Maximizing On-Farm Nitrogen and Carbon Credits from Alfalfa to Corn

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Introduction:

Corn is the leading field crop in the USA and in Minnesota in terms of acreage and economic return. However, concerns about energy use, global climate change, and the high cost of nitrogen (N) fertilizer require that alternative production strategies for corn be evaluated and refined. In the past, excessive N rates were justified in part because the value of yield loss in under-fertilized areas of the field was larger than the additional cost of over-application of N (Scharf et al., 2005). This situation may no longer be valid when N is expensive and grain is cheap. It is well known that excessive N applications cause disproportionately high N losses.

Serious questions are being raised about the use of corn grain and stover for ethanol production (Scharlemann and Laurance 2008). These questions focus on greenhouse gas emissions, fertilizer (energy) use, and carbon (C) balance. Many of these concerns may be addressed by an old practice – that of rotating corn with alfalfa (Vadas et al., 2008). Each year, corn is grown after alfalfa on an estimated 250,000 acres in Minnesota. Although this amounts to only 3% of total field corn acreage in the state today, it may represent the path to a more secure future. For example, during a 35-year-long field trial in Wisconsin, corn yields have increased over time when corn followed alfalfa, regardless of fertilizer N rate (Stanger and Lauer, 2008). Thus, corn producers and policymakers need to learn more about the benefits of this rotation.

As much as 200 lb N/acre is contained in alfalfa forage from biological N fixation, much more than soybean (Russelle and Birr, 2004). In addition, up to 200 lb N/acre is available to subsequent crops grown after alfalfa (Rehm et al., 2006). This is commonly referred to as the alfalfa N credit. Alfalfa also absorbs excess soil nitrate and reduces nitrate losses in tile drainage (Randall et al., 1997; Russelle et al., 2001). At Lamberton, nitrate leaching was not increased during the corn crop following alfalfa (Huggins et al., 2001), but this finding should be verified on other soils and in other weather conditions.

Alfalfa also replaces soil C lost during corn production (Angers, 1992). Soil C can decline under long-term continuous corn production, even under high N fertilization and with only grain being removed. When corn stover is removed, soil C inevitably declines on some soils. Alfalfa adds new C to the soil through large amounts of root and crown biomass, high rate of production and loss of small roots, and addition of aboveground residues (Goins and Russelle, 1996). When both corn grain and stover are removed for feed or bioenergy production, what kind of alfalfa management is needed to assure a net C balance?

With the high cost of N fertilizers, improved corn genetics, and tight economic margins, the University's guidelines for the alfalfa N credit to corn need to be tested and refined. Current University of Minnesota fertilizer guidelines are to reduce fertilizer N on first-year corn after alfalfa by 150 lb/acre when 4 or more alfalfa plants/sq ft are present, 100 lb/acre for 2 to 3 plants/sq ft, and only 40 lb/acre for 1 and fewer plants/sq ft (Rehm et al., 2006). Current second-year N credits are 75, 50, and 0 lb N/acre, respectively. The cost savings for corn production are huge for farmers that accept these alfalfa N credits and reduce fertilizer input accordingly. At the same time, the energy input to the corn crop decreases 22,128 BTU per pound of N, amounting to nearly *one-half billion* BTU per 160 acres at 150 lb N/acre.

Two important unanswered questions relate to the timing of alfalfa tillage and the amount of herbage regrowth incorporated. Current recommendations by the University of Minnesota are based on alfalfa stand density, but assessing alfalfa stand within fields may be difficult. Can the N credit be predicted based on alfalfa regrowth before termination by herbicide or tillage? Fertilizer N recommendations in Wisconsin combine the two by suggesting an additional 40 lb N/acre credit be given if 8 or more inches of regrowth is present when the alfalfa stand is killed (Laboski et al., 2006).

Legume N credits are usually higher with fall tillage rather than spring tillage. The longer interval after tillage allows more N mineralization from the alfalfa residue and soil organic matter. It is preferable, however, to plow down alfalfa in the spring on sandy soils, where nitrate leaching can occur before the corn crop can recover the N. Does alfalfa regrowth alter this effect of tillage time? If moving tillage time from spring to fall or incorporating alfalfa regrowth increases the N credit by 50 lb N/acre, a corn grower could greatly reduce production costs for first-year corn.

