FINAL REPORT

PROJECT TITLE: Evaluating nitrogen credits to corn following manured and non-manured alfalfa
PROJECT NUMBER: 6123-24DD
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ABSTRACT

Nitrogen (N) credits for corn production systems typically come from manure that was applied in the previous year or from alfalfa that was grown into the previous two years. However, there is limited research on what to do when the two practices are combined. Would a nitrogen credit be taken for both? Since alfalfa N fixation is limited when there is sufficient N in the soil (like when manure was recently applied), it is unclear if the N credit is affected. This research aims to evaluate N credits following manured and non-manured alfalfa. We will leverage existing alfalfa research plots at the Rosemount and Southern Research and Outreach Centers (ROCs) that grew alfalfa for three years before it was terminated. Corn will be grown for two years following alfalfa termination during the 2024/2025 and 2026/2027 growing seasons at the Rosemount and Southern ROCs, respectively. The first year will have no additional N added while in the second year, the large plots will be split into smaller plots so that several different N rates (0-160 lbs N/acre) can be evaluated. Overall, the goal is to develop best management practices for fertilizing corn following manured alfalfa and develop guidance for farmers using these practices. The first year of the study has been completed at one site – the Rosemount ROC.

INTRODUCTION

In recent years, there has been a push to expand the length of traditional cropping rotations (continuous corn and corn-soybean) to promote water quality and soil health benefits. The addition of alfalfa to the rotation is particularly attractive because living roots are in the ground year-round during this segment of the rotation. This helps to reduce nitrogen (N) leaching losses, especially in spring and early summer when soil water movement is high in cold climates (MAWRC, 2016). Other benefits include reduced weed, insect, and disease pressure on the following crops, as well as the substantial amount of symbiotically fixed inorganic nitrogen available in the soil as alfalfa residues decompose (Yost et al., 2021). This leads to a nitrogen credit for corn that follows alfalfa for at least two years.

One of the challenges with adding a perennial crop to a rotation is determining what to do with livestock manure in the region. In Minnesota, most manure is currently applied in annual crops (MacDonald et al., 2009) in the fall or spring when no crops are growing (MDA, 2017). If more land were to shift to alfalfa production, however, manure may need to be applied annually to this crop. An on-going research project funded by the U.S. Department of Agriculture is evaluating the use of low-disturbance manure application technology to inject manure into alfalfa and comparing it to alfalfa without manure application.

One question that remains is how the fertilization practices will affect the following corn crop. Application of manure during the alfalfa phase of the rotation suppresses biological N fixation in the crop, with the plant preferentially taking up mineral N from the soil when available (Lamb et al., 1995). With

adequate N supply to the alfalfa, the N credit to subsequent crops should persist regardless of the original N source (manure versus biological fixation). However, the size of the alfalfa N credit is generally determined by alfalfa stand density at the time of termination (Walker et al., 2021). The increased traffic associated with manure applications can influence alfalfa crown health and stand density and may therefore impact the subsequent N credit. However, little is known about the interacting effects of manure application and alfalfa stand vigor on N credits and first year corn yield. More research is needed to understand how manure application will impact the N credit to corn following alfalfa, especially since manure itself often provides a N credit for two to three years after application but may also impact alfalfa stand vigor. When applying manure to corn following alfalfa, many producers do not take the proper N credit (MDA, 2017), which results in surplus N application and likely increases N losses from corn. This problem could be exacerbated if manure is also being applied during the alfalfa phase and proper N credits are not carefully calculated. Additional information about this topic could help producers better manage N fertility and reduce N losses in corn following alfalfa.

Our primary goal is to evaluate N credits in corn for two years following alfalfa that has been manured annually or commercially fertilized according to standard soil tests. At this time, we have the unique opportunity to leverage existing research plots at the UMN Rosemount and Southern Research and Outreach Stations that are currently in alfalfa and will soon be ready for the corn portion of the rotation.

OBJECTIVE AND GOAL STATEMENTS

Evaluate manure application practices for alfalfa on following corn crop for two years

MATERIALS AND METHODS

This experiment will be conducted at two University of Minnesota Research and Outreach Centers (ROCs) to evaluate treatments across different climates and soil types. We will leverage existing field trials at the Rosemount ROC (RROC) in Rosemount, MN that began in spring in 2021 and at the Southern ROC (SROC) in Waseca, MN that began in 2023. In order to understand the setup of the corn portion of the research trials, details of the alfalfa experiments are summarized below.

