The Influence of Drought on Carbon-Use Efficiency and Soil Carbon Formation in Rhizosphere and Detritusphere Microbial Communities

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Project Goals: Soil organic matter (SOM) is critical to soil health and Earth's climate. Microorganisms play key roles in SOM turnover via their metabolic activities, cellular biochemistry, and extracellular products. We hypothesize that microbial cellular-chemistry, functional potential, and ecophysiology fundamentally shape SOM persistence, and we are characterizing this via stable isotope probing (SIP) of genome-resolved metagenomes and viromes. We focus on soil moisture as a 'master controller' of microbial activity and mortality, since altered precipitation regimes are predicted across the temperate U.S. *Our SFA's ultimate goal is to determine how microbial soil ecophysiology, population dynamics, and microbe-mineral-organic matter interactions regulate the persistence of microbial residues under changing moisture regimes.*

Abstract: Microbial residues are dominant ingredients of persistent soil organic matter (SOM). Via the 'microbial carbon pump,' plant carbon from litter and rhizodeposition is processed by the microbial community *en route* to forming SOM. As the largest actively cycling reservoir of carbon, SOM is of critical importance to the global carbon balance and soil health. Yet, major uncertainty surrounds the microbial ecophysiological traits that regulate the microbial carbon pump, and how the relative importance of these traits varies in different soil microhabitats (e.g. the rhizosphere and detritusphere) and under different moisture conditions. Most attention to date has focused on the role microbial carbon-use efficiency (CUE), because this trait captures the partitioning of carbon to new microbial growth versus microbial respiration. For this reason, CUE has been widely posited to be positively related to MAOM formation. Yet there exists virtually no mechanistic evidence in support of this relationship to date.

We conducted a 12-week ^{13}C tracer study to track the movement of two dominant sources of plant carbon – rhizodeposition and root detritus – into soil microbial communities and SOM pools under normal moisture (15 ± 4.2 %) or droughted (8 ± 2%) conditions. Using a continuous $^{13}CO_2$-labeling system, we grew the annual grass *Avena barbata* in controlled growth chambers and measured formation of SOM from ^{13}C-enriched rhizodeposition. As the plants grew, we harvested rhizosphere and bulk soil at three time points (4, 8, and 12 weeks) to capture changes in SOM pools and microbial community dynamics. In a second set of microcosms, we tracked the formation of SOM derived from ^{13}C-enriched *A. barbata* root detritus during 12 weeks of decomposition, harvesting detritusphere and bulk soil at 4, 8, and 12 weeks. In a third set of

microcosms, we studied the combined influence of rhizodeposition and root detritus, separately tracking the contributions from each root C source using a reciprocal ^{13}C-labeling design.

For all harvest points, we density fractionated the soil to isolate the slower-cycling, mineral-associated organic matter (MAOM) fraction, as well as the faster-cycling particulate organic matter (POM) fraction. We also measured a suite of microbial ecophysiological traits that we predict are important in soil carbon formation and persistence. Here, we present data on ^{13}C-MAOM formation, as well as microbial CUE, measured via the ^{18}O-H_2O method.

We found CUE was on average 22% higher in the rhizosphere than in the detritusphere, and 34% higher under normal moisture versus drought conditions. The magnitude of difference in CUE between normal moisture vs. drought treatments also increased through time in both the rhizosphere (coeff. = 0.62; p=0.04) and detritusphere (coeff.=0.69, p=0.02). Similarly, we observed greater ^{13}C-MAOM formation under normal moisture vs. drought conditions in both the rhizosphere (25% increase) and detritusphere (13% increase). Notably, we did not find support for a positive relationship between CUE and ^{13}C-MAOM formation. Across treatments, there was a weak negative relationship between CUE and ^{13}C-MAOM formation ($r^2 = 0.11$, $p<0.01$). There were, however, key differences in both the direction and magnitude of this relationship based on microbial habitat, moisture status, and time (three-way interaction; F=3.75, p=0.05).

Overall, we found the CUE-MAOM relationship was context-dependent, and that CUE was often a poor predictor of MAOM formation. By extension, there may be other microbial ecophysiological traits (e.g. production of extracellular polymeric substances, growth rate) that better predict MAOM formation than CUE alone. This implies that new research must focus on a broader suite of microbial traits – including but not limited to CUE – to model the role of microbes in MAOM formation and SOM persistence.

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