Objectives:

In this research project, we are investigating the effect of two management factors on the N credit from alfalfa to first-year corn: i) alfalfa regrowth (alfalfa regrowth after September 1 removed prior to tillage vs. incorporated with tillage); and ii) the timing of primary tillage to terminate the alfalfa stand (fall vs. spring). This is being done in order to:

1) Quantify the response of first-year corn to N fertilizer.

2) Improve prediction of the alfalfa N credit to corn.

3) Determine apparent fertilizer N uptake efficiency by corn.

4) Estimate potential ethanol yield from corn grain, cobs, and stover.

5) Measure impacts on residual soil nitrate.

6) Evaluate effects on soil C.

Hypotheses:

1) The benefit of alfalfa for reducing fertilizer N requirements of corn will be higher with fall tillage than with spring tillage.
2) Leaving alfalfa regrowth in the field rather than harvesting before tillage will reduce fertilizer N needs for corn more when primary tillage occurs in spring than in fall.
3) Soil C storage will be improved by incorporation of regrowth, regardless of when primary tillage occurs.
4) Application of fertilizer N above the rate required for maximum yield will reduce net economic return, decrease the value of stover and cobs for ethanol production, and increase nitrate leaching risk.

Background and Trial Locations:

For this study, we are in the process of conducting two years of research at 17 on-farm locations in southern and central Minnesota (Figures 1 and 2). This involved the establishment of six new on-farm trials in the fall of 2009 (Figure 1 and Table 1), where we implemented regrowth and tillage time treatments to alfalfa in the fall of 2009 and will measure corn and soil response to N fertilizer within these treatments in 2010. These six new trials were established specifically for this Minnesota Corn Growers Association (MCGA) project. We had originally planned on establishing just five on-farm trials in the fall of 2009, but we established six trials because: i) we had interest from six growers with good field sites; ii) the additional site will be useful for increasing the range of soil and weather conditions that we test under, thereby allowing more confidence in the research results; and iii) the additional site will be useful in case one of the sites experiences drought or is lost due to some other unexpected reason.

We also used plots from six on-farm trials established in the spring of 2008 (Figure 2) for a study funded by the Agricultural Fertilizer Research and Education Committee (AFREC) to collect validation data on corn response to N fertilizer following alfalfa, which will be used to validate predictive equations that will be developed from the MCGA trials established in the fall of 2009. Similar validation data will be obtained from the five on-farm trials that were established in the spring of 2009 for this AFREC-funded project (Figure 2). In addition, we implemented alfalfa regrowth treatments (alfalfa regrowth after early September removed vs. not removed prior to alfalfa termination) in the fall of 2009 at four of the five locations associated with the AFREC-funded project. The information obtained from these four sites about the effect of alfalfa regrowth management or N availability to corn can be combined with the information that will be obtained from the MCGA trials to strengthen our results.

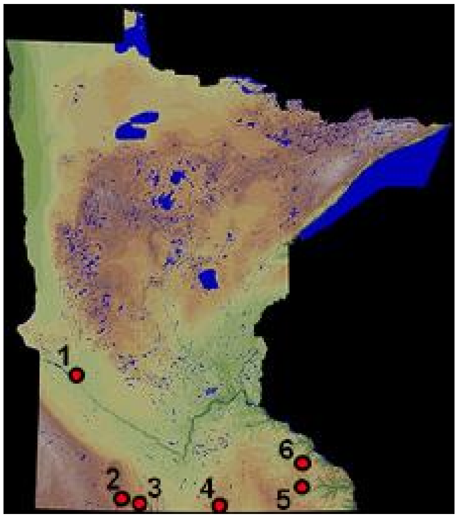

Figure 1.Minnesota Corn Growers Association (MCGA) trial locations. These locations were alfalfa in 2009, and will be corn in 2010.

