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Moving beyond stoichiometry: Simple substrates do not fully capture complex pathways of root exudate decomposition

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The vulnerability of vast carbon (C) stocks stored in Arctic soils to rapid climate warming is widely recognized. But, climate warming is also increasing plant productivity, which could either ameliorate or enhance soil C loss. The potential for new C inputs to balance losses will depend on how efficiently plant-derived C is incorporated into microbial products, the precursor of soil organic matter (SOM) formation, versus converted to CO_2 and released to the atmosphere. Additionally, new plant litter and root exudates could induce a priming effect, enhancing the turnover and loss of older SOM stocks.

To test whether enhanced plant productivity in the Arctic promotes new soil C formation, or increases SOM losses, we amended mineral soils collected from northern Alaska with isotopically enriched (13C and 15N) root products collected from two dominant Arctic plants: B. nana, a dwarf shrub with relatively high-quality litter, and E. vaginatum, a tussock-forming sedge with lower quality litter. We also amended soils with isotopically enriched model compounds—including glucose (no N), glycine (low C:N), and a mixture of glucose and glycine (intermediate C:N)—to test whether substrate stoichiometry controls the fate of SOM stocks. We hypothesized that (1) substrate chemistry controls the efficiency of microbial metabolism and (2) C:N ratios are sufficient in describing the fate of SOM stocks. To test these hypotheses, we used stable isotope tracing techniques to quantify the fraction of each substrate that was converted to CO_2, assimilated into microbial biomass, or transformed into necromass after 10 or 30 days of incubation. We quantified the proportion of substrate associated with soil fractions (particulate, sand, or silt/clay) to estimate turnover rates of substrate remaining in mineral soils. Finally, we used ultrahigh resolution FT-ICR mass spectrometry to elucidate the chemical diversity of shrub versus shrub-derived root products, and to assess shifts in the molecular composition of metabolites following microbial metabolism during incubation.

We found that model compounds induced priming responses, resulting in significant turnover of native SOM stocks. Glycine was metabolized more efficiently than glucose, resulting in a significant transformation of the metabolite profile. Specifically, higher quality compounds were consumed (high O/C), microbial derived metabolites were produced (including proteins, amino sugars, and lipids), and lower quality compounds accumulated (lignins and tannins). As microbe-derived products are more easily stabilized within the mineral matrix, the addition of higher quality substrates may contribute to SOM formation, even as high-latitude regions warm. However, while these results suggest variable C:N ratios induce different microbial responses, we found no evidence of priming when soils were amended with chemically diverse, natural root exudates. This was particularly evident in soils amended with sedge-derived root products, which increased microbial growth and SOM formation relative to soils amended with less diverse, tannin-rich shrub-derived root products. Together, our results suggest model compounds may overestimate SOM losses, and C:N ratios alone may be insufficient in predicting the fate of SOM stocks.