PROJECT PROPOSAL

Project Title:
Is Foliar Feeding an Economical Way for Organic Dairy Farmers to Boost the Quality and Quantity of Forages?

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Description

Foliar feeding is the practice of applying water-soluble fertilizers directly onto foliage of target plants (Kaushal et al. 2014). Foliar application of nitrogen (N), phosphorus (P), potassium (K) and a number of micronutrients has become fairly common for several crops, including corn, soybean, wheat, fruit trees and forage (Reuveni and Reuveni 1998; Dhiraj and Kumar 2012; Wang et al. 2016). In legume and grass forages, farmers usually apply some sort of fertility booster after each cutting throughout the growing season to ensure a consistent supply of high-quality forage (Weiss 2008; Geauga News 2013). High quality forage is important for milk production and to reduce the need for supplemental feed. A growing number of dairy farmers find foliar feeding to be a handy and reliable alternative to traditional soil- applied fertilizers for boosting crop fertility (Ron Milner, organic dairy farmer, Holmesville, Ohio, pers. comm.; Appendices 1 & 2). Interest is increasing in our area as farmers consistently claim to see a superior effect on yield and crop quality when compared to the soil application of fertilizers (Mike Kline, Organic Valley Regional Pool Manager, pers. comm.).

Environmental and crop protection benefits have been claimed as another advantage of foliar feeding. Giskin et al. (1984) reported that substituting some soil fertilizer applications with foliar applications to vegetables reduced the need for fertilizer inputs by 25%, with no reduction in yield. They concluded that foliar feeding would decrease water contamination from nutrient run off (Giskin et al. 1984). Foliar feeding may also induce plant protection responses to pathogens. Reuveni and Reuveni (1998) found that a single NPK application suppressed powdery mildew on cucumber, greenhouse-grown roses, field- grown mango, nectarine and grapevine.

Despite the purported benefits, foliar feeding remains a highly controversial practice with little robust scientific data in support. Promoters of foliar feeding advertise better absorption efficiency of micro- and macronutrients into crop leaf tissue when compared to soil applications, as much as 8, 10 or 20 times (Kaushal et al. 2014; MSU, field trials). However, only a few studies have demonstrated an increase in yield when the soils' ability to provide nutrients is limited (https://puyallup.wsu.edu/lcs/;

Kaushal 2014). Under temporary drought and saline conditions, the application of foliar fertilization did not improve corn growth (Hu et al. 2010). The authors also observed a reduction in the uptake of potassium (K), calcium (Ca) and magnesium (Mg), which they attributed to reduced transpiration. Ling et al. (2007) found no consistent or significant yield response in corn, even when there was an increase in NPK in the leaf tissue. Similar results were observed in soybeans foliar-fed at the V5 growth stage (Haq et al. 2000) and at the start of podding (R1) (Moreira et al. 2017). Woolfolk et al. (2002) reported an increase in wheat grain protein content, but not yield, following N foliar-applied at early post flowering. And while evidence supports rapid absorption of nutrients through leaves (Wittwer et al. 1959), foliar feeding has no substantial residual effect and applications need to be repeated throughout the growing season.

The foliar-feeding response seems to differ with crop type and growth stage, as well as environmental and local soil conditions, which increases the chance for variable results within and across research studies. Foliar absorption of specific micro- and macronutrients are absorbed by leaves through their stomata or in some cases their cuticles (Wittwer et al. 1959). Factors such as time of day, temperature and plant maturity can then affect how well nutrients are absorbed (MacPherson et al. 1975; Hu et al.
2010). However, because foliar feeding recommendations are provided mainly by the industry rather than universities, these recommendations tend to be generalized and may not take into account differences among farms regarding soils and crops, or differences in application time of day and other environmental conditions.

