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Understanding microbial contributions to soil aggregation and organic matter accumulation

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Abstract
The goal of the project investigators was to characterize soil bacterial and fungal communities and the rates at which they break down specific plant-derived carbon (C) molecules within soil aggregates in three farming systems.

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Agronomy and Crop Sciences | Environmental Microbiology and Microbial Ecology | Soil Science

Understanding microbial contributions to soil aggregation and organic matter accumulation

Abstract: The goal of the project investigators was to characterize soil bacterial and fungal communities and the rates at which they break down specific plant-derived carbon (C) molecules within soil aggregates in three farming systems.

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$39,548 for year one

ECOLOGY

Q How do soil fungal communities, and their associated activity, affect soil structure, fertility, and long-term storage of carbon in conventional and alternative cropping systems?

A Evidence for improved soil structure was seen through the positive relationship between increased microbial biomass, increased microbial enzyme activity and increased soil aggregation in the fertilized prairie systems compared to the other cropping systems. These differences coincided with decreased soil carbon (C) loss in fertilized prairie as measured by total soil C between 2008, when the plots were established, and 2012 when soils were collected for the study.

Background

An understanding of the mechanisms regulating soil carbon cycling is essential to help producers and their advisors identify optimal practices and management strategies. This research was conducted to provide an explicit understanding of microbial community and ecological mechanisms that regulate soil organic matter (SOM) storage in agricultural soils.

To meet these objectives, the project team leveraged an existing collaborative project, Comparison of Biofuel Systems (COBS), which involves members of the Iowa State University Departments of Agronomy; Ecology, Evolution and Organismal Biology; and Agricultural and Biosystems Engineering. This collaboration facilitated integration of soil microbial community and functioning data with plant community, root growth and turnover, soil greenhouse gas emission, and nutrient leachate data also generated at the COBS research site. To identify the specific microbial mechanisms, the researchers proposed to characterize soil fungal communities within soil aggregates from three bioenergy farming systems (continuous corn, prairie, fertilized prairie) using next generation DNA sequencing technology. These new data were integrated with existing data measuring soil bacterial communities and microbial enzyme activity within the same aggregates, generating a complete picture of the microbial mechanisms controlling C cycling within these farming systems.

Specific objectives for this project were to:

- Compare the belowground mechanisms (i.e., microbial biomass, composition, and enzyme activity) regulating SOM formation, aggregation and long term C storage among conventional and alternative cropping systems; and
- Enhance understanding among agricultural stakeholders in how to manage soil C.

Soil core (0-10 cm) from unfertilized prairie managed for bioenergy. (Photo courtesy of Elizabeth Bach.)

Approach and Methods

The completed work was part of the COBS research and education project located at Iowa State University's South Reynoldson Farm in Boone County, Iowa. This large-scale experiment (24 plots, each 27 m x 61 m) was designed to compare five biofuel feedstock production systems; only three were considered in this work: (1) continuous corn harvested for grain and biomass; (2) unfertilized multispecies prairie harvested for biomass; and (3) N-fertilized multispecies prairie harvested for biomass. Each cropping system treatment was replicated four times. The experiment was established in 2008 and all cropping systems were managed without tillage.

To specifically evaluate soil fungal communities, the investigators extracted fungal DNA from soil and soil aggregate fractions taken from the continuous corn, prairie, and fertilized prairie treatments. Soil aggregates enabled them to observe soil fungal communities at spatial scales in which fungi interact with each other and the organic matter, which they decompose. The researchers measured soil microbial activity by measuring the activity of digestive enzymes produced by soil microbes. They also measured soil carbon and nitrogen content.

Results and discussion

The results suggested that fungal and bacterial activity play a key role in soil aggregation and carbon and nitrogen retention in the COBS management systems. The research team found prairie systems had larger and more diverse fungal communities, supporting 33 percent more fungal taxa than corn systems. Indicator taxa analysis showed that fungal communities in corn systems were characterized by the fungal families Pleoporaceae, Cystofilobasidiaceae, and Chaetomiaceae. Chaetothyriaceae, Mycoshaerellaceae, Lasiosphaeriaceae, and unclassified Helotiales were indicators for fertilized prairie communities, and unfertilized prairies supported a high abundance of uncultured fungi and fungi with poorly understood taxonomic placement. These results could reflect an increase in fungi which primarily break down complex plant-derived organic matter in prairie systems, particularly unfertilized prairie, as these fungi may be the most difficult to culture in laboratory conditions. Communities in large macro-aggregates were characterized by Glomeromyocta, underscoring their importance in soil aggregate formation and stabilization. Data also showed that soil microbial biomass and enzyme activity were greater in fertilized prairie systems.

Greater soil microbial biomass and activity corresponded with greater soil aggregation in fertilized prairie systems, despite fewer root inputs in fertilized prairie compared with unfertilized prairie. This underscores that soil microorganisms play a central role in the processing of plant inputs and retention of soil organic matter through aggregate formation.

Differences in soil microbial communities and aggregation, coupled with plant community differences, contributed to produce unique soil C pools and cycling among the cropping systems. Fertilized prairie systems retained more soil C than unfertilized prairie and corn systems. In addition, temporal shifts in microbial communities and activities were distinct among the cropping systems. Microbial

*Soil and Big Bluestem (*Andropogon gerardii*) stem from prairie managed for bioenergy. (Photo courtesy of Racheal Erb.)*

activity in fertilized prairie systems reached higher levels earlier in the growing season than in unfertilized prairie and corn systems. This may be driven by increased abundance of cool-season plants like Canada wild rye in the fertilized prairie system. This synchrony of microbial activity with plant nutrient uptake may play a role in retention of nutrients in perennial prairie agroecosystems.

Conclusions

Overall, this research provides new insights into soil fungal community composition in classic and alternative cropping systems. It also highlights the importance of soil microorganisms, particularly fungi, in providing key ecosystem services such as soil C retention in managed agricultural systems.

Impact of results

This research demonstrates the critical role soil microorganisms play in processing and storing soil organic matter and retaining soil C. The alternative tallgrass prairie systems outperformed traditional continuous corn systems in providing these microbiologically-driven ecosystem services. These data provide farmers, policy makers, and businesses with the ability to consider these ecosystem services in future management decisions in Iowa. In addition to the many wildlife and pollinator benefits of diversified cropping systems, these results provide new evidence that diversified cropping systems also contribute toward enhancing soil structure, diverse microbial communities and reduced loss of soil carbon.

The outreach brochure, to be published in 2016, will provide these valuable belowground data to farmers, managers, and interested Iowans. Belowground ecosystem services are critical to addressing Iowa's environmental challenges such as surface water nutrient loads and potential mitigation for global climate change. This information can help individual Iowans feel empowered that their land management decisions can have profound impacts on local and global issues.

Education and outreach

Elizabeth Bach presented data from the project at the Midwest-Great Lakes Chapter meeting of the Society for Ecological Restoration (March 2015, Chicago, IL), and at two invited seminars at the University of Illinois at Urbana-Champaign (April 2015, October 2015).

A manuscript and descriptive brochure are being prepared based on the findings of the project.

Leveraged funds

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