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Pore-scale simulation of mucilage drainage using phase field method.

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Rhizosphere differs from bulk soil due to the presence of root mucilage, which affects physical, chemical, and microbial processes. It is well known that the rhizosphere responds slowly to water potential changes, which buffers changes in water content and helps keep the rhizosphere wetter than bulk soil during drying. Mucilage can affect solute transport and gas diffusion by affecting the distribution of liquid and gas phases. Despite increased recognition of the importance of mucilage, there still is a lack of models that describe the connectivity between different phases in the pore space of the rhizosphere during wetting and drying. The main challenge for model development is the complex concentration-dependent behaviour of mucilage. At low concentrations, mucilage is more like a liquid, whereas at higher concentrations, dry mucilage becomes a solid. In between, a viscoelastic state is observed where mucilage can be considered as a hydrogel.

In previous work, we have developed a model based on a lattice spring method (LSM). This model was able to simulate the distribution of mucilage in the dry state at the pore scale. However, for wetter states, it is necessary to consider additional physical phenomena like surface tension, contact angle and viscoelasticity. In this study, we therefore aim to develop a Lattice-Boltzmann simulation framework to simulate two phase flow involving mucilage. To capture the interface between the two phases, a phase-field method will be used for interface tracking as this approach has gained considerable attention in recent years. The simulations will proceed as follows. We first assign the properties of a Newtonian fluid to the mixture of water and mucilage and calculate the equilibrium distribution of the liquid phase (mixture of water and mucilage) and gas in a simple pore geometry. Then, the water content will be gradually decreased, which will lead to an increase of mucilage concentration. This will in turn affect the viscosity, surface tension and contact angle, which will result in the emergence of the required viscoelastic behaviour of the mixture. For each of the water contents, the distribution of liquid (or hydrogel) and gas phases will be calculated.

The newly developed model will provide us with new perspectives on hydrodynamic processes within the pore space of the rhizosphere. In addition, the model will help to better understand processes that strongly depend on hydraulic dynamics in the rhizosphere, such as solute transport, root penetration resistance, rhizosheath formation, and microbial activity.

Participation

In-Person

References

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