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Regional Characterization of Alfalfa & Manure Legacy Impacts on Soil Quality in Crop Rotations

Joshua Gamble, Sarah Castle, Deborah Samac, USDA-ARS

The USDA-ARS Dairy Agroecosystem Working Group (DAWG) is a multi-location research collaboration established in 2014 to support efforts to improve productivity, competitiveness, and environmental sustainability of U.S. dairy farming systems. A central focus of DAWG is to develop a common experiment across all locations. Starting in 2017, multiple DAWG locations began implementing the "manure priming study" with the objective of determining the long-term impacts (economic; environmental; and soil chemical, biological, and physical) of a one-time or short-term manure application. The study idea originated at the USDA-ARS Northwest Irrigation and Soils Lab in Kimberly, ID, where researchers observed improved crop yields from plots that had received manure nearly a decade ago, but now received only mineral fertilizer, compared to plots that only ever received mineral fertilizer.

Figure 1. University of Minnesota Long-term Agricultural Research Network (LTARN) locations where the manure priming study will be conducted.

Table 1. At each LTARN site, experimental plots represent different phases of a 2-year Corn – 3-year Alfalfa rotation (CC/AAA).

System	Sequence	2018	2019	2020	2021	2022
Corn-Alfalfa (CC/AAA)	A	Alf3	Corn1	Corn2	Alf1	Alf2
	B	Corn1	Corn2	Alf1	Alf2	Alf3
	C	Corn2	Alf1	Alf2	Alf3	Corn1

Findings suggest even short-term or single manure applications may influence soil properties, and likely soil microbes, to the benefit of crops for years following application. However, mechanisms responsible for this benefit are unknown. Quantifying true benefits of manure to long-term soil health and crop production could enhance its value and improve economic feasibility of longer-distance manure hauling. This will expand acreage available for land-application, reduce likelihood of overloading soils near livestock operations, and reduce risk of nitrogen (N) and phosphorus (P) losses. The study has been initiated at Kimberly, ID; University Park, PA; and St. Paul, MN, with plans to expand to Bushland, TX, and Fort Collins, CO. The Minnesota experiment was established spring 2019 in corn-alfalfa rotations at three sites representative of the range of soil and climatic variation found in the state (Figure 1).

Objectives are to: 1) determine impacts of dairy manure applications on soil microbial communities and crop yield in forage cropping systems, and 2) explore relationships between soil microbial communities, nutrient-cycling functions, and soil edaphic characteristics in the context of forage-cropped agricultural soils. Treatments include:

1. **Agronomic recommended rate of cattle manure + fertilizer.** A one-time application of manure in spring 2019; from 2020 onward, fertilizers applied based on soil tests and established recommendations.

2. **High rate cattle manure + fertilizer.** A one-time application of manure in spring 2019; from 2020 onward, fertilizers applied based on soil tests and established recommendations. Manure and fertilizer for yield goals that are 10-20% higher than expected.

3. **Agronomic recommended conventional fertilizer.** Annual fertilizers applied based on soil tests and established recommendations.

4. **Control.** No nutrient inputs.

Dairy manure and fertilizer were applied in mid-May 2019 and corn and alfalfa planted soon after. Soil samples were collected prior to manure application and will be collected each spring for the duration of the study (expected to be at least 5 years). DNA will be extracted from samples and microbial composition and diversity will be evaluated using next-generation sequencing. Soil subsamples will be sent for chemical analysis at the University of Minnesota Research Analytical Laboratory.

In total, these data will be used to evaluate impacts of dairy manure additions, cropping system phase (alfalfa vs. corn), and agricultural site, on soils and microbial communities. For each site, we will characterize treatment impacts on soil chemical and physical properties, and composition, richness, diversity, and relative abundances of key bacterial and fungal taxa. We will examine relationships between these microbial indices and soil chemical and physical parameters. Though these initial efforts are focused on broadly characterizing microbial community structure, they will provide important insight into how manure and fertilizer treatments impact the relative abundances of microbial taxa associated with plant health and nutrient cycling (e.g., N-fixers, mycorrhizal fungi, pathogens, N-cycling bacteria). Beyond year one, in coordination with DAWG, we will begin exploring whether observed shifts in relative abundances of certain microbial groups translate to variations in potential soil functions. This work will attempt to link key N-cycling processes (e.g., biological nitrogen fixation, nitrification) and key N-cycling marker genes (e.g., *nifH* encoding nitrogenase – key enzyme for N fixation; *amoA* encoding ammonia monooxygenase – key enzyme for nitrification) with microbial community structure and soil properties.

Figure 2. Liquid dairy slurry was hand-broadcast with five-gallon buckets, then immediately incorporated with a field cultivator.