Regardless of the lack of scientific support, foliar-feeding of forage legumes and grasses is getting more and more popular, and many organic farmers are investing heavily in OMRI-approved products to boost fertility. In Ohio, the number of organic dairy producers using foliar feeding has increased by 500% over the last five years (Mike Kline, Organic Valley Co-op, Holmes County, Ohio, pers. comm.; Appendix
3). The largest segment using foliar-feeding is the all-grass milk producer community. SoilBiotics, a company based in Illinois, is one of the main providers of foliar-applied products in Wayne and Holmes Counties, Ohio. The Maysville Grain Elevator (Apple Creek, Ohio) sold about 8,500 gallons of eFISHnt, SoilBiotics' most commonly used product, in Ohio in 2016, and close to 14,000 gallons in 2017. Some of the products are used for other crops, but 65% is for foliar application to forages (Doug Billman, Twinbill Agricultural Services, LLC and Agronomy Consultant for SoilBiotics, pers. comm.; Mike Kline, pers. comm.; Appendices 3 & 4).

Limited information is available on the efficiency of foliar-applied fertilizers. Is it an economically viable practice? What benefits does the foliar-feeding actually provide? The few previous studies that have been done to evaluate the effects on alfalfa and mixed forage yield provide equivocal support (Lang and Pecinovsky 2015; Lewandowski 2015; Appendix 5). Despite these uncertainties, dairy farmers in our area continue to rely heavily on foliar feeding to boost yield and quality of their forage.

We propose to conduct research trials during the 2018 field season on the effects of the most commonly used organic foliar fertilizers in Wayne and Holmes Counties on organic forage yield and quality. The product manufacturer, SoilBiotics, is willing to provide product, testing and technical support for the proposed trials (Appendix 4). We anticipate that organic dairy farmers will be enthusiastic to participate in this project, because the research objectives address their current needs and observations, rather than simply addressing an interesting scientific question for which their farms are suited. Moreover, we already have strong research-focused relationships, which includes on-farm gypsum trials, with this group of farmers through our soil-balancing project.

We are aware of the challenges in conducting on-farm research and maintaining the enthusiasm and engagement of farmers despite the inconvenience, such as yield loss due to treatment. In addition, on-farm management per se (coordinating treatment applications or sampling with the farmer) can be difficult. *However, because of farmers' increasing investment in foliar feeding, it is important to evaluate these repeated nutrient inputs and determine if they are indeed increasing forage yield or quality (Appendix 5).* Results from this study will form a basis for: evaluating current management strategies, developing reliable recommendations for Extension Educators and farmers to make better decisions, and addressing the next scientific questions directed at a more sustainable way of farming (Appendix 5). Expansion of this research into a future PhD would further help us to generate a better and more comprehensive understanding of this farmer-favored practice.

The specific objectives of our research are to:

1) Evaluate the effects of a foliar fertilization program on yield and quality of alfalfa and mixed grass on organic dairy farms,

2) Estimate the costs and benefits of a foliar feeding program compared with the standard practice of soil-applied livestock manure, and

3) Share these results with Extension Educators and the farming community via various forms of outreach.

Our operational and scientific hypothesis is that soil is the most effective medium for consistent and long-term nutrient supply; therefore, if the ability of the soil to provide plant nutrients is not limited, foliar feeding will have no effect on yield. However, foliar feeding could impact crop quality by temporarily increasing the nutrient content in the leaves.

3. Methodology

Study Location: The on-farm experiments will be conducted on organic dairy farms in Wayne and Holmes Counties. We hope to have six sites of established forage. We have already identified two organic farmers who practice foliar feeding as part of their fertility management program who are willing to work with us. Ron Milner (Holmes County) farms 350 acres of corn, wheat and alfalfa (Appendix 1). Tim Kline (Wayne County) farms 70 acres total: 25 in corn and 50 in alfalfa and pasture from which he milks 60 cows (Appendix 2). Both use foliar-applied products manufactured by SoilBiotics (2902 West State Route 17, Kankakee, IL 60901), and have offered one or more sites on their farm where we can conduct the research.

Study Design and Treatments: The experimental design will be a randomized complete block design (RCBD) with four replications of two treatments:

Treatment #1 – Control (standard organic management program),
Treatment #2 – Foliar application of a custom SoilBiotics blend after each cutting (in addition to the standard management program).