Previous alfalfa experiment

Alfalfa was established and grown for three years at each site. Two alfalfa varieties were chosen, including a Round-up Ready variety with a fall dormancy rating of 4 (“Dormant”) - Pioneer 54VR10 (Variety A) - and Ameristand 455TQ-RR (Variety B), a traffic tolerant variety. It was anticipated that these varieties would provide a contrast in response to the increased field traffic associated with manure applications. The experiment was set up as a strip trial with plots that were approximately 10 ft × 45 ft.

The experimental design was randomized complete blocks with split plots. Each block was replicated three times. Ten whole plot treatments (Table 1) included a combination of manure timing (prior to establishment, annually after last summer cutting, or the combination of the two) and application method after the alfalfa was established. This allowed us to evaluate a variety of techniques that are used by farmers in the region.

Prior to establishment, manure was injected at a rate to meet the annual P removal needs of the alfalfa crop according to University of Minnesota guidelines. Additional K was only applied via fertilizer if needed based on soil test values. In plots where manure was not applied prior to establishment, commercial fertilizers were used to supply P, K, and sulfur (S) needs of the crop according to University of Minnesota guidelines. Manure application methods after alfalfa establishment included surface broadcast across the entire plot; surface banding (with bands approximately 15 inches apart); and shallow, minimal-disturbance injection (injectors will be spaced 30 inches apart with 3-4 inch depth) using a plot-sized manure tank system with flow rate control. These will be compared to spring-applied fertilizer applications (as needed according to soil tests), and a no-additional-nutrients control. As with the pre-

establishment treatments, manure was applied after the last summer cutting at a rate to meet the annual P removal needs of the following year's alfalfa crop to avoid P buildup in the soil. Split plots within each whole plot treatment will include the two different alfalfa varieties described above for a total of 60 plots.

Table 1. Treatments for alfalfa.

Whole plot treatments			Split plot treatments	
	Prior to establishment in Year 1	**Annually after last cutting in Years 1 & 2**	**Alfalfa varieties**	
1	Injected dairy manure	None	A	Regular
			B	High traffic
2	Injected dairy manure	Fertilizer	A	Regular
			B	High traffic
3	Injected dairy manure	Manure - surface broadcast	A	Regular
			B	High traffic
4	Injected dairy manure	Manure - surface band	A	Regular
			B	High traffic
5	Injected dairy manure	Manure - shallow injection	A	Regular
			B	High traffic
6	Fertilizer	None	A	Regular
			B	High traffic
7	Fertilizer	Fertilizer	A	Regular
			B	High traffic
8	Fertilizer	Manure - surface broadcast	A	Regular
			B	High traffic
9	Fertilizer	Manure - surface band	A	Regular
			B	High traffic
10	Fertilizer	Manure - shallow injection	A	Regular
			B	High traffic

Evaluating Corn following Alfalfa

Silage corn will be grown for two years following alfalfa termination to evaluate the effect of the alfalfa treatments on yield, nutrient uptake, and soil nutrient levels. Additionally, corn yield response to fertilizer N will be evaluated in second-year corn following alfalfa. Research trials will be conducted in 2024 and 2025 at the Rosemount ROC and in 2026 and 2027 in Southern ROC to align with the end of the existing alfalfa plots.

Previous research has shown that first-year corn following alfalfa rarely responds to fertilizer N and that there may be an alfalfa N credit for up to two years after termination of a well-established alfalfa stand. In this experiment, no N will be applied to first-year corn. In the second year, one set of subplots (where alfalfa variety A was located) will be split into four sub-subplots and different N rates will be

applied. This will allow us to understand if alfalfa treatments will affect the economically optimum N rate in second-year silage corn.

Task 1 - Growing corn the first year after alfalfa

Task 1A - Corn production. Silage corn will be managed consistently at both sites throughout the growing season according to typical practices in the region, including planting rates and pesticide management. Phosphorus and K fertilizers will be applied according to UMN Extension guidelines, if needed, according to soil tests on samples collected from the 0-6 inch depth in each plot the previous fall. The P and K fertilizer sources will not have N (i.e., triple superphosphate and potash, respectively). Corn will be planted in 30-inch rows using a conventional 4-row planter in late April or May when field conditions allow.

Task 1B - Sample collection. Stand counts will be conducted when the corn has reached the four leaf collar (V4) growth stage by counting the number of plants in the middle 5 feet of the middle two rows in each plot. When the corn has reached the half-milk stage, the middle two rows of the plots will be harvested and chopped with a forage harvester or by hand, depending on location and availability of equipment. Plants will be cut 6 inches above the soil surface and chopped. The chopped silage from each plot will be weighed for fresh weight and a subsample (approximately 1 kg) will be collected for moisture and nutrient content analyses. The subsamples will be weighed, dried at 60 °C in a forced-air oven until constant mass, and then weighed again to determine DM yield. Plot yield will be calculated using the plot's fresh weight and percentage DM. Subsamples will then be ground to pass through a 2-mm screen and sent to a commercial laboratory for total N and P analysis. Plant N and P uptake will be calculated as the product of plot DM yield and N or P concentration.

