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Single Root Model for the Impact of Root Exudates on the Fate of Phosphorus in the Rhizosphere

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Mathematical models are invaluable for the design of rhizotechnologies that help to improve nutrient and water efficiency. In our work, we present a mechanistic one dimensional model accounting for the complex plant-induced chemical processes in soil on single root scale. The equations are based on conservation of mass and the law of mass action and consider interactions between phosphorus, exudates, diverse complexes, including equilibrium and kinetic sorption, transformation, degradation, and decay processes, as well as dispersion in soil. For the numerical solutions, the software packages COMSOL Multiphysics 3.5A and Matlab 7 are used. Sensitivity analysis of the highly parameterised model, accomplished by coupling to the software PEST, provides information on the factors that mostly contribute to the model output variability. On the other hand, it helps to reduce the complexity of the underlying model. We show simulation studies regarding ad- and desorption of phosphorus and citrate that compete for sorption sites, modeled by a Langmuir-type isotherm. We additionally compare phosphorus root uptake for concentration- and time-dependent exudation patterns versus constant exudation. This model will build the basis for three dimensional root-scale simulations of phosphorus uptake (Leitner et al. 2010). Comparison of the parameter sensitivities on both scales should enable to figure out processes that are leveled out or even have more impact on phosphorus efficiency on the higher root system scale.

Leitner D, Klepsch S, Bodner G, Schnepf A (2010a) A dynamic root system growth model based on L-systems. Plant and Soil 332:177–192.