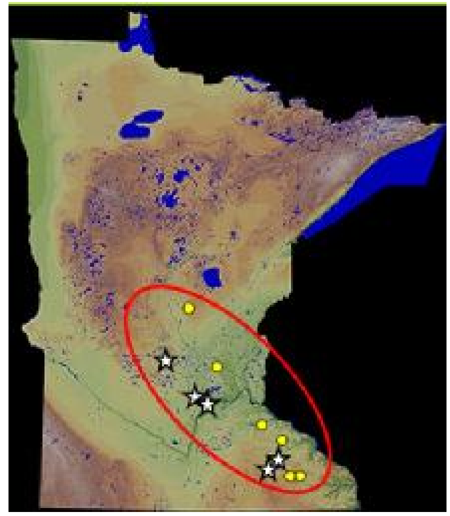

Figure 2. Agricultural Fertilizer Research and Education Committee (AFREC) trial locations.

● = alfalfa in 2008; corn in 2009.

☆ = alfalfa in 2009 (with regrowth removed vs. no regrowth removed treatments established in fall 2009); corn in 2010.

Table 1. Site information for Minnesota Corn Growers Association (MCGA) trials.

Site	Cooperating Grower	Location in Minnesota	Soil Series	Soil Test Levels			
				pH	Bray P (ppm)	K (ppm)	OM (%)
1	Mark Weckwerth	Montevideo	Colvin-Quam silty clay loams	7.0	16	183	5.9
2	Mike McCarvel	Brewster	Waldorf silty clay and Wadena loam	6.5	22	170	5.1
3	Jerry Ackermann	Lakefield	Nicollet and Clarion clay loams	Soil samples not yet analyzed.			
4	Scott Marpe	Emmons	Clarion loam	6.7	46	289	4.3
5	Kevin Borgen	Chatfield	Tama and Downs silt loams	6.3	>100	135	4.5
6	Mike Zabel	Plainview	Downs and Hersey silt loams	5.7	20	169	4.4

Minnesota Corn Growers Association (MCGA) Trials:

Graduate student: In June 2009, we hired Matt Yost to work on this project beginning in September 2009. When we recruited Matt, he was an undergraduate student majoring in agronomy at Brigham Young University-Idaho, and needed to complete an internship prior to graduation in December. We hired Matt to work on this project as an intern from September 2009 to January 2010. In January 2010, Matt will begin graduate school at the University of Minnesota, and will continue to work for us as a research assistant, focusing specifically on this research project. He is expected to graduate with a M.S. degree in Applied Plant Sciences from the University of Minnesota in December 2012. Matt has, and will continue to conduct a considerable amount of the research for this project.

Site selection: Between July and September of 2009, suitable fields were identified and cooperative agreements were established with corn/alfalfa growers at six sites (Figure 1 and Table 1). These sites cover a range of soils and climatic conditions across southern Minnesota.

Experimental design: The experimental design at each site is a randomized complete block with four replications. Main plot treatments are all combinations of alfalfa regrowth management in the fall of 2009 (alfalfa fall regrowth removed vs. not removed prior to alfalfa termination) and tillage timing for alfalfa termination (primary tillage in fall 2009 vs. spring 2010), while subplot treatments are six N fertilizer rates to first-year corn in 2010. Individual subplots are 15 feet wide by 35 feet long. With four replications, this is a total of 96 plots/site, or 576 plots total. Treatment details follow:

- ***Alfalfa regrowth management treatments:*** Alfalfa was harvested three to five times, and the alfalfa regrowth occurring after the last harvest was either left in place or harvested and removed after the first freeze. At most sites, alfalfa regrowth was harvested by cutting, raking, and baling (Photo 7). However, at two sites the alfalfa regrowth was too short to be picked up by a baler, so we had to use a mower/bagger to pick it up (Photo 8).
- ***Tillage time treatments:*** Tillage time treatments include disk-chiseling in either: i) the fall of 2009 after the regrowth management treatments were implemented; or ii) the spring of 2010 (Photos 9-11). Both the fall and spring tillage treatments will be field cultivated to prepare the seedbed prior to planting.
- ***Fertilizer N treatments:*** We will apply six N fertilizer rates ranging from 0 to 160 lb N/acre as broadcast ammonium nitrate immediately after planting corn in spring 2010. All six N fertilizer rates will occur within each of the alfalfa regrowth management by tillage time combinations.
- ***Standard grower treatments:*** Due to interest by cooperating growers in the response of corn grain yield to N fertilizer for their specific alfalfa regrowth management method and termination technique, an additional main plot treatment representing the grower's standard practice was implemented at three sites in the fall of 2009. The main plot treatment representing the standard grower practice will have the six N rate treatments evaluated within it in 2010. When we began this project, we did not anticipate including additional plots to evaluate the grower's standard practice. With four replications, this treatment results in an additional 24 plots/site, or 72 plots total. While