Soil samples from the 0-6 and 6-24 inch soil layers will be collected from each plot prior to planting and after harvest (post-harvest samples will also include the 24-36 inch soil layer). All depths will be analyzed for soil nitrate and ammonium concentrations. The pre-planting 0-6 inch depth soil samples will also be analyzed for phosphorus (Bray-1 P) and potassium. In-season soil samples from the 0-12 inch soil layer will be collected when corn is at the 6th leaf collar (V6) growth stage and analyzed for nitrate (this is usually referred to as the corn sidedress nitrate test) to evaluate the nitrogen status of the soil when the corn is about to enter a period of high N uptake.

We will leverage existing suction cup samplers that are installed in the Variety A plots to monitor nitrate leaching over the growing season and each fall and spring. The samplers are installed at the 4-foot depth (below the majority of roots) and will collect pore water that percolates through the soil so that it can be analyzed for nitrate weekly or whenever soil water drainage is expected to have occurred.

Task 1C - Partial economic analysis. A partial economic analysis will be conducted by calculating cost, revenue, and net return for each treatment.

Task 2 - Growing corn the second year after alfalfa

Task 2A - Corn production. Second year corn will follow the same protocols as can be found in Task 1A, with one difference. In the second year, one set of subplots (where alfalfa variety A was located) will be split into four sub-subplots (10 ft × 10 ft each with 1.5-ft alleys) and we will apply different rates of N (0, 40, 80, and 160 lb N ac^{-1}) with urea prior to planting.

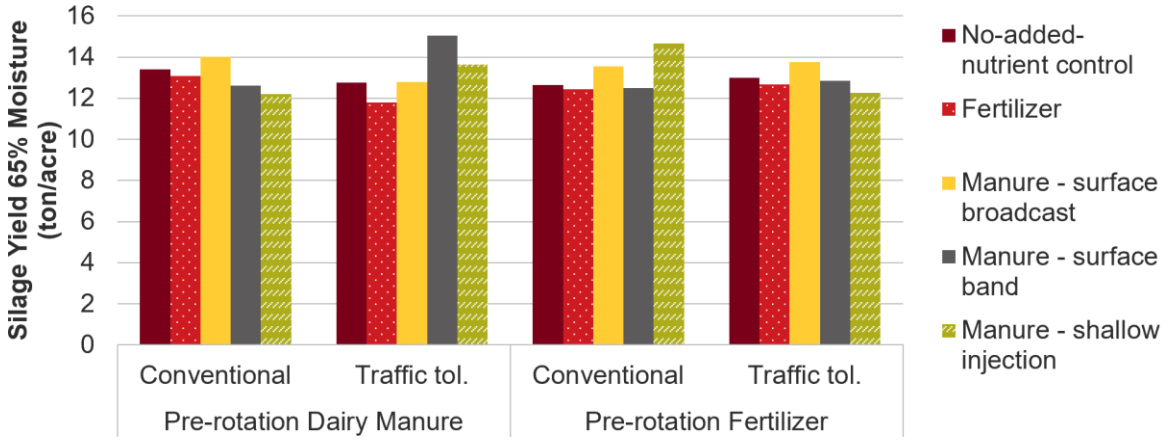
Tasks 2B (Sample Collection) and 2C (Partial Economic Analysis) will follow the same methodology as Tasks 1A and 1B. Because the plots will be subdivided and randomly assigned an additional N fertilizer treatment, the suction cup samplers will be removed and not used in this portion of the study to monitor nitrate leaching.

RESULTS AND DISCUSSION

This project began in April 2024 so objectives have not yet been met. Task 1A at the Rosemount site has been completed. We had an issue as the crop was accidentally terminated in July due to a spraying error. We immediately replanted with 85-day corn. Task 1B is still underway as of writing this report. Plant and

soil samples have been analyzed, as have water samples from the suction cup collectors. Sample data has not yet been organized and statistically analyzed, however.

Yield data are shown in the figure below.



We have not analyzed the data statistically at this time, but yield was lower than anticipated, likely due to having to replant the field in July 2024 after the initial crop was destroyed.

CONCLUSIONS

This study will be completed after the 2027 growing season and we will have a better understanding of nutrient credits following manured alfalfa at that time.

EDUCATION, OUTREACH, AND PUBLICATIONS

Preliminary research results were presented at the Agricultural Fertilizer Research and Education Council annual meeting January 6, 2025. There were approximately 20 people in attendance.

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