Developing a Novel Plant-Microbial Interactions Model to Predict the Impacts of Bioenergy Crops on Soil Carbon and Nitrogen Cycling

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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 in the rainfed US by maintaining or enhancing existing 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 predictive model formulations that do not represent the diversity of microbial traits as well as the ability of plant-microbial interactions to feedback on soil biogeochemical cycling. Thus, the goal of this project within CABBI is to develop and validate plant-microbial interactions model that predicts interactions between plant and microbial traits and the resulting impacts on ecosystem services.

Accurate projections of the impacts of bioenergy crop production on soil carbon (C) and nitrogen (N) cycling by ecosystem models depend on how they represent the interactions between roots, free-living microbes, and symbiotic microbes. While empirical research has highlighted the rhizosphere as a hotspot for the trading of photosynthate C for soil N between roots and microbes; this plant C allocation pathway and the resulting impacts on soil microbial activity are missing from most models. To bridge this knowledge gap, we have adapted a state-of-the-art model that dynamically predicts plant-microbial interactions, Fixation and Uptake of Nitrogen – Carbon, Organisms, and Rhizosphere Processes in the Soil Environment (FUN-CORPSE), to bioenergy crop systems by incorporating representations of tillage, fertilization, and harvest fluxes and timing. In addition, we have begun work to integrate quantitative stable isotope probing data that allows us to develop distinct fungal and bacterial guilds in the model that vary in key traits such as carbon use efficiency and turnover.

First, we confronted and validated the newly developed bioenergy crop model with datasets from two bioenergy crop systems—switchgrass and corn. We ran model experiments to examine the extent to which C-N dynamics vary as a function of agricultural management practices and N availability in soils. Results from our model experiments showed that soil C in corn was more sensitive than in switchgrass to management practices. However, incorporating a no-till method in the model on the corn systems was able to reduce the impact on soil C losses. Altering harvesting methods in our model to allow more standing biomass to remain as crop residues resulted in a significant increase in soil C stocks. Second, we performed a preliminary model experiment to test whether parameterizing distinct fungal and bacterial guilds that vary in carbon use efficiency, turnover, and their ability to degrade soil organic matter substrates were able to capture soil respiration data from a lab incubation experiment. As we iteratively improved parameterizations of whole microbial community traits to distinct fungal and bacterial traits, the ability of the model to predict soil respiration improved. Collectively, our newly developed bioenergy crop model provides a novel framework that will enhance our ability to predict how interactions between plant and microbial traits impact the sustainability of new bioenergy crops and management techniques.

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