Distribution of soil microbial necromass accumulation controlled by microbe-mineral interactions

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Project Goals: The overall goal of this project is to test if plant-microbe interactions are limited to influencing the rate of C accrual, while mineralogy regulates the sink capacity of biofuel cropping systems. To accomplish this goal, we are identifying the microbial functions and biopolymers of microbial necromass that contribute to soil C accumulation under controlled conditions and characterizing microbial necromass accumulation in response to crop selection and edaphic factors in situ.

Abstract:
Soil organic matter (SOM) is a reservoir for global carbon (C) that maintains soil fertility and prevents the release of greenhouse gases. A major contributor to SOM is necromass, consisting of dead microbial cells and cellular components. Yet methods for enhancing the accumulation of microbial residues and necromass in soil are still unknown. We hypothesized that the quantity of microbial residues that accrue and persist is positively correlated with the abundance of poorly crystalline iron minerals in soil. To test this hypothesis, we incubated soils from two agricultural research sites varying in soil texture and background C content, derived from the Great Lakes Bioenergy Research Centers. Sandy and silty loam soils were incubated with ^{13}C-glucose for 12 months to trace the fate of microbial-derived residues. We found an average of 30% of added ^{13}C was recovered as microbial necromass after the course of the incubation. Density fractionation was used to separate light and heavy fractions of the mineral-associated organic matter (MAOM). Approximately 88% of the total recovered ^{13}C labeled necromass was found in the fine (<53 μm), MAOM fraction. The light MAOM fraction, which is typically dominated by organo-mineral complexes, accumulated three times more ^{13}C necromass than the heavy MAOM fraction. Further investigation via Mössbauer spectroscopy revealed that the light MAOM contained more amorphous iron-bearing minerals, whereas the heavy MAOM fraction had more phyllosilicates. Specifically, light MAOM had twice the amount of nano-size goethite and organo-Fe complexes compared with heavy MAOM. Most interestingly, light MAOM of the sandy loam soil had up to 11 times the ferrihydrite content as the heavy MAOM. This high concentration of amorphous iron-bearing minerals likely contributed to the accumulation of microbial-derived necromass in light MAOM via sorption or complexation. In addition, nanoscale secondary ion mass spectrometry (NanoSIMS) images revealed more ^{13}C enriched hotspots in light MAOM than that in heavy MAOM, supporting the abundance of microbial-derived necromass in light MAOM after the long-term incubation. Surface C chemistry analysis by X-ray photoelectron spectroscopy (XPS) revealed that light MAOM fraction had a lower abundance of alkyl or aryl compounds commonly derived from plant detritus (i.e., carbohydrates or lignin) and a higher abundance of carbonyl or

carboxylic compounds (i.e., proteins) compared to heavy MAOM. By labeling and tracing microbial residues, we demonstrate the importance of fine amorphous mineral surfaces in accumulating microbial-derived necromass in both sandy and silty loam soils.

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