8-2021

Nitrogen Fertilizer Showed Little Effect on First- and Second-Year Corn Yield and Quality Following Alfalfa

Bailey Brent Shaffer
Utah State University

NITROGEN FERTILIZER SHOWED LITTLE EFFECT ON FIRST- AND SECOND-

YEAR CORN YIELD AND QUALITY FOLLOWING ALFALFA

by

Bailey Brent Shaffer

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Soil Science

Approved:

Grant Cardon, Ph.D. Major Professor	Earl Creech, Ph.D. Committee Member
Paul Grossl, Ph.D. Committee Member	D. Richard Cutler, Ph.D. Interim Vice Provost for Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2021

ABSTRACT

Nitrogen Fertilizer Showed Little Effect on First- and Second-Year

Corn Yield and Quality Following Alfalfa

by

Bailey B. Shaffer, Master of Science

Utah State University, 2021

Major Professor: Dr. Grant Cardon
Department: Plant, Soils and Climate

Silage corn (*Zea mays* L.) following alfalfa (*Medicago sativa* L.) is a common crop rotation in Utah and southern Idaho. This is done, in part, to take advantage of residual nitrogen (N) fixed by bacteria that work in symbiosis with the roots of alfalfa. After alfalfa is terminated, much of the N that was fixed by the plant is released into the soil and becomes available for use by the rotational crop. This reduces the amount of N fertilizer that growers need to apply. The Utah Fertilizer Guide currently recommends an N credit to a rotational crop following alfalfa of 112 kg N ha^{-1}. On-farm experiments were conducted to test whether this credit is valid and to what extent residual N from a previous alfalfa crop benefits corn silage yield and quality in the first- and second-year corn following alfalfa. Four N rates were tested in this experiment (0, 56, 112, and 224 kg N ha^{-1}). The data from 27 site-years of first-year corn showed that yield increased from 22.1 to 23.1 Mg ha^{-1} as the nitrogen application increased from 0 to 224 kg N ha^{-1}. The economic optimum nitrogen rate (EONR) was lower than the currently accepted recommended rate on all 27 first-year sites. Nine site-years of second-year corn showed that yield also increased 19.8 to 21.8 Mg ha^{-1} as application rate went from 0 to 224 kg N ha^{-1}. Eight of the nine sites had an EONR of 0 kg N ha^{-1}. A better understanding of how residual nitrogen affects crop growth will improve nitrogen recommendations and reduce farm costs for rotational crops following alfalfa.

(42 pages)

ACKNOWLEDGMENTS

I would like to thank Dr. Grant Cardon, Dr. Earl Creech, and Dr. Paul Grossl for their guidance, patients, and direction on this project. Also, I thank Mike Pace, Chad Reid, Mark Nelson, Clark Israelsen, Ron Patterson, Derik Despain, Jody Gale, Boyd Kitchen, Jeff Banks, and James Barnhill for their help and support in their respective counties. My thanks go out to Mark Pieper, Bob Clawson, and Ryan Hodges for all of their hard work and help on this project.

I especially want to thank my wife, Tiffany Shaffer. Her love, encouragement, and support have carried me through all of our adventures. This project was no different. I would like to thank my parents for always believing in and supporting me. I would not have gotten far without them.

Bailey B. Shaffer

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

NITROGEN FERTILIZER SHOWED LITTLE EFFECT ON FIRST- AND SECOND-YEAR CORN YIELD AND QUALITY FOLLOWING ALFALFA

1 | INTRODUCTION0

Stories about shipwrecks often include reference to survivors floating on a life raft with nothing to drink. They longingly gaze at the salty water surrounding them, and dream of an ice-cold glass. Plants have a similar affair with nitrogen (N). The air surrounding them is just shy of 80% N, yet plants cannot use it in a gaseous state. N gas (N_2) must become nitrate (NO_3^-) or ammonium (NH_4^+) in order to be taken up by a plant. Alfalfa forms a mutually beneficial, symbiotic, relationship with an N-fixing bacteria called Rhizobium (*R. Meliloti* D.) which has the ability to fix N gas into ammonium (NH_4^+). The bacterium shares excess N with the plant host in return for photosynthate supplied by the plant.

Fertilizer costs for silage corn production can be expensive. There are about 21,000 hectares of silage corn grown in Utah (Vilsack and Clark, 2014). The typical rate for N application in corn in Box Elder County, Utah is approximately 224 kg N ha^{-1} (Holmgren and Pace, 2015). Assuming this application rate holds true for the rest of the state and N costs \$1.00 kg^{-1} then the annual cost of N for silage corn production in Utah is about \$4.7 million annually.

Taking advantage of Rhizobium's N-fixing ability is one way to reduce the rotational crop's need for N fertilizer. Alfalfa is the most common crop in Utah, with approximately 222,500 hectares in production in 2012. Normally, alfalfa stands in Utah are kept in rotation for 4 to 6 years. During that time, N accumulates in the soil and the alfalfa itself. When alfalfa stands are terminated, the N becomes available, through mineralization, for use by the following rotational crop. The Utah Fertilizer Guide gives an alfalfa N credit of 112 kg N ha^{-1} to first-year rotational corn after alfalfa, and 0 kg N ha^{-1} to second-year corn (James and Topper, 1989).

The symbiotic relationship begins when Rhizobium infects the root. Bacteria recognize the proper host plant through flavonoids released from the alfalfa root, signaling to the bacteria that the plant is ready for infection. Bacteria then develop within infected nodules on the roots. During this period, Rhizobium will act more like parasites, taking carbohydrates and not giving much in return, but, in the end, fixed N becomes available to the host plant. At this point the host sees dividends in the form of plant-available N, and true symbiosis begins (Marschner, 1995).

Soil properties and nutrient availability may affect root nodulation and N fixation. A study conducted in Canada considered the effect of soil pH on root nodulation (Rice et al., 1977). As pH increased from 4.9 to 6.0, root nodulation and alfalfa yield increased as well. This may have been due to higher amounts of available calcium in more alkaline soils, more protons, or the bacteria's inability to survive in more acidic soils. However, when alfalfa was planted in a soil with a pH of 6.0 to 8.0, no differences were detected in yield or nodulation. As available soil phosphorus (P) increased, the number of root nodules also increased (Tang et al. 2001). At a phosphorus level of 4 μM P and 8 μM P alfalfa had the highest amount of large nodules (>3.5 mm in length), hinting that P plays a role in both nodule development and nodule population. When calcium increased from 4 μM Ca to 720 μM Ca, the number of root nodules on Subterranean Clover (*Trifolium subterraneum* L.) increased from 0 to 24 nodules (Lowther and Loneragan 1968). Though the number of nodules increased it did not affect nodule growth and development. An excess amount of nitrate may also inhibit the growth of nodules, and limit the amount of N fixation (Ferguson and Mathesius, 2003). The reason for this is not fully understood. However, N fixation will take place as long as the soil properties and nutrients are not limiting and the alfalfa stand is healthy.

The age of alfalfa at termination may affect the corn yield response to N fertilizer. A study was conducted in two locations in Minnesota to see how first-year corn responded to alfalfa stand age (Yost et al., 2015). Alfalfa stand age ranged from one to three years when terminated using herbicide, and corn was then no-till planted. Grain yield showed a response to N application following one- and two-year-old alfalfa stands. When corn followed three-year-old alfalfa stands, grain yield responded at only one of the two sites. A similar study was conducted to see the effect of alfalfa stand age on organic grain corn yield (Fernandez et al., 2017). Alfalfa stand age ranged from one to four years, and a no-alfalfa control was added for comparison. All three Minnesota fields showed that grain yield increased with alfalfa stand age, even though soil mineral N and potentially mineralizable N only increased during the first year of alfalfa. This suggests that other there are other beneficial soil effects from this perennial crop. Alfalfa was also studied as a cover crop before corn in 2012 to 2014 in Ontario, Canada (Coombs et al., 2017). Along with the alfalfa treatment, three no-cover-crop treatments received 0, 112 and 224 kg N ha^{-1}. Soil samples were taken to a depth of 60 cm at fall and spring termination then again at corn harvest. The authors found that in the alfalfa treatments, plant-available N increased at termination in October compared to May. The amount of plant-available N was significantly higher in the cover crops than a no-cover-crop treatment. When following an alfalfa cover crop, corn grain yield increased when compared with the no-cover-crop treatment receiving 0 kg N ha^{-1}, but was lower than the no-cover-crop treatment that receive 224 kg N ha^{-1}. A long-term crop rotation study was conducted in southwestern Wisconsin (Stanger and Lauer, 2008). Four crop rotations that contained first-year corn after alfalfa were studied. Three of which were five-year rotations and the last was a two-year rotation. The rotations containing older alfalfa stands showed that grain yield increased between each cycle regardless of N application. The two-year rotation consisting of corn following one year of alfalfa showed that grain yields actually declined over time if no N fertilizer was applied. However, at higher N application rates, 112 and 224 kg N ha^{-1}, grain yields increased from cycle to cycle. All of these studies suggest that young (one to three years old) alfalfa stands can affect the responsiveness of corn yield to N fertilizer.

