Quantifying the Plant-Microbial Interactions Controlling Soil Organic Matter Formation in Bioenergy to Improve Model Representations of Sustainability

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Project Goals: The Center for Advanced Bioenergy and Bioproducts Innovation's (CABBI) mission is to develop efficient ways to grow bioenergy crops, transform biomass into valuable chemicals, and market the resulting biofuels and other bioproducts. A key part of this mission is to ensure the sustainability of a bioenergy economy by maintaining or enhancing ecosystem services (e.g., soil carbon sequestration, nitrogen retention). However, our ability to predict the extent to which different management strategies and bioenergy feedstocks impact ecosystem services is limited by simplified models that do not represent the diversity of microbial traits or the ability of plant-microbial interactions to feedback on soil biogeochemical cycling. Thus, the goal of this project within CABBI is to quantify these traits and interactions that regulate soil carbon and nitrogen cycling to develop and validate a plant-microbial interactions model that predicts impacts on ecosystem services.

Enhancing soil carbon sequestration may enable the bioenergy industry to achieve carbon neutrality. To realize this potential, we must develop a predictive understanding of how management and feedstock decisions impact carbon stabilization in soil organic matter (SOM). However, there remains uncertainty in how interactions between plant traits (i.e. litter chemistry, rhizosphere exudation) and microbial traits (i.e. carbon use efficiency (CUE), turnover) drive SOM formation for bioenergy feedstocks. This hinders modeling efforts to predict the long term effects of transitioning between bioenergy feedstocks on soil carbon sequestration.

To address this uncertainty, we investigated key plant and microbial trait interactions influencing SOM formation for traditional bioenergy corn and alternate Miscanthus x Giganteus (miscanthus) feedstock systems. Plant-microbial interactions influence SOM formation indirectly through litter chemistry with rapidly, decomposing litters driving efficient microbial biomass production that upon death is thought to preferentially form mineral-associated SOM over particulate SOM. Thus, we hypothesized that low carbon to nitrogen ratio (C:N) corn litter decomposes faster and forms more mineral associated SOM than high C:N miscanthus litter. Directly, plants influence SOM formation by exuding carbon to microbes in the rhizosphere (zone of soil proximal to plant roots) in exchange for nutrients, promoting microbial activity and mineral-associated SOM formation. Given differences in fertilization rates and root traits between feedstocks, we hypothesized that soil microbes in miscanthus systems have a greater capability to use root exudates to drive greater biomass production and mineral associated SOM formation than heavily fertilized corn systems. To test these hypotheses in the lab, we incubated

^{13}C isotopically labeled aboveground and belowground litter from each crop in soil collected from experimental plots at the University of Illinois Energy Farm to assay microbial traits and trace the fate of litter into microbial biomass, CO_2, and mineral vs. particulate SOM pools. We simulated root exudates by adding a cocktail of organic acids to half of the incubated samples.

In support of our first hypothesis, preliminary results show that corn litter initially decomposed very rapidly, prompting greater respiration losses of carbon compared to miscanthus litter. In the last four weeks, corn litter decomposition slowed as litter C was likely immobilized in microbial biomass and mineral associated SOM. By contrast, miscanthus litter C continued to decompose at a consistent rate by less efficient microbes with more of the litter likely remaining in particulate SOM forms. Supporting our second hypothesis, exudate carbon additions promoted decomposition of litter over SOM in corn. By contrast, miscanthus showed the opposite pattern with exudates primarily speeding up SOM decomposition. Collectively, these results indicate that there is an important interaction between litter chemistry and root traits that controls the formation and decomposition of SOM in bioenergy systems. In addition, these data can be used directly to reduce parameter uncertainty in microbial traits and the fate of bioenergy plant inputs in microbial-mediated decomposition models.

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