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Microbial carbon use efficiency and priming of soil organic matter mineralization by glucose additions in boreal forest soils with different C:N ratios

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The controlling factors and role of different soil microorganisms in rhizosphere priming effects (PE) are not yet well understood, especially the link between microbial growth and their carbon use efficiency (CUE) and PE remains poorly understood. We hypothesized that the positive PE (enhanced SOM decomposition) results from microbes using the additional C/energy from added labile substrates to decompose recalcitrant materials to release N ("microbial N mining hypothesis"). High CUE could lead to efficient growth of microbes and thus more decomposition of SOM and higher PE.

To test these hypothesis we assessed PE along a boreal forest gradient ranging from Estonia to Northern Finland, with soil C:N ratios and fungal to bacterial ratios increasing towards north. The soils received daily additions of ^{13}C-labelled glucose during one week (dissolved in heavy water, 5 at% D_2O). Control soils received D_2O only. Respiration of glucose and respiration of SOM were distinguished by continuously measuring $^{13}CO_2$ using a Picarro analyzer. We also measured microbial incorporation (into PLFAs) of ^{13}C and D to assess to which extent different microbial groups rely on labile C input (^{13}C-labelled) and on SOM. We further used these results to calculate the CUE of glucose and of SOM decomposition.

Glucose additions induced PE (12-52% increase in SOM respiration) in all soils, but there was no linear relationship between PE and soil C:N ratio. Instead, cumulative PE (μg C g^{-1} SOM) and the relative magnitude of the PE (%) were positively correlated with the average C:N imbalance experienced by the microbes (calculated as soil C:N ratio/microbial biomass C:N ratio). There was a positive relationship between the potential activity of total oxidative enzymes and the cumulative SOM respiration, but the same enzyme concentration resulted in higher SOM respiration in the glucose treatment. We suggest that glucose additions increased the activity of these enzymes rather than their concentrations.

Microbial incorporation of D and ^{13}C into in PLFAs demonstrated that glucose additions stimulated both fungal and bacterial growth. Our results indicate that increased growth of fungi on the added ^{13}C glucose was especially important for the PE, since the magnitude of PE was correlated with the

ratio of fungal/bacterial growth on glucose and on SOM. High C:N ratio soils were fungal dominated, and there was a clear positive relationship between glucose CUE and fungal to bacterial ratio, indicating that fungal dominated communities had higher CUE. Bacteria were more affected by low N availability, since total bacteria growth and ^{13}C uptake were lower in the high C:N ratio soils. When fungal growth was high relative to bacterial growth CUE was consistently higher, whether it was the total CUE, CUE of glucose or SOM respiration. Our results indicate that if fungal dominated communities can efficiently grow on the added glucose, they will have excess resources for decomposing N releasing recalcitrant substrates. This releases bioavailable C and N that can also increase bacterial respiration of SOM derived C.