Once the alfalfa stand is terminated, it potentially leaves large amounts of plant-available N to be used by the following rotational crop. As much as 70% of the N embodied in a terminated alfalfa stand can be mineralized during the first year, 20%

during the second year, and the remaining 10% in the third year (Fox and Piekielek, 1988).

The termination timing and method may also affect the amount of available N for rotational crops. Spring terminated alfalfa stands had the highest amount of nitrate-N for the following growing season (Malhi et al., 2007). Stand termination through tillage alone resulted in the highest amounts of nitrate-N, when compared with herbicide plus tillage, and herbicide alone.

The effect of N fertilizer was tested on two first year no-till corn fields in Wisconsin and five fields in Minnesota (Yost et al., 2013). The soil texture of these fields was either a clay loam, loam or silt loam. The soil pH spread from 6.3 to 7.4. No response to N fertilizer was found in either grain yield or silage yield. Thirteen on-farm trials and three research station trials were hosted in 2005 and 2006 in New York (Lawrence, 2008). These were all first-year corn fields following alfalfa, grass or alfalfa-grass mixture. Four sites were turned over in the fall and the remaining sites in the spring. Soil tests showed that a small amount of starter N was recommended, and was applied to the trials. The research station trials had a no-starter N control added to the experiment. The on-farm trials showed no response to added N, regardless of the percent grass in the mixture and stand termination timing. However, the research-station trials showed a statistical difference between no starter N and applying a small amount. In all 16 sites the N treatments did not affect NDF, dNDF, lignin or starch. Crude protein and soluble protein increased with N application, but not enough to change predicted milk production. In Ontario Canada, the effect of added N on grain corn was examined under conventional till and no-till operations (Aflakpui et al., 1993). Alfalfa stands were 75% alfalfa with the remainder being grass. Five treatments of N (0, 40, 80, 120 and 160 kg N ha^{-1}) were applied to four replications. Plant height was measured 47, 56, 70, and 100 days after planting. Soil nitrate–N was measured in the top 15 cm in May, June, July, and August. First-year grain yield and plant height did not respond to added N in both no-till and conventional till systems. On the other hand, second-year grain yield showed an increasing response to added N in both systems.

Previous studies show that second-year corn after alfalfa shows only an occasional response to N fertilizer. Two second-year corn crop rotations showed that, from one rotation to the next, corn grain yields increased or remained constant without the addition of N fertilizer (Stanger and Lauer, 2008). However, yields increased at a greater pace when N was applied. The authors noted that some of the yield increase is due to improved corn hybrids and management techniques. In Spain, second-year corn yield response to N depended on the amount of N applied during the first year after alfalfa (Cela et al., 2011). If no N was applied in the first year, then a greater response to a second year application was found. They noted that, at responsive sites, net economic return was usually maximized at 200 or 300 kg N ha^{-1}. At the unresponsive site 0 kg N ha^{-1} was the most profitable choice. In 2011 and 2012 a study was done in Minnesota to compare grain and silage yield to N application (Yost et al., 2014). Corn silage yield was measured in eight sites. Among these sites, only five showed a response. The effect of stover removal and incorporation was also studied. In the five fields that responded to N application, yield was not dependent on stover management. Second-year grain yield in Iowa and Minnesota responded positively about 50% of the time.

The objectives of this experiment were to (1) determine how much N is necessary to maximize yield, forage quality and farm profit when growing first- and second-year silage corn after alfalfa in Utah; and (2) determine if the N application recommendations in the Utah Fertilizer Guide (James and Topper 1989) need to be adjusted. Based on the literature we studied, we did not think our corn trials would respond to added N in the first year, but they might in the second year after alfalfa. We also hypothesized that the Utah Fertilizer Guide recommendations would be too high. To answer these questions, we conducted on-farm trails throughout Utah to test the responsiveness of silage corn yield and quality to varying rates of N fertilizer.

2 | METHODS AND MATERIALS

On-farm studies were conducted in 10 counties across Utah (Beaver, Box Elder, Cache, Carbon, Iron, Juab, Millard, Sevier, Uintah, and Weber) to test the effect of added N on first- and second-year silage corn after alfalfa. The effect on first-year corn was studied at 27 sites over the course of the 2014, 2015, 2016 and 2017. In 2015, 2016, and 2017 the effect of added N was tested at nine sites. Sites had a variety of weather patterns (Tables 2), management strategies, and field histories (Table 4 and Table 5) and served as representative sample of the corn growing areas of Utah.

Treatments included four rates of N fertilizer application (0, 56, 112, and 224 kg N ha^{-1}) in the form of ammonium sulfate ($(NH_4)_2SO_4$) (AMS). AMS was used to limit the amount of nitrate leaching. Treatments were arranged in a randomized complete block design with four replications. Fertilizer was applied just after the field was planted, this was usually in May. No additional N fertilizer was applied to the study area after alfalfa was terminated. A 1.5 m wide Gandy drop spreader (Gandy Company, Owatonna, MN) was used to broadcast AMS on the soil surface. Each plot was 9 m in length and 3 m (four rows) in width. Due to the size of the fertilizer box, two identical passes were required to cover the width of one plot. Other than fertilizer application, the farmers managed the research sites using management practices identical to the balance of the field and representative of those commonly used in the area.

At the time of fertilizer application, three soil cores were taken to a depth of 90 cm. They were separated into three 30 cm sections (1-30 cm, 31-60 cm, and 61-90 cm). The nine samples were placed into separate plastic bags, and kept cool until they could be sent to the Utah State University Analytical Lab for analysis. Soil texture was found by feel according to the USDA NRCS Guide to Texture by Feel (NRCS, 1979). Nitrate–N was measured using a potassium chloride extraction (Sims and Jackson, 1971) and analyzed by flow-injection analysis on a Hach QuikChem 8000 (Hach, Loveland, CO), and a cadmium-reduction column. The results from each site were averaged by depth and then scaled from mg kg^{-1} to kg NO_3 ha^{-1} assuming that soil bulk density was 1.55 g cm^{-3}. An Elementar Vario Max Cube (Elementar Group, Mt. Larel, NJ) combustion analyzer was used to measure total soil N. The results from each site were also averaged by depth.

In early August, the county Extension agents contacted the trial hosts in their respective county to note harvest dates for each field. Once harvest dates were determined, a sampling schedule was assembled to facilitate plant sampling as close to the harvest date as possible.

At harvest, 3 m of the two middle rows from each plot were harvested by cutting stalks at ground level using a machete. Stalks were weighed in the field to obtain a plot fresh weight. Three stalks from each plot were selected at random then passed through a wood chipper (ECHO Bear Cat SC3206; ECHO Bear Cat, West Fargo, ND). A subsample of the chopped corn was bagged, labeled, and placed in a cooler on dry ice. The wood chipper was cleaned between each sampling. Once the samples were back to the lab weighed to find a sample fresh weight using a Sartorius 3862 MP balance (Sartorius Lab Instruments GmbH & Co., Goettingen, Germany) and then dried for seven days at 60˚ C. For the first three days of drying, samples were stirred two times each day to prevent mold growth. The dried samples were then weighed using the same scale and dry matter content was calculated. Using the dry matter content, dry matter plot weights were calculated and scaled to Mg ha^{-1}.

After drying, samples were ground to pass through a 2 mm sieve using a Wiley Mill (Thomas Scientific, Swedesboro, NJ). Samples were split at random until they weighed 50 grams. The 50-gram subsample was ground a second time using a Udy grinder (Udy Corporation, Fort Collins, CO) to pass through a 0.5 mm sieve. Near Infrared Reflectance Spectroscopy (NIRS) was used to measure forage quality on the finely-ground samples using a Foss XDS Rapid Content Analyzer (Foss, Eden Prairie, MN). The 2016 unfermented corn silage equation (NIRS, 2016, Unfermented Corn Silage Equation) was used to calculate the results. Quality parameters that were measured included protein, starch, neutral detergent fiber digestibility (NDFD) 24, NDFD30, and NDFD48. Some of these parameters were used to calculate predicted milk production.