Treatment #1 will be based on a standard nutrient management program for organic alfalfa/grass forage production, which typically involves the application of organic manure in the fall and again in the spring at green-up. Treatment #2 will include the standard nutrient management program, plus the foliar application of a custom blend of two SoilBiotics products, 1 gallon/acre of Organic Blend 5-0-0 and 2 gallons/acre of eFISHnt 5-1-2, after each cutting of the forage. The Organic Blend 5-0-0 is a 5% N (amino acid-based) product that also includes humic acid and a mix of microorganisms. The eFISHnt is a liquid fish nutrient concentrate for plants with 5% protein N and a high level of dissolved solids.

(*Note*: All SoilBiotics products are OMRI certified; more information can be found in their website: http://soil-biotics.com/Products/Organic_Products/OMRI)

Plots and Treatment Application: Each plot will measure 10 by 20 feet (block dimension, 20 by 20 feet). For Treatment #1, the cooperating farmers will be responsible for making the manure applications. For Treatment #2, the foliar products will be applied in the spring at green-up (first application) and subsequent applications will be done 5 to 10 days after each forage cutting, for a total of four applications during the growing season (mid-May to mid-August). Care will be taken to make foliar applications in the mornings, before temperatures reach 75 F, to keep environmental conditions as consistent as possible among farms and applications. A 10-ft sprayer boom (with each outer nozzle closed, for an effective spray width of 8 feet) will be used for treatment applications.

Data Collection: Mineral nutrient analysis will be done on baseline soil and foliar samples taken at the block level before the first foliar treatment application, and on final soil and foliar samples taken at the plot level at the last forage sampling time. The soil and leaf mineral analysis will be done by Spectrum Analytic Labs (Washington Courthouse, Ohio), and will provide information on the overall status of micro- and macronutrients at the start and end of the trial.

The following measurements and samples will be taken right before each of the four forage cuttings:

A. *In-field estimates of forage quality* – Two in-field measurements will be taken to estimate different aspects of forage quality. A handheld NDVI (normalized difference vegetation index) meter will be used to estimate N content of the forage. A handheld refractometer will be used to calculate BRIX, which is the sugar content level in the forage tissue. Forage with higher BRIX is more energetic and tends to be preferred by cows due to increased palatability.
B. *Lab estimates of forage quality* – For lab-based estimates of forage quality, a fresh foliage sample will be removed from each plot, bagged, labelled and kept at 8 C until transported to Rock River Laboratory (Apple Creek, Ohio) for NDFD (neutral detergent fiber digestibility) analysis via near- infrared (NIR) spectroscopy. The analysis will provide measurements to predict livestock performance, including CP (crude protein), NDF (neutral detergent fiber), ADF (acid detergent fiber), RFQ (relative forage quality), NEL (net energy of lactation) and a milk/ton measurement.