the standard grower practice differs among the three sites where the grower's standard practice is being evaluated, the preliminary information gained from evaluation of this additional main-plot treatment will be useful to corn growers. Specific details of the grower's standard practice at the three sites with this treatment are as follows:

i) Mike McCarvel (Brewster, MN): Harvest alfalfa regrowth in the fall, followed by one pass with the anhydrous ammonia applicator in the fall (with ammonia turned off for the plot area) and two passes with a field cultivator in the spring prior to planting corn.

ii) Jerry Ackermann (Jackson, MN): Make a late final harvest of alfalfa in the fall, followed by one herbicide application after a small amount of regrowth occurs. There is no tillage performed in the spring, and corn is no-tilled into alfalfa stubble.

iii) Mike Zabel (Plainview, MN): Allow alfalfa to regrow after the final harvest in early September. Apply herbicide in fall, then make two passes with a field cultivator in the spring prior to planting corn.

Baseline data collection: Prior to implementation of the treatments in the fall of 2009, baseline data were collected from each replication at each site. Baseline data collected include the biomass and height of alfalfa regrowth, alfalfa stand density, and soil test phosphorus (P), potassium (K), organic matter in the 0- to 6-inch depth. These variables were measured to determine whether they influence N supply to the following corn crop.

The quantity of alfalfa regrowth was determined by hand harvesting alfalfa regrowth within a 10 square foot frame at three locations within each main plot (Photo 2). The height of alfalfa regrowth was determined by measuring the height at six locations within each main plot. Alfalfa stand density was determined by digging up all alfalfa plants within a 10 square foot frame at two locations within each main plot (Photos 3-5). Soil test values for each main plot were based on six composited soil samples. Baseline data on alfalfa height and stand density are in Table 2.

Table 2. Alfalfa regrowth and stand density information for Minnesota Corn Growers Association (MCGA) trials.

Site	Cooperating Grower	Location in Minnesota	Height of alfalfa regrowth in fall 2009 (inches)	Average alfalfa stand density in fall 2009 (plants/sq ft)
1	Mark Weckwerth	Montevideo	18	5.8
2	Mike McCarvel	Brewster	6	6.1
3	Jerry Ackermann	Lakefield	15	4.7
4	Scott Marpe	Emmons	4	4.3
5	Kevin Borgen	Chatfield	13	5.6
6	Mike Zable	Plainview	10	8.2

Soil labile carbon: Prior to implementation of the regrowth management and tillage treatments in the fall of 2009, baseline composite soil samples were collected from the 0- to 1-foot and 1- to 2-foot depths using a hydraulic probe (Photo 6). These samples will be analyzed for soil labile C (the C in the soil that responds quickly to changes in agronomic management such as tillage or residue management, and thus serves as an indicator of future changes in total soil C). Each composite sample was based on three subsamples, and two composite samples were collected from each main plot.

Soil bulk density was also determined for these soil depths, and will be used to convert soil labile C concentrations to pounds/acre. Soil samples for labile carbon were collected from four of the six sites. Soil samples were not collected from the Brewser, MN or Emmons, MN sites because the amount of alfalfa regrowth was limited, and not likely large enough to influence soil labile C. At the end of this experiment in the fall of 2010, soil samples will be collected from these same plots to determine whether the tillage and alfalfa regrowth management influenced soil labile C.

Photo 1. Cooperating crowers with suitable fields were identified between July and September of 2009. This photo is from Mike Zabel's farm near Plainview, MN.

Photo 2. Alfalfa regrowth was measured at each site after the first freeze, but before the regrowth removal treatments were implemented.



Photos 3, 4, and 5. Digging alfalfa roots to determine plant density of the alfalfa stand. Matt Yost (graduate student working on this project) is in the photo on the left.