Field history and management strategies were gathered for most fields by interviewing the growers. However, some growers were not able to be contacted while this data was being collected. We noted the answers to the following questions: 1) What was the alfalfa fertilizer program? 2) How old was the stand at termination? 3) How was the alfalfa terminated? 4) Was it terminated in the fall or spring? 5) What was the stand density? 6) How much regrowth occurred in the alfalfa before it was killed? 7) What corn hybrid was planted? 8) What corn planter was used? 9) What was the seed rate? 10) What was the date the corn was planted? 11) How much N is normally applied to the corn? 12) What herbicides were applied to the corn? 13) How was the corn irrigated? 14) Were there any pest or disease problems? And 15) If so, how were those diseases dealt with? Answers were assembled in tables four and five. If the grower was not able to be contacted, they did not remember the answer, or if the question was not applicable, then it was noted with a dash mark on the table (Table 4 and Table 5).

Pooled dry matter yield and forage quality was analyzed using the following statistical model.

$$Y_{ijk} = \mu + N_i + R_j + F_k \qquad \text{(Equation 1)}$$

Where Y_{ijk} is yield or forage quality, μ is the grand mean, N_i is the effect of the i^{th} treatment of N (which had four levels and was a fixed factor), R_j is the effect of the j^{th} replication (which had four levels, but was a random factor), and F_k is the effect of the k^{th}

field (which had 27 levels of first-year corn and nine levels of second-year corn, and was a random factor).

Single site analysis of dry matter yield and forage quality was conducted with a similar model as follows.

$$Y_{ij} = \mu + N_i + R_j \qquad \text{(Equation 2)}$$

Where Y_{ij} is the yield or forage quality, μ is the grand mean, N_i is the effect of the i^{th} treatment of N which has four levels and is a fixed factor, and R_j is the effect of the j^{th} replication which also has four levels, but is a random factor.

Statistical analysis of the pooled data was carried out by creating an ANOVA table using the SAS procedure MIXED (SAS, Cary, NC). Differences were considered statistically significant if the p-value was less than 0.05.

The economic optimum N rate (EONR) is the N application rate that maximizes additional profit. Additional profit was calculated for N application rates from 0 to 250 kg N ha^{-1} at 1 kg N ha^{-1} increments using the following formula.

$$Additional\ Profit = \left(Y_p - Y_0\right) x\ P_s - \left((N_a * P_n) + P_a\right) \qquad \text{(Equation 4)}$$

Where Y_p is the predicted yield in Mg ha^{-1}, Y_0 is the predicted yield at 0 kg N ha^{-1} in Mg ha^{-1}, P_s is the price of corn silage, and is assumed to be \$33.00 Mg^{-1}, N_a is the amount of N applied in kg N ha^{-1}, P_n is the price of N, and is assumed to be \$0.99 kg^{-1}, P_a is the price of application, and is assumed to be \$11.12 ha^{-1}. While calculating additional profit water content is assumed to be 65%. If a site did not respond to added N, then the EONR was assumed to be 0 kg N ha^{-1}. Predicted yield was found by fitting a quadratic plus plateau curve to the yield data of each responsive site. The SAS procedure NLIN (SAS, Cary, NC) was used to find the parameters of the quadratic model. The maximum of the parabola was considered to be the plateau value.

Two methods for finding a recommended N application rate are given in the Utah Fertilizer Guide (James and Topper, 1989). The first method takes the results of soil test N (STN), and plugs it into the following formula.

$$N_{STN} = 100 + 5(Y_{goal}) - 5(STN) \quad \text{(Equation 5)}$$

Where N_{STN} is the recommended N application rate in lb ac^{-1}, Y_{goal} is the yield goal in tons ac^{-1}. STN is the soil test N results in mg kg^{-1}. However, if STN is not tested for then the same guide gives a blanket N credit of 100 lb ac^{-1} which converts to 112 kg N ha^{-1}. This method uses the following equation.

$$N_{Blanket} = 100 + 5(Y_{goal}) - 100 \quad \text{(Equation 6)}$$

Where $N_{Blanket}$ is the recommended N application rate, Y_{goal} is the yield goal in tons ac^{-1}, the 100 at the end of the equation is the blanket N credit in lb ac^{-1}.

Both recommended N rates were found for each research site, assuming a yield goal of 30 tons $acre^{-1}$ or 67.3 Mg ha^{-1}. These rates were compared with the EONR to see how closely and often they matched.

3 | RESULTS AND DISCUSSION

Both first- and second-year sites showed little response to added N. Yield at the highest N rate was significantly different from the control. However, in terms of actual yield, the increase was small, 1.0 Mg ha^{-1} for first-year and 2.2 Mg ha^{-1} for second-year sites (Figure 1). These findings are similar to results of other studies. A first-year trial in South Dakota saw no yield response to added N. However, the highest application rate was 135 kg N ha^{-1} (Riedell, 2014). At that rate, we also saw no statistical differences. On-farm trials conducted in Minnesota and Wisconsin suggest that first-year dry matter yield showed little to no response to added N despite a range of soil types, alfalfa stand health at termination, tillage timing and soil pH (Yost et al., 2013).

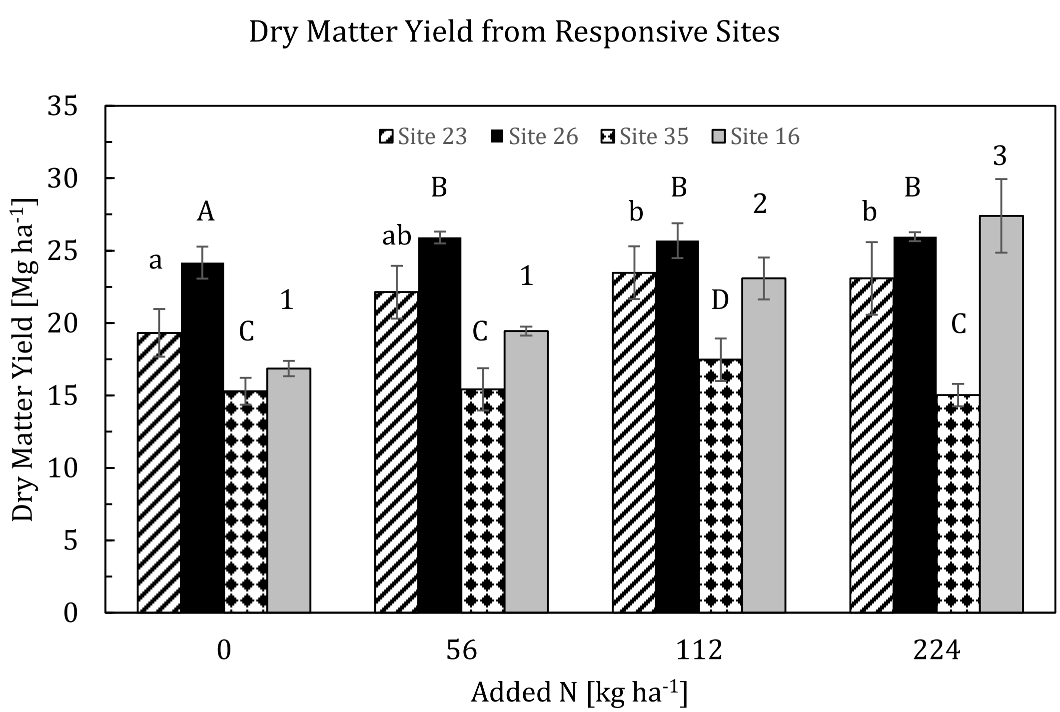

FIGURE 1 The bars indicate dry matter yield of the responsive sites. Sites 23, 26 and 35 are first-year sites, and site 16 was a second-year site. Error bars represent the standard error and letters indicate statistically significant differences.

Almost all sites showed no significant response when analyzed individually. However, three first-year sites (23, 26 and 35) and one second-year site (16) responded to added N. At site 23 adding no N was significantly lower than the three higher treatments, but the 56, 112, and 224 kg N ha^{-1} treatments were not different from each other. Site 26 showed a similar response where adding no N was significantly lower, but the 56 kg N ha^{-1} treatment was not different from any other treatment. The 112 or 224 kg N ha^{-1} treatments were not different from each other (Figure 2). This suggests that, at these two sites, a small amount of N was needed to maximize yield. Another study showed that a

Location of Site 16 in the Field

FIGURE 2 Photo of the plot location of site 16 in the field, indicated by the rectangle.

small amount of starter N boosted dry matter yield, but no response was found to any additional N beyond that (Lawrence et al., 2008). At site 35, adding 112 kg N ha^{-1} showed the highest yields, and was an unexpected result. Site 16 was the only second-year corn trial that showed an increased yield as we added more N (Figure 2). This may have been due to the location of the trial within the field. It was situated at the tail end of a furrow- irrigated field (Figure 3). Because of this I hypothesize that our plot was over-irrigated, and subject to significant N leaching. Nonetheless, another study showed that second-year dry matter yield may respond to added N, and as much as 200 kg N ha^{-1} may be required to maximize yield (Cela, 2011). Thus, this result from site 16 is not unheard of.

