Soil habitats and water limitation shape microbial traits correlated with formation of mineral-associated organic matter

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Project Goals: Microorganisms play key roles in soil carbon turnover and stabilization of persistent organic matter via their metabolic activities, cellular biochemistry, and extracellular products. Microbial residues are the primary ingredients in soil organic matter (SOM), a pool critical to Earth's soil health and climate. We hypothesize that microbial cellular-chemistry, functional potential, and ecophysiology fundamentally shape soil carbon 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: Soil microorganisms are frontline managers of the terrestrial carbon cycle. To better understand and model their effects under a changing climate, it is critical to determine which microbial ecophysiological traits are associated with soil organic matter formation – particularly mineral-associated organic matter (MAOM). Yet major uncertainty surrounds the traits that regulate this process, and how environmental context (e.g. spatial habitat, moisture conditions) shapes the manifestation of these traits. Microbial carbon-use efficiency (CUE) is posited to be positively correlated with MAOM formation, yet direct evidence for this relationship is sparse, and few other microbial traits have been directly tested as predictors of MAOM formation.

To investigate the relationship between different microbial traits and MAOM, we conducted a 12-week ^{13}C tracer study to track the movement of rhizodeposits and root detritus into microbial communities and SOM pools under moisture replete (15 ± 4.2 %) or water-limited (8 ± 2%) conditions. Using a continuous $^{13}CO_2$-labeling growth chamber system, we grew the annual grass *Avena barbata* for 12 weeks and measured formation of ^{13}C-MAOM from either ^{13}C-enriched rhizodeposition or decomposing ^{13}C-enriched root detritus. We also measured active microbial community composition (via ^{13}C-quantiative stable isotope probing; qSIP) and a suite of microbial traits including carbon-use efficiency, growth rate, and turnover (via the ^{18}O-H_2O method), extracellular enzyme activity, bulk ^{13}C-extracellular polymeric substances (EPS), and total microbial biomass carbon (^{13}C-MBC).

We found that microbial traits associated with MAOM formation were distinct between the rhizosphere versus the detritusphere, and their effect was influenced by soil moisture. In the rhizosphere, fast growth and turnover were positively associated with MAOM, as were total ^{13}C-MBC and ^{13}C-EPS production. In contrast, growth rate was negatively associated with MAOM formation in the detritusphere, as were CUE, ^{13}C-MBC, and ^{13}C-EPS. However, total extracellular enzyme activity was positively associated with MAOM in the detritusphere. These results, paired with data on the chemical composition of MAOM (via STXM-NEXAFS) suggest that traits associated with fast growth and turnover, as well as high necromass yield, generate microbial-derived MAOM in the rhizosphere, whereas traits associated with resource acquisition generate plant-derived MAOM in the detritusphere. In these soil habitats, ^{13}C-qSIP indicated that fungal taxa were more active in the detritusphere, whereas certain bacterial phyla (e.g., *Firmicutes*) were more active in the rhizosphere. Together, our results show that the rhizosphere has distinct traits, communities, and pathways of MAOM formation relative to the detritusphere. Future research should consider a broad suite of microbial traits – including but not limited to CUE – to model the role of microbes in MAOM formation in distinct soil environmental conditions.

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