Photo 6. Soil sampling to 2 feet for labile carbon and removal of regrowth at Jerry Ackermann's farm near Lakefield, MN.

Photo 7. Implementing regrowth removed vs. no regrowth removed treatments at Jerry Ackermann's farm near Lakefield, MN.

Photo 8. A mower/bagger was used to remove the alfalfa regrowth at two locations because the alfalfa was too short to remove with a rake and baler.

Photo 9. Fall vs. spring primary tillage treatments were established with a disk-chisel.

Photo 10. Regrowth removed vs. no regrowth removed, along with fall vs. spring primary tillage treatments at Kevin Borgen's farm near Chatfield, MN.

Photo 11. Fall vs. spring primary tillage treatments at Mike McCarvel's farm near Brewster, MN.

Corn production: In the spring of 2010, soils will be fertilized with recommended levels of all required nutrients necessary for corn production except for N. High-yielding corn hybrids of appropriate relative maturity for each site will be planted in 2010 by cooperating growers using their field-scale planters. The targeted final corn population will be 32,000 to 34,000 plants/acre. All sites will be planted in 30-inch rows, except for the site near Montevideo, MN, which will be planted in 22-inch rows. Insects will be controlled using a combination of insect resistant hybrids and insecticides as needed. Weeds will be controlled using herbicide-resistant corn hybrids and herbicides as needed.

Data collection in 2010*:*

- Corn grain, cob, and stover yields will be measured after corn grain reaches physiological maturity by harvesting within the center two rows of each plot. Grain will be separated from cob.
- Stover and cob samples will be subjected to cellulose and hemicellulose hydrolysis (saccharification) to determine potential sugar concentration. Ethanol production potential will be calculated using sugar content information for stover and cob, and typical conversion factors for grain.
- Total N and C concentrations in corn grain, stover, and cob will be determined by dry combustion.
- Soil nitrate N concentrations will be measured on soil samples collected from each site in 1-foot increments to a depth of 4 feet in the fall of 2010 after corn harvest.
- Soil labile C concentrations will be measured on soil samples collected from four of the six sites in 1-foot increments to a depth of 2 feet after harvest in the fall of 2010.
- Soil bulk density will be determined at each site for the upper 4 feet of the soil profile, and will be used to convert soil nitrate N and labile C concentrations to pounds/acre.

Statistical, economic, and energy analyses: Results will be subject to appropriate analysis of variance (ANOVA). The economic optimum N fertilizer rate (EONR) for first-year corn after alfalfa will be calculated using least squares regression. This EONR can be compared to the N recommendation for corn after corn from any consultant, but we will calculate the apparent N credit by subtracting it from the University of Minnesota EONR for corn following corn. The N credit estimates will be subjected to ANOVA using the imposed or measured regrowth treatments for each tillage treatment.

We will also conduct economic and energy analyses that will consider the potential value of the commodity and energy production from grain, stover, and cobs, as well as the costs of production. The economic analysis will be based on FINPACK and the energy analysis will be based on table values of fuel use for farm operations and materials. For both analyses, we will compare the results from the alfalfa-corn system to continuous corn and corn-soybean systems using data for these systems obtained from local or regional farm business management reports.

Agricultural Fertilizer Research and Education Committee (AFREC) Trials:

Background: This project is focused on alfalfa response to K fertilizer applied during the final year of alfalfa production, and subsequent effects on the fertilizer N credit for corn grain production. We are utilizing these plots to obtain additional corn N response data for corn following alfalfa, which will be used to validate predictive equations developed from the MCGA trial discussed above.

Site selection: Suitable fields were identified and cooperative agreements were established with corn/alfalfa growers in the winter/spring of 2008 and again in the winter/spring of 2009. Fields were selected that: i) had medium soil test K levels (less than 120 ppm K); ii) were going to be in their final year of alfalfa; and iii) would be rotated to corn after alfalfa. There were six on-farm trials in 2008-2009, and five in 2009-2010 (Figure 2). All sites had alfalfa stands of 4 or more plants/sq ft. These sites cover a range of soils and climatic conditions between southeast and central Minnesota.