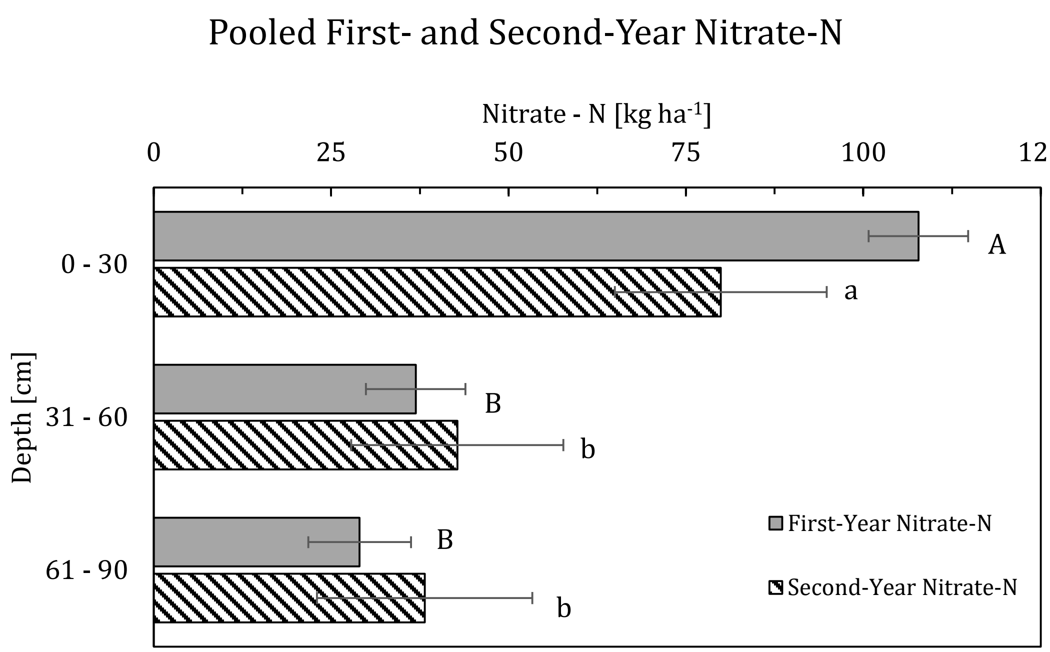

FIGURE 3 Nitrate-N, represented by the bars, of pooled first- and pooled second-year soil data at three soil depths. Standard error is plotted by the error bars. Letters indicate statistical differences.

Both first- and second-year Nitrate – N content show similar differences and groups. The top 30 cm is significantly higher than 31 to 60 cm and 61 to 90 cm. The two lower depths are not different from each other (Figure 4). Aflakpui showed that, throughout the growing season, nitrate – N content was lowest in May (Aflakpui 1993).

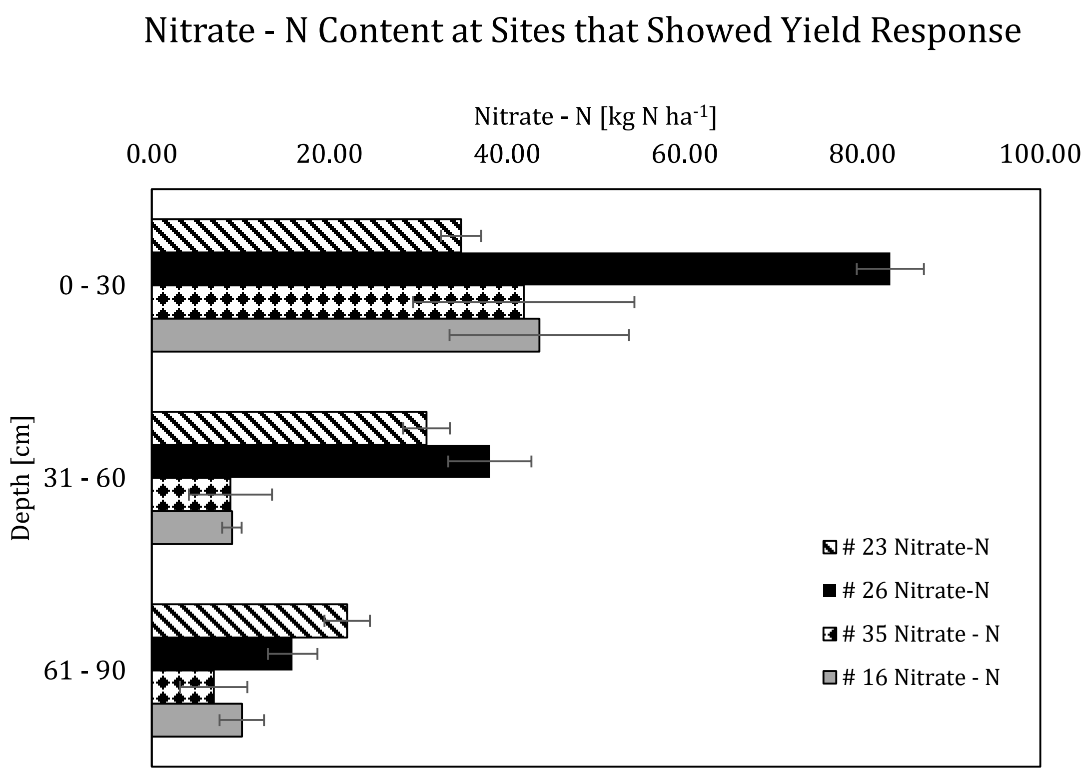

FIGURE 4 Nitrate - N content, represented by the bars, versus soil depth of the four sites that showed a yield response. Error bars represent the standard error.

This suggests that, after our samples were collected in May, more N may have mineralized later in the growing season. Nitrate – N, in the top 30 cm ranged from 294.3 kg ha^{-1}, at site 1, to 8.35 kg ha^{-1}, at site 28. The four sites that showed a yield response were at the lower end of this range (Figure 5). However, they were not the minimum, and a number of unresponsive sites showed similar nitrate - N content. We measured 33.1, 10.1, 27.6, and 32.0 kg N ha^{-1} in the top 30 cm at site 31, 28, 6, and 22, respectively. This suggests that nitrate – N content, alone, may not be a good predictor of which fields will and won't increase yield to added N.

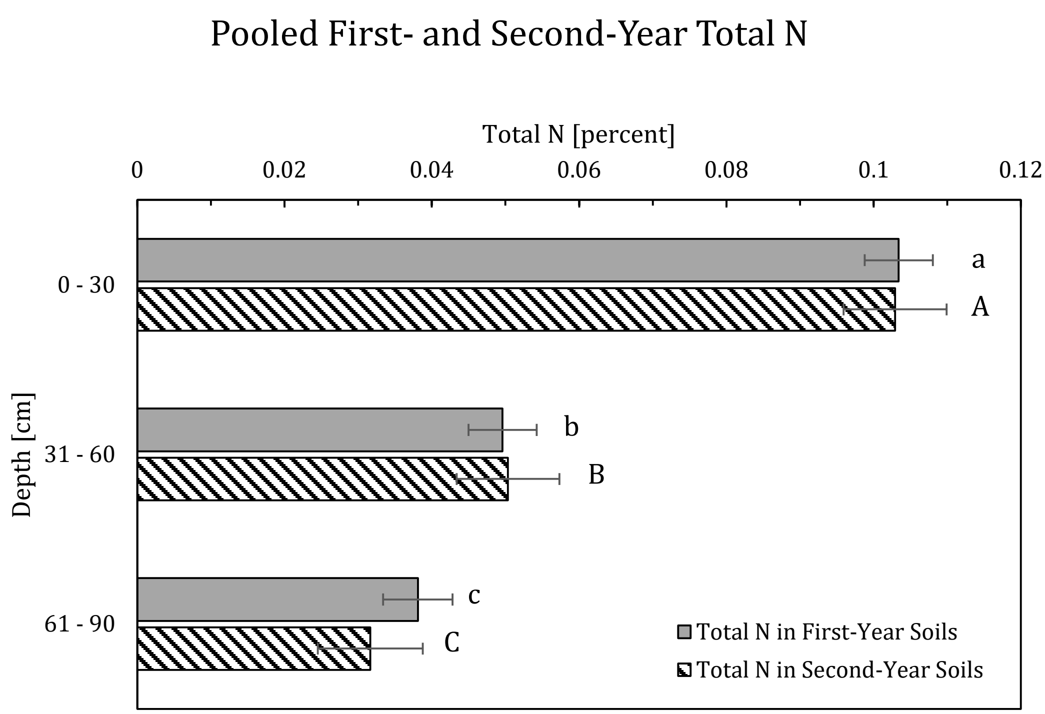

FIGURE 5 Total N versus depth in the soil column. Error bars represent the standard error. Letters indicate statisical differences.

