have their own diffusion coefficients and decomposition rates. Their re- lease patterns, root growth dynamics and solute transport are jointly responsible for the distribution of the rhizodeposit in the soil . Here, we derive a mathematical model that simulates the spatio-temporal distribution of rhizodeposits. The model is based on convolutions of the analytical solution of the 3D convection diffusion equation coupled to a root growth model. In terms of the rhizodeposit distribution, we define the mathematical formulas to describe the rhizosphere and hotspot for each single root of the root system. The model simulations did involve two plant species differing in root architecture (Vicia faba and Zea mays) and two kinds of rhizodeposits (citrate and mucilage) were examined. The impact of the transport parameters (diffusion and sorption coefficients) and the root architecture on the spatio-temporal evolution of the rhizodeposit distribution was also evaluated. The spatio-temporal distribution of the rhizodeposits can be characterized by discriptors, such as the width of the rhizodeposit zone, reactor ratio . The following information about the rhizosphere was highlighted by the model simulation: (a) the dynamics of the root architecture development strongly affects the rhizodeposit distribution in the root zone; (b) each growing root develops a dynamic rhizosphere (i.e. the width of the rhizosphere is varying for a given position behind the root tip-it is increasing over a certain time interval and then decreasing). Its width depends on the value of the diffusion coefficient of the compound in soil. The overlap of individual rhizospheres is more likely to occur for citrate than for mucilage rhizodeposits . Our results improve our understanding of the impact of the spatial and temporal heterogeneity of rhizodeposits input on rhizosphere development for different root system types and substances and gain insight into the computation and interpretation of the development of the rhizosphere mathematically .