Experimental design: The experimental design at each site is a randomized complete block with three or four replications. Main plots are K fertilizer rate on final-year alfalfa on these medium-K-testing soils, and subplots are N rate on first-year corn. Individual subplots are 15 feet wide by 30 feet long. There are 90 or 120 corn plots at each location, depending on the number of replications. Treatment details follow:

- ***Fertilizer K treatments:*** At each site, final-year alfalfa received six K rates in the spring (0 to 200 lb K_2O/acre) and was harvested according to the farmer's schedule. Corn yield data obtained from plots that received the optimum K rate on final-year alfalfa will be used for validation purposes in the MCGA project.
- ***Regrowth:*** In the fall of 2008, alfalfa regrowth at the six sites was a function of grower practice and no treatment was imposed. The biomass and height of alfalfa regrowth, along with the alfalfa stand density was measured before stands were terminated by herbicide or tillage. In the fall of 2009, an alfalfa regrowth treatment was implemented adjacent to the main plot areas at each of the five sites, so that the effect of alfalfa

regrowth management N supply can be monitored in the following corn crop. Corn yield data from these plots can be combined with the information generated from the MCGA trials in order to strengthen our results.

- ***Tillage:*** The time of tillage in the AFREC trials was a function of grower preference, so no tillage time treatments could be implemented at these sites. These plots will, however, allow us to independently validate prediction equations that involve time of tillage derived from the MCGA trials.
- ***Fertilizer N treatments:*** Within each K fertilizer rate main plot, there are five subplots representing five N fertilizer rates (0, 20, 40, 80, and 160 lb N/acre), applied as broadcast ammonium nitrate in the spring immediately after planting corn.

Corn production: In the spring, soils are fertilized with recommended levels of all required nutrients necessary for corn production except for N and K. High-yielding corn hybrids of appropriate relative maturity for the given area are planted by cooperating growers using their field-scale planters. The targeted final corn population is 32,000 to 34,000 plants/acre. All sites are planted in 30-inch rows. Insects are controlled using a combination of insect resistant hybrids and insecticides as needed. Weeds are controlled using herbicide-resistant corn hybrids and herbicides as needed.

Data collection in AFREC trials for use with MCGA research:

- Corn grain, cob, and stover yields are measured soon before or after corn grain reaches physiological maturity, depending on whether the cooperating grower will harvest the field for silage or grain. Harvesting is done within the center two rows of each plot. Grain is separated from cob.
- Stover and cob samples are subjected to cellulose and hemicellulose hydrolysis (saccharification) to determine potential sugar concentration. Ethanol production potential will be calculated using sugar content information for stover and cob, and typical conversion factors for grain.
- Total N and C concentrations in corn grain, stover, and cob will be determined by dry combustion.
- Soil nitrate N concentrations are measured on soil samples collected from each site in 1-foot increments to a depth of 4 feet in the fall of 2010 after corn harvest.
- Soil bulk density is determined at each site for the upper 4 feet of the soil profile, and is used to use in convert soil nitrate N concentrations to pounds/acre.

Corn yield results from the 2009 AFREC trials:

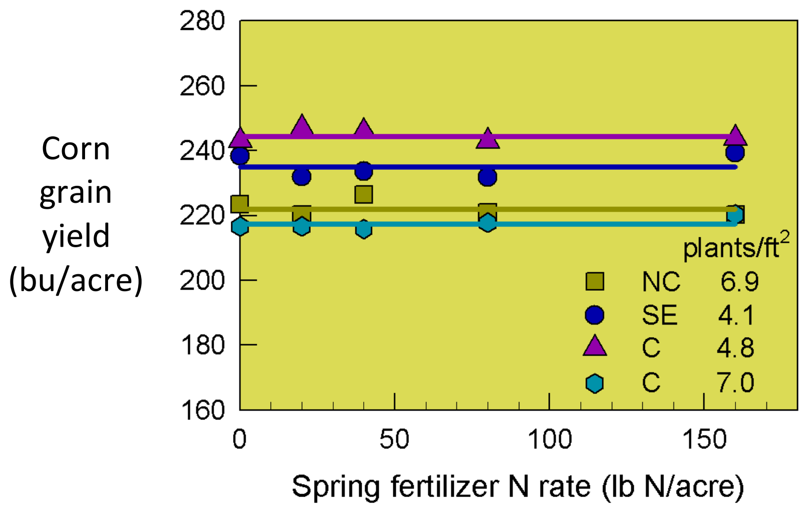

Figure 3. Response of corn grain yield to N fertilizer following alfalfa at four locations in central and southeast Minnesota in 2009. Data are averaged across all K fertilizer rates applied to final-year alfalfa, since the K fertilizer rate applied to final-year alfalfa did not influence corn grain yield, or the response of corn grain yield to N fertilizer.