First- and second-year total N results are similar to each other. It decreased as depth increased, and each sampled depth was significantly different from the other two (Figure 5). Total N from three of the four sites that showed a yield response were measured. In each case measured total N was lower than the average (Figure 6). Sites 16, 23, and 27 total N was 0.080, 0.093, and 0.084 percent, respectively. These measurements were all lower than the first- and second-year averages. However, two unresponsive sites 7 and 9 had 0.065 and 0.061 percent, respectively.

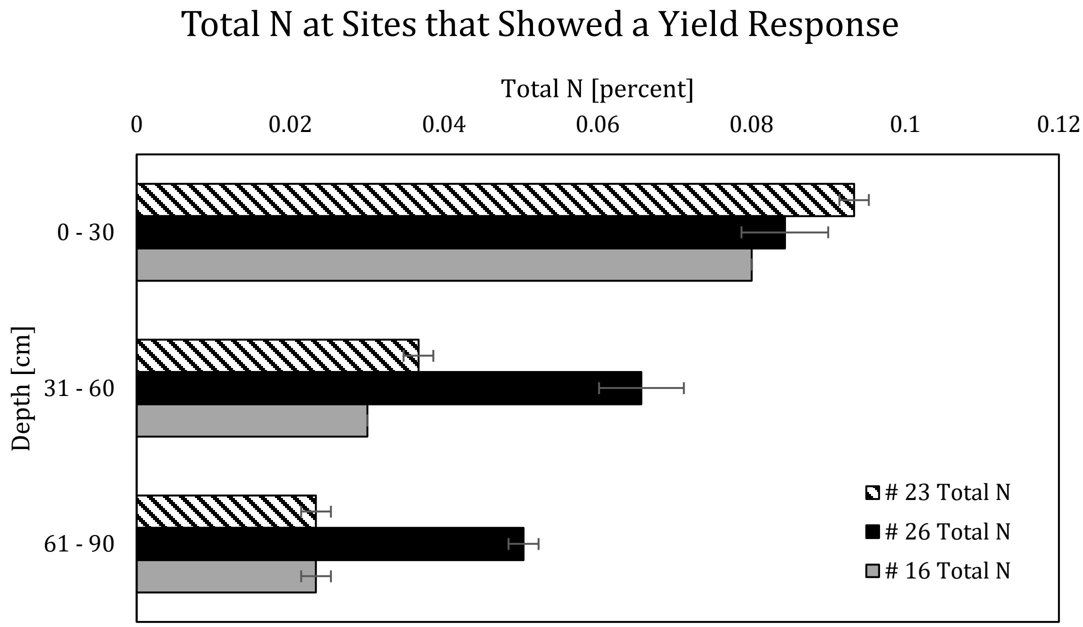

FIGURE 6 Total N of 3 of the 4 responsive sites is represented by the bars. Total N at site # 35 was not measured. Error bars represent the standard error.

From April to September the average max temperature at site 16 was below the 30-year average high 4 times, in May, July, August, and September. At site 23 the monthly average high fell below the 30-year average 1 time, in September. At site 26 the monthly average high fell below the 30-year average 2 time, in May and July. The monthly average high was also below the 30-year average 2 times, in June and August (Table 1). It was observed that site 16 and 23 had a wetter-than-normal spring and then received less precipitation than normal during the summer months. Site 26 received above-average amounts of precipitation during May, June, and September. Site 35 received less than average amounts of rain in May and June, but the rest of the growing season was wetter than normal (Table 2).

Table 1. High temperature averages for April, May, June, July, August, and September. Numbers in the parenthesis are the differences from the 30 year average.
✢ indicates a site that showed a yield response.
* 20 year averages were used in lieu of 30 year averages.

Average Monthly High Temperature

ID	County	Calendar Year	April	May	June	July	August	September
			Temperature, ˚C					
1	Beaver	2017	18.0 (-0.3)	24.6 (0.6)	33.5 (2.6)	35.9 (1.3)	33.9 (0.9)	26.0 (-1.8)
2	Box Elder	2017	15.2 (-1.3)	22.5 (0.6)	30.0 (-2.0)	33.9 (1.1)	31.9 (0.3)	24.9 (-1.4)
3	Box Elder	2017	15.2 (-1.3)	22.5 (0.6)	30.0 (-2.0)	33.9 (1.1)	31.9 (0.3)	24.9 (-1.4)
4	Box Elder	2017	15.2 (-1.3)	22.5 (0.6)	30.0 (-2.0)	33.9 (1.1)	31.9 (0.3)	24.9 (-1.4)
5	Cache	2017	13.7 (-2.0)	20.5 (-0.4)	28.3 (1.6)	32.3 (0.6)	30.6 (-0.5)	23.6 (-2.0)
6	Cache	2017	13.7 (-2.0)	20.5 (-0.4)	28.3 (1.6)	32.3 (0.6)	30.6 (-0.5)	23.6 (-2.0)
7	Iron	2017	16.9 (-0.2)	23.3 (0.7)	32.3 (-3.0)	33.8 (1.2)	31.8 (0.8)	24.9 (-1.8)
8	Sevier	2017	17.8 (-0.2)	22.7 (-0.1)	32.3 (3.2)	33.9 (1.6)	32.0 (1.0)	27.9 (0.9)
9	Weber*	2017	14.3 (-1.3)	21.6 (0.5)	29.6 (1.8)	35.0 (1.6)	32.5 (1.0)	23.5 (-2.0)
10	Beaver	2016	18.4 (0.1)	23.3 (-0.7)	34.3 (3.3)	35.3 (0.8)	33.2 (0.2)	27.4 (-0.4)
11	Beaver	2016	18.4 (0.1)	23.3 (-0.7)	34.3 (3.3)	35.3 (0.8)	33.2 (0.2)	27.4 (-0.4)
12	Box Elder	2016	17.9 (1.3)	21.3 (-0.5)	30.7 (2.8)	32.9 (0.2)	31.4 (-0.3)	24.9 (-1.3)
13	Box Elder	2016	17.9 (1.3)	21.3 (-0.5)	30.7 (2.8)	32.9 (0.2)	31.4 (-0.3)	24.9 (-1.3)
14	Box Elder	2016	17.9 (1.3)	21.3 (-0.5)	30.7 (2.8)	32.9 (0.2)	31.4 (-0.3)	24.9 (-1.3)
15	Cache	2016	16.9 (1.2)	19.6 (-1.3)	28.9 (2.3)	31.3 (-0.4)	30.7 (-0.3)	24.0 (-1.6)
16	Cache ✢	2016	16.9 (1.2)	19.6 (-1.3)	28.9 (2.3)	31.3 (-0.4)	30.7 (-0.3)	24.0 (-1.6)
17	Carbon	2016	18.9 (0.8)	22.0 (-1.1)	32.7 (3.6)	32.9 (0.7)	31.0 (0.4)	25.8 (-0.7)
18	Iron	2016	16.7 (-0.4)	21.8 (-0.8)	32.8 (3.5)	33.4 (0.8)	30.9 (-0.2)	25.6 (-1.1)
19	Juab	2016	16.7 (-0.6)	19.7 (-2.8)	31.1 (2.3)	32.9 (-0.1)	31.1 (-0.5)	24.6 (-2.2)
20	Millard	2016	20.1 (0.7)	24.2 (-0.6)	34.3 (3.2)	36.0 (0.9)	33.6 (-0.1)	27.0 (-1.1)
21	Sevier	2016	18.0 (0.0)	21.2 (-1.6)	32.6 (3.4)	33.3 (1.0)	31.2 (0.2)	25.8 (-1.2)
22	Uintah	2016	18.4 (-0.5)	21.4 (-2.7)	33.3 (3.1)	33.6 (-0.1)	31.7 (-0.4)	25.5 (-1.5)
23	Weber* ✢	2016	17.3 (1.8)	21.2 (0.1)	31.0 (3.2)	33.7 (0.3)	32.1 (0.6)	24.8 (-0.8)
24	Beaver	2015	18.9 (0.6)	21.2 (-2.7)	33.2 (2.2)	32.7 (-1.9)	33.7 (0.8)	30.7 (2.9)
25	Box Elder	2015	17.6 (1.1)	20.3 (-1.5)	30.9 (2.9)	29.6 (-3.1)	31.3 (-0.4)	26.9 (0.6)
26	Iron ✢	2015	17.4 (0.3)	19.4 (-3.2)	30.9 (1.6)	30.4 (-2.1)	31.2 (0.2)	28.2 (1.5)
27	Sevier	2015	17.4 (-0.6)	19.5 (-3.3)	31.2 (-2.0)	31.1 (-1.2)	31.2 (0.1)	29.2 (2.2)
28	Uintah	2015	21.2 (2.2)	21.1 (-3.0)	32.6 (2.4)	32.1 (-1.6)	32.3 (0.3)	28.5 (1.5)
29	Weber*	2015	17.0 (1.4)	20.2 (-0.9)	31.7 (3.8)	30.7 (-2.7)	31.3 (-0.2)	27.5 (2.0)
30	Beaver	2014	19.1 (0.9)	24.7 (0.7)	31.8 (0.9)	35.4 (0.9)	30.8 (-2.1)	29.4 (1.6)
31	Box Elder	2014	15.9 (-0.6)	22.1 (0.3)	26.7 (-1.2)	33.2 (0.4)	28.7 (-3.0)	26.8 (0.5)
32	Cache	2014	16.2 (0.5)	22.4 (1.5)	26.3 (-0.4)	32.4 (0.7)	28.4 (-2.7)	25.7 (0.1)
33	Sevier	2014	17.6 (-0.4)	23.5 (0.7)	29.5 (0.3)	33.4 (1.1)	29.2 (-1.9)	27.7 (0.7)
34	Uintah	2014	17.8 (-1.2)	24.0 (-0.1)	30.3 (0.1)	34.8 (1.1)	30.1 (-1.9)	28.0 (1.0)
35	Weber* ✢	2014	15.9 (0.3)	22.5 (1.4)	26.9 (-1.0)	33.9 (0.5)	29.1 (-2.4)	26.8 (1.3)
36	Sevier	2015	17.4 (-0.6)	19.5 (-3.3)	31.2 (-2.0)	31.1 (-1.2)	31.2 (0.1)	29.2 (2.2)

