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Using glucose to mimic root exudates overestimates the rhizosphere priming effect

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Glucose is frequently employed as a surrogate for root exudates in priming studies due to its simplicity and prevalence in plant physiology. Glucose-induced priming can accelerate the decomposition of organic matter through co-metabolism. This may lead to increased releases of greenhouse gases such as CO_2 and CH_4, thereby exacerbating climate change feedback loops, which is especially relevant for thawing permafrost regions. Root exudates themselves are more complex than glucose, containing a diverse array of organic acids, amino acids, phenolics, and nitrogen-containing compounds. Many priming studies do not capture this complexity and associated functions beyond co-metabolism, including mineral dissolution, nutrient acquisition, microbial interactions, and soil structure modulation. We hypothesize that glucose will prime soils to unnaturally high respiratory output compared to plant-derived root exudates and unidirectionally drive carbon decomposition and biogeochemical responses.

To examine our hypothesis, we primed a thawed permafrost mineral soil in anoxic microcosms with four distinct exudate compositions at realistic concentrations: glucose, a more complex carbon mix of sugars and organic acids without nitrogen, the same complex carbon mix with nitrogen, and plant-derived exudates. Lower CO_2 emissions were noted for plant-derived root exudates and the nitrogen-containing complex mix within days after spiking, compared to glucose and the non-nitrogen complex mix. This suggests that nitrogen may play a pivotal role in diversifying metabolisms once released into soils. Interestingly, the impact on CH_4 emission was even more pronounced than on CO_2, with significantly more CH_4 being primed by glucose and the non-nitrogen complex mix, compared to plant-derived and nitrogen-containing root exudates. Considering the influence of aqueous carbon characteristics and the fate of electron acceptors such as iron and nitrogen-species, we infer that glucose-based priming studies may fail to capture prolonged mineral dissolution facilitated by organic acid components of root exudates and may overstimulate methanogenesis due to nitrogen cycling deficiencies.

Thus, our findings indicate that for priming studies, artificial mixes of sugars and organic acids with a nitrogen-containing compound should be favored over using glucose to better capture biogeochemical responses to priming, as the latter may lead to exaggerated responses.