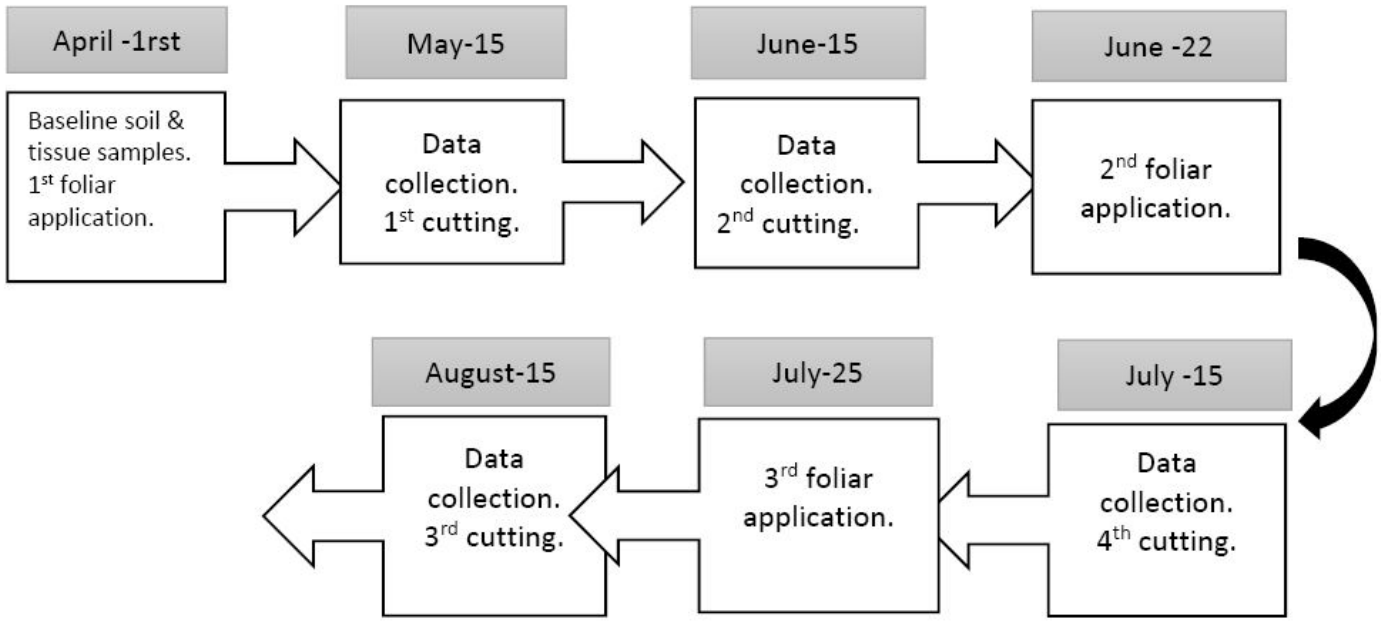
C. *Yield* – To determine yield, a 1-m^2 quadrat will be placed in the middle of each plot, and forage will be cut at 4 inches above the ground. Samples will be dried for 4 days at 100 F and dry biomass will be determined and recorded.
D. *Forage composition and morphometric*s – Since the palatability and quality of forage is influenced by species, we will estimate the proportion of alfalfa to grasses at each study site by taking two 0.25- m^2 forage samples at the first cutting, sorting by grass vs legume, and determining weight on a dry matter basis. Forage quality is also influenced by the proportion of leaves to stems in the alfalfa component of the forage. We will estimate the leaf: stem ratio by separating the leaves from the stems of the dried alfalfa and weighing separately.

Statistical analysis: Analysis of Variance (ANOVA) (PROC GLM procedure in SAS 9.4) will be conducted to determine if there is a significant difference between the two treatments for any of the variables measured. If the data do not meet the assumptions of ANOVA, the data will be transformed. Since there are only two treatments, it will not be necessary to calculate an LSD.

Economic Analysis: The costs and benefits of the two treatments will be estimated and compared as a way to evaluate if foliar feeding is an economical way for organic dairy farmers to boost the quality and quantity of forages. We will compare estimates of fixed and variable costs associated with each field input, such as the cost of the manure or foliar product, labor, and depreciation of equipment, to estimates of all quantifiable benefits, such as yield, savings cost associated with reduced supplemental feeds, and milk production. The cost of nutritional supplement will be calculated as an average of the animal's daily requirement at different stages of lactation. We will then compare the gross value to the total costs for each treatment.

Outreach: We hope that the information generated from these on-farm research trials will provide a basis for discussion and education among farmers, researchers, Extension Educators, product distributors and others in the farming community. Our findings and inferences will be shared in a variety of ways, including presentations at field days with Organic Valley, OARDC's OFFER (Organic Food and Farming Education and Research) Field Day series, or other events in the area. Rory Lewandowski, an Ag and Natural Resources Extension Educator in Wayne County, has offered to help us with our outreach efforts (Appendix 5). We also hope to combine our results with the trials conducted by Lewandowski (2015) into a fact sheet or bulletin that can be shared with the farming community online and in hard copy.

Timeline for field work



Activities	Date	Nutrient / soil	Nutrient/ tissue	Biomass	In-field data/ Brix, NDVI	Sample for RFQ	Grass:Alfalfa	Alfalfa leaf:stem	Trt application
At green up	1-Apr	*	*		*				*
Before 1st cutting	15-May			*	*	*	*	*	
5-10 days post cutting	20-May								*
Before 2nd cutting	15-Jun			*	*	*			
5-10 days post cutting	21-Jun								*
Before 3rd cutting	15-Jul			*	*	*			
5-10 days post cutting	22-Jul								*
Before 4th	15-	*	*	*	*	*			