Table 2. Precipitaion totals in mm for April, May, June, July, August, and September. Numbers in the parenthesis are the differences from the 30 year average.
✢ indicates a site that showed a yield response.
* 20 year averages were used in lieu of 30 year averages.

Average Monthly Precipitation

ID	County	Calendar Year	April	May	June	July	August	September
			Precipitation, mm					
1	Beaver	2017	13.8 (-3.5)	10.2 (-7.4)	0.3 (-9.1)	23.4 (5.9)	10.0 (-3.0)	34.3 (19.4)
2	Box Elder	2017	67.1 (23.7)	30.4 (-25.8)	24.4 (-2.5)	0.3 (-11.1)	4.8 (-11.2)	31.2 (1.0)
3	Box Elder	2017	67.1 (23.7)	30.4 (-25.8)	24.4 (-2.5)	0.3 (-11.1)	4.8 (-11.2)	31.2 (1.0)
4	Box Elder	2017	67.1 (23.7)	30.4 (-25.8)	24.4 (-2.5)	0.3 (-11.1)	4.8 (-11.2)	31.2 (1.0)
5	Cache	2017	47.2 (4.6)	18.6 (-33.1)	14.4 (-11.6)	18.4 (4.2)	2.8 (-15.1)	43.6 (21.7)
6	Cache	2017	47.2 (4.6)	18.6 (-33.1)	14.4 (-11.6)	18.4 (4.2)	2.8 (-15.1)	43.6 (21.7)
7	Iron	2017	21.8 (-5.0)	20.8 (-3.0)	0.0 (-13.1)	31.9 (5.4)	24.0 (0.0)	35.5 (15.5)
8	Sevier	2017	2.8 (-14.3)	13.0 (-10.9)	0.0 (-11.7)	8.7 (-7.9)	14.8 (-3.3)	39.9 (18.7)
9	Weber*	2017	63.8 (30.9)	21.7 (-14.8)	17.8 (-0.4)	2.3 (-4.0)	5.9 (-8.0)	57.3 (37.3)
10	Beaver	2016	18.0 (0.7)	14.8 (-2.8)	10.4 (-1.0)	20.3 (2.8)	23.7 (10.7)	9.0 (-5.9)
11	Beaver	2016	18.0 (0.7)	14.8 (-2.8)	10.4 (-1.0)	20.3 (2.8)	23.7 (10.7)	9.0 (-5.9)
12	Box Elder	2016	52.4 (-9.0)	75.1 (18.9)	22.0 (-4.9)	0.0 (-11.4)	0.0 (-16.0)	103.4 (73.2)
13	Box Elder	2016	52.4 (-9.0)	75.1 (18.9)	22.0 (-4.9)	0.0 (-11.4)	0.0 (-16.0)	103.4 (73.2)
14	Box Elder	2016	52.4 (-9.0)	75.1 (18.9)	22.0 (-4.9)	0.0 (-11.4)	0.0 (-16.0)	103.4 (73.2)
15	Cache	2016	56.8 (14.2)	51.9 (0.2)	12.2 (-13.8)	10.9 (-3.3)	7.0 (-10.9)	79.7 (57.8)
16	Cache ✢	2016	56.8 (14.2)	51.9 (0.2)	12.2 (-13.8)	10.9 (-3.3)	7.0 (-10.9)	79.7 (57.8)
17	Carbon	2016	35.5 (20.7)	19.5 (2.2)	0.0 (-12.5)	16.5 (-0.9)	13.5 (-13.3)	68.8 (40.2)
18	Iron	2016	41.5 (14.7)	8.4 (-15.4)	7.4 (-5.7)	28.0 (1.5)	37.3 (13.3)	17.4 (-2.6)
19	Juab	2016	35.6 (-4.3)	30.9 (-7.4)	3.6 (-17.8)	3.6 (-10.9)	3.1 (-17.3)	35.0 (8.3)
20	Millard	2016	24.7 (1.6)	16.6 (-6.1)	8.6 (-3.9)	0.0 (-11.3)	3.1 (-12.1)	17.8 (-0.4)
21	Sevier	2016	26.5 (9.4)	34.7 (10.8)	6.4 (-5.3)	9.5 (-7.1)	13.3 (-4.8)	27.2 (6)
22	Uintah	2016	19.3 (0.2)	61.9 (-39.0)	1.1 (-13.0)	9.7 (-2.5)	12.4 (-4.1)	124.5 (95.7)
23	Weber* ✢	2016	47.3 (14.4)	33.7 (-2.8)	12.8 (-5.4)	0.0 (-6.3)	3.4 (-10.5)	90.2 (70.2)
24	Beaver	2015	11.5 (-5.8)	76.9 (59.3)	21.1 (11.7)	12.0 (-5.5)	15.4 (2.4)	6.2 (-8.7)
25	Box Elder	2015	39.4 (-4.0)	171.9 (115.7)	0.0 (-26.9)	19.8 (8.4)	17.5 (1.5)	40.5 (10.3)
26	Iron ✢	2015	16.2 (-10.6)	79.3 (55.5)	18.5 (5.4)	10.3 (-16.2)	25.0 (-1.0)	22.4 (2.4)
27	Sevier	2015	21.1 (-4.0)	81.6 (57.7)	23.9 (12.2)	19.6 (-3.0)	18.6 (0.5)	1.3 (-19.9)
28	Uintah	2015	9.2 (-9.9)	73.9 (-51.0)	6.9 (-7.2)	17.4 (5.2)	1.8 (-14.7)	17.4 (-11.4)
29	Weber*	2015	56.6 (23.7)	134.5 (-98.0)	4.3 (-13.9)	37.0 (30.7)	31.7 (17.8)	33.0 (13)
30	Beaver	2014	19.6 (2.3)	25.0 (7.4)	0.3 (-9.1)	11.5 (-6.0)	29.2 (16.2)	73.2 (58.3)
31	Box Elder	2014	44.5 (1.1)	33.7 (-22.5)	23.5 (-3.4)	15.6 (4.2)	38.6 (22.6)	66.7 (36.5)
32	Cache	2014	48.4 (5.8)	35.8 (-15.9)	51.4 (25.4)	26.9 (12.7)	77.0 (59.1)	48.5 (26.6)
33	Sevier	2014	10.5 (-6.6)	17.3 (-6.6)	1.3 (-10.4)	19.1 (2.5)	40.9 (22.8)	52.7 (31.5)
34	Uintah	2014	17.8 (-1.3)	19.0 (-3.9)	0.8 (-13.3)	7.9 (-4.3)	69.8 (53.3)	49.8 (21)
35	Weber* ✢	2014	40.2 (7.3)	29.3 (-7.2)	33.2 (-15.0)	7.2 (0.9)	37.8 (23.9)	54.8 (34.8)
36	Sevier	2015	21.1 (-4.0)	81.6 (57.7)	23.9 (12.2)	19.6 (-3.0)	18.6 (0.5)	1.3 (-19.9)

