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The Co-Effect of Root Exudates and Incubation Time on Solute Transport in the Rhizosphere

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Root exudates alter the rhizosphere's physical properties, but the impact these changes have on solute transport is largely unknown. Additionally, root exudates enhance the microbial activity in soil, which may further change the rhizosphere's physical properties, including solute transport. In this study, we tested the effects of chia mucilage and wheat root exudates on the transport of iodide in saturated soil. Solute breakthrough experiments, conducted in loamy sand soil or coarser textured quartz sand, revealed that increasing the exudate concentration in soil resulted in non-equilibrium solute transport. This behavior was demonstrated by an initial solute breakthrough after fewer pore volumes and the arrival of the peak solute concentration after greater pore volumes in soil mixed with exudates compared to soil without exudates. These patterns were more pronounced for the coarser textured quartz sand than for the loamy sand soil and in soil mixed with mucilage than in soil mixed wheat root exudates. Parameter fits to these breakthrough curves with a mobile-immobile transport model indicated the fraction of immobile water increased as the concentration of exudates increased. For example, in quartz sand, the estimated immobile fraction increased from 0 without exudates to 0.75 at a mucilage concentration of 0.2%. Saturated breakthrough experiments were also conducted in a loamy sand soil mixed with mucilage and incubated at 25 °C for different time periods of up to 28 days. In this set of experiments, mucilage at a concentration of 0.2% in the soil had no effect on the iodide breakthrough curve prior to soil incubation, while 0.4% mucilage concentration altered the transport pattern (as described above), and its breakthrough curve pattern remained stable for the entire incubation period. However, after a 7-day incubation period, the breakthrough curve of soil with 0.2% mucilage concentration was also altered, again showing earlier breakthrough and later arrival of the peak iodide concentration compared to the breakthrough curve before incubation. This breakthrough pattern persisted for the remainder of the incubation period. The results of this study indicate that root exudates alter the rhizosphere's transport properties and that enhanced microbial activity following root exudation may further affect solute transport. We hypothesize that this is due to exudates creating low-conducting flow paths that result in a physical non-equilibrium solute transport. Additionally, we hypothesize that enhanced microbial activity following root exudation results in secretion of extracellular polymeric substances and generation of biofilm that further affect the flow paths in soil, thus potentially altering solute transport in the rhizosphere with time.