Corn grain yields from four AFREC-funded trials in 2009 are presented in Figure 3. One trial was in north-central (NC) Minnesota, one was in southeast (SE) Minnesota, and two were in central (C) Minnesota, as depicted in Figure 2. These sites had good alfalfa stands, ranging from 4.1 to 9.2 plants/sq ft. Corn grain yields were high at these sites. At all sites, air temperature during the growing season was below normal, thereby reducing water use by the crop and minimizing stresses associated with high temperatures. The highest yielding site was under irrigation. The other three sites received less than normal rainfall, but the rainfall was well distributed throughout the growing season.

At all sites, corn grain yield and the response of corn grain yield to N fertilizer were not affected by the K fertilizer rate applied to final-year alfalfa, or by the soil test K level. Thus, it is most appropriate to look at the response of corn grain yield to N fertilizer when it has been averaged across the K fertilizer rates applied to final-year alfalfa, as that improves our predictive ability. When averaged across K fertilizer rates applied to final-year alfalfa, grain yield of corn following alfalfa did not respond to N fertilizer and the economically optimum N fertilizer rate was 0 lb N/acre at all four sites (Figure 3). The N supplied from the previous alfalfa crop was enough to maximize corn grain yield, even at these very high yield levels. The yield data that we have from the other two AFREC corn trials in 2009, along with the data that we will get from the 11 AFREC and MCGA corn trials in 2010, will be useful for validating these results on a wider range of soils and growing conditions.

Work Plans for Next Period (January 1, 2010 through July 31, 2010):

Winter:

- Finish processing alfalfa regrowth biomass samples from the MCGA and AFREC trials.
- Finish processing the 0 to 6 inch soil samples from the MCGA and AFREC trials for P and K.
- Finish processing stover, cob, and grain samples from the AFREC trials.
- Process baseline soil labile C samples collected from the MCGA trials.
- Determine fertilizer needs for the MCGA and AFREC trials, then order and pick up fertilizer.
- Present results from the AFREC trials through Extension activities.
- Analyze data from the MCGA and AFREC trials.
- Begin writing Extension and technical articles for the AFREC trials.

Spring:

- Work with cooperating growers to apply spring primary tillage treatments in the MCGA trials.
- If needed, apply fertilizer to meet corn nutrient requirements, with the exception of N for the MCGA trials, and with the exception of N and K for the AFREC trials.
- Work with cooperating growers to perform seedbed tillage, plant corn, and control weeds with herbicides in the MCGA and AFREC trials.
- Stake plots and apply N fertilizer treatments in the MCGA and AFREC trials.
- Work with cooperating growers to control weeds with postemergence herbicide applications as needed in the MCGA and AFREC trials.

Summer:

- Prepare for harvest and fall soil sampling in the MCGA and AFREC trials.
- Continue to present results from the AFREC trials through Extension activities.
- Continue to analyze data from the MCGA and AFREC trials.
- Hold field days at some of the MCGA and AFREC trial sites.

Planned Impact:

We will use the results of this research to validate and improve the University of Minnesota fertilizer N recommendations for corn following alfalfa. The results will form the foundation of an educational program that involves summer field days, winter workshops, an on-line Extension bulletin, articles in the farm press, and a technical article. Availability of validated and refined alfalfa N credit estimates will provide a more reliable tool to corn producers to achieve a smaller C footprint and improve their economic margins for corn production.

The Minnesota Department of Agriculture (MDA) is interested in this research. With the Natural Resources Conservation Service (NRCS), they are currently conducting a study of corn fertilizer N requirements to evaluate the University of Minnesota guidelines, but have specifically avoided fields with recent alfalfa or manure histories. This work may provide guidance for future work funded by MDA and NRCS.

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