The blanket N application recommendation, taken from the Utah Fertilizer Guide, was in every case higher than EONR. Even sites 16, 23, 26 and 35, the four responsive sites, required 56, 69, 121, and 168 kg N ha^{-1} less than the recommended amount. These results agree with other studies that have been conducted. The EONR at most first-year corn sites, 14 out of 17, in Minnesota and Wisconsin was 0 kg N ha^{-1}. The EONR at the other 3 sites were 117, 93, and 105 kg N ha-1 (Yost, 2013). This is a similar range to what we saw. A similar study conducted on second-year corn showed that half of the sites had an elevated EONR, ranging from 67 to 196. The other half of the sites had an EONR of 0 kg N ha^{-1} (Yost, 2014). These results are different from what we observed. Many of our second-year sites, all but one, had an EONR of 0 kg N ha^{-1}. At site 16 the EONR was 224 kg N ha^{-1}. This was also the only site that had an observed EONR that was higher than a recommended rate (Table 3).

First-year results showed a slight increase in crude protein. The control averaged 7.10 % protein, and the highest treatment resulted in 7.62 % protein. Those two treatments were significantly different, but the two middle treatments were not significant from any other treatment. These findings agree with other studies where crude protein increased as N application rate increased (Lawrence, 2008). However, second-year protein data showed no significant differences (Figure 7).

No statistically significant differences were found between treatments when predicted milk production was analyzed in either kg_{milk} Mg_{corn}^{-1} or kg_{milk} ha^{-1}. These results agreed with another study that found no statistically significant differences in predicted milk production (Lawrence, 2008).

Table 3. Recommended N rate, the EONR, and the difference of the individual sites.

		EONR and Nitrogen Application Recommendations					
ID	**County**	**Rec_{STN}**	**$Diff_{STN-EONR}$**	**$Rec_{Blanket}$**	**$Diff_{Blanet-EONR}$**	**EONR**	**EONR Yield**
		kg N ha^{-1}					Mg ha^{-1}
1	Beaver	0	0	168	168	0	71.6
2	Box Elder	233	233	168	168	0	63.7
3	Box Elder	128	128	168	168	0	73.6
4	Box Elder	2	2	280	280	0	57.5
5	Cache	106	106	168	168	0	81.9
6	Cache	223	223	280	280	0	68.5
7	Iron	126	126	168	168	0	61.1
8	Sevier	29	29	168	168	0	63.4
9	Weber	112	112	168	168	0	68.5
10	Beaver	0	0	168	168	0	67.4
11	Beaver	0	0	280	280	0	72.3
12	Box Elder	28	28	168	168	0	56.0
13	Box Elder	38	38	168	168	0	32.1
14	Box Elder	0	0	280	280	0	51.5
15	Cache	200	200	168	168	0	75.3
16	Cache	205	-19	280	56	224	85.4
17	Carbon	144	144	168	168	0	49.6
18	Iron	51	51	168	168	0	66.7
19	Juab	124	124	280	280	0	54.4
20	Millard	142	142	168	168	0	69.5
21	Sevier	159	159	280	280	0	56.9
22	Uintah	220	220	280	280	0	47.1
23	Weber	174	75	168	69	99	67.1
24	Beaver	77	77	168	168	0	70.5
25	Box Elder	0	0	168	168	0	62.3
26	Iron	115	68	168	121	47	41.7
27	Sevier	164	164	280	280	0	63.0
28	Uintah	263	263	168	168	0	50.7
29	Weber	67	67	168	168	0	77.0
30	Beaver	0	0	168	168	0	73.1
31	Box Elder	225	225	168	168	0	52.0
32	Cache	31	31	168	168	0	70.6
33	Sevier	0	0	168	168	0	48.2
34	Uintah	119	119	168	168	0	60.1
35	Weber	0	0	168	168	0	45.2
36	Sevier	53	53	168	168	0	64.7

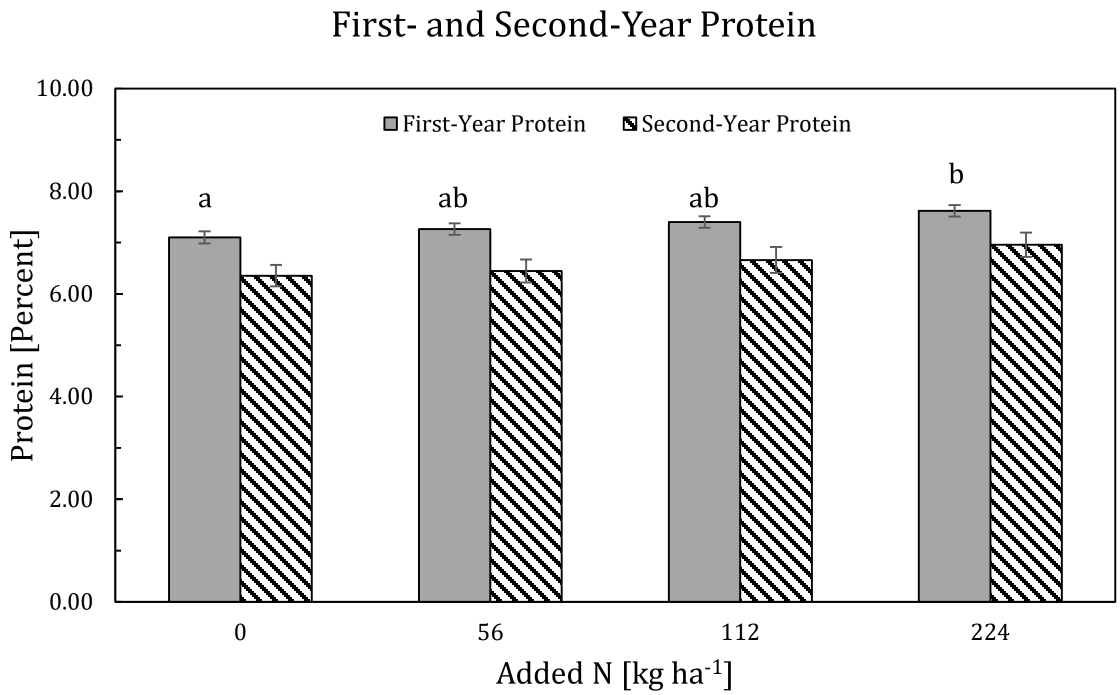

FIGURE 7. The bars represent first- and second-year crude protein. Error bars are the standard error of the data set. Letters show statistically significant differences. No differences were found between second-year treatments.

4 | CONCLUSIONS

Pooled, unresponsive site, data showed that maximizing yield, in both first- and second-year corn fields, required a high N application rate. However, though statistically significant, the yield increase was minimal at best. The response to applied N was greater in second-year corn than the first-year. This could be caused by lower amounts of nitrate – N in the top 30 cm during the second year after alfalfa. However, when analyzing individual fields, no N was required in 89% of the first- and second-year fields. Further research needs to be conducted to find out what causes a yield response to added N after alfalfa. Protein was unaffected in 85% of first-year corn sites, and 89% in second-year sites. Forage quality was largely unaffected by applied N, and when it did respond it was a small change. Predicted milk production was also unaffected.

Site 16 showed us that irrigation scheduling and nutrient management go hand in hand. Suspected over irrigation can flush nitrate below the root zone. This could have caused the large yield response at site 16 thereby increasing the EONR.

The bottom line is that most fields we studied maximized profit by eliminating N application. The current blanket N recommendation from the Utah Fertilizer Guide was higher than the EONR at all first- and second-year sites. This suggests that the N credit in the fertilizer guide is too low, and should be increased. The STN recommendation was closer to the EONR than the blanket recommendation. However, both recommendations were too high in the first year and even higher in the second year.

CHAPTER II

FIRST- AND SECOND-YEAR CORN AFTER ALFALFA USUALLY DOES NOT NEED NITROGEN. AN EXTENSION FACT SHEET

1 | INTRODUCTION

Plants and Nitrogen (N) have an arduous relationship. Air surrounding the plant is about 80% N. However, atmospheric N (N_2) is not plant available. To be plant available, it must be converted into nitrate (NO_3^-) or ammonium (NH_4^+). Atmospheric N can be transformed into ammonium by a bacteria called rhizobium (R. Meliloti). These bacteria infect the roots of alfalfa to form a mutually beneficial relationship. The alfalfa provides the bacteria with carbohydrates. In return, the bacteria provide the alfalfa with plant-available N. This relationship continues throughout the life of the plant, and builds up a large account of N within the soil and the plant itself.

When alfalfa is killed the plant will begin to decompose releasing the N embodied within. During the first year after termination, as much as 70% of that N can become available. During the second year about 20% can become available (Fox and Piekielek, 1988). This is known as the "alfalfa N credit." Studies have shown that the alfalfa N credit is large enough to adequately supply N to first year corn (Yost et al., 2013; Lawrence, 2008; Aflakpui et al., 1993). They have also shown that, in many cases, it can supply enough N for second-year corn as well (Stanger and Lauer, 2008; Cela et al., 2011; Yost et al., 2014).

The objectives of this study were to 1) find how much N is required to maximize corn silage yield, and 2) determine the economic optimum N rate (EONR) for each site.

2 | STUDY DETAILS

Over the course of 4 growing seasons (2014-2017) the effect of added N on silage corn yield after alfalfa was studied. The study took place in 27 first-year corn fields, and nine second-year corn fields. At each field 0, 50, 100 and 200 lb N ac^{-1} was applied using ammonium sulfate. Three soil cores were taken to a depth of 3 ft. and separated into 1 ft. sections. They were sent to the USU analytical lab to measure nitrate – N (NO_3) and total N. Other than fertilizer application and harvest the farmers tended the corn in the same manner as the rest of the field.

The corn was harvested at a moisture content of 60 to 70 %. At each N application rate silage yield was measured in 5 ft. by 10 ft. plots. A sub sample was collected by running 3 stalks through a wood chipper. That sample was weighed wet, dried for 7 days, and weighed dry. This data was used to calculate dry matter yield and the EONR. The EONR was assumed to be the point where the farmer maximized profit, assuming that silage sold for \$30.00 ton^{-1}, urea was \$0.45 lb^{-1}, and custom application cost was \$4.50 ac^{-1}.

3 | RESULTS AND CONCLUSIONS

The combined first-year silage corn data showed that yield increased slightly as N application increased. Second-year silage corn yield showed a similar trend only the yield increase was greater than first-year corn (Figure 8). Only 3 first-year corn fields (11%)

and 1 second year corn field (11%) showed a yield bump as N application increased, see (Figure 9). Site 16 showed the largest yield increase. This may have been due, in part, to leeching nitrate from the root zone caused by over irrigation. The EONR at all but 3 sites was 0 lb_N $acre^{-1}$ (Table 4). This data suggests that most farmers in Utah could eliminate, or at least reduce, N application on first- and second-year corn after alfalfa without a significant yield loss.

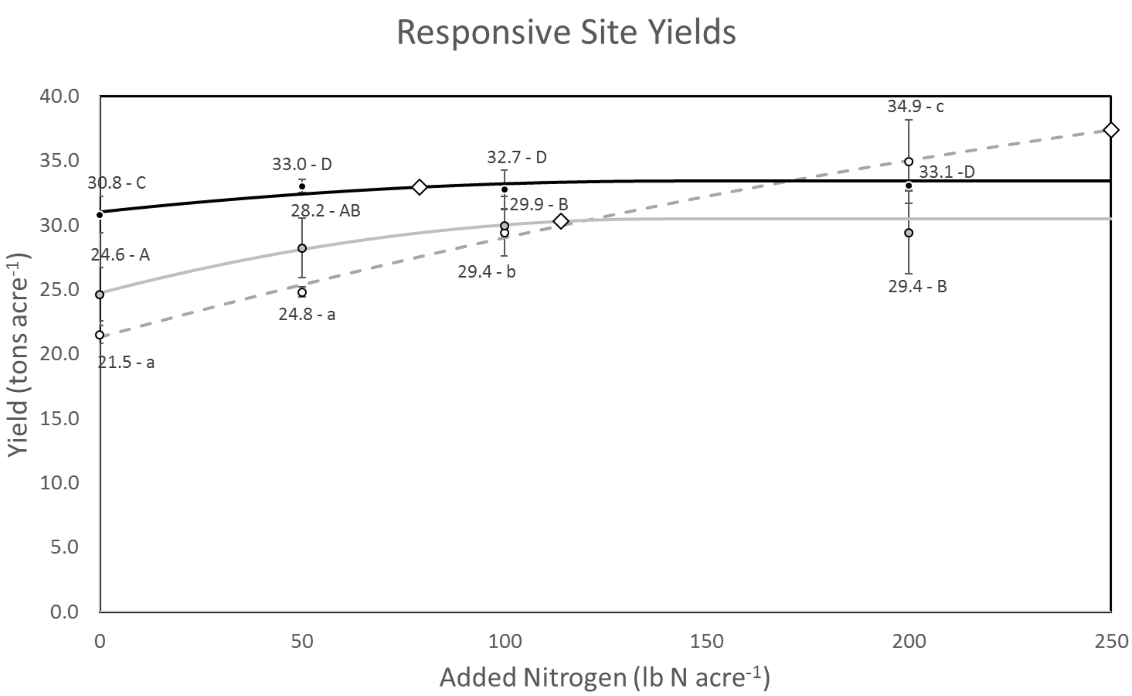

FIGURE 8 Observed and predicted yield of the individual sites that showed a response to added N. The EONR is indicated by a white diamond along each line. Yields are normalized to 65 % moisture.

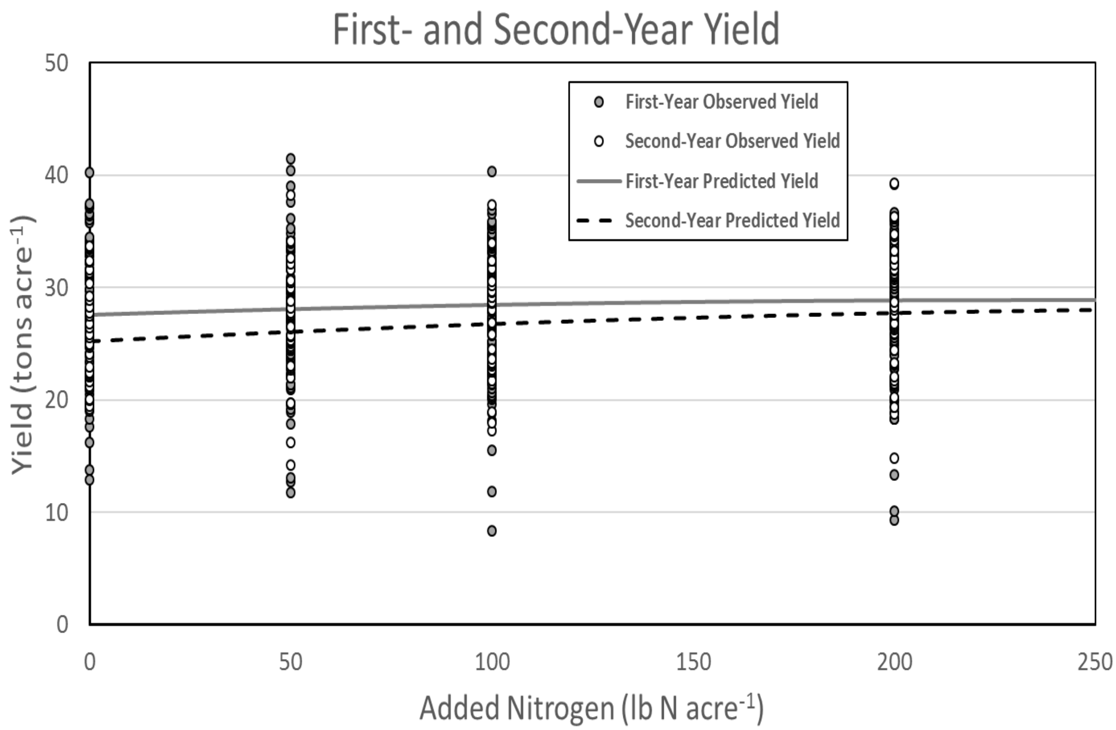

FIGURE 9 Observed and predicted yield for first- and second-year silage corn.

Table 4. Economic optimum nitrogen rate (EONR) and predicted yield at the EONR for each field.

Economic Optimum Nitrogen Rate

County	Year	Year After Alfalfa	EONR lb N $acre^{-1}$	EONR Yield Tons $acre^{-1}$
Beaver	2014	1	0	32.6
Beaver	2015	1	0	31.4
Beaver	2016	1	0	30.1
Beaver	2017	1	0	31.9
Box Elder	2014	1	0	23.2
Box Elder	2015	1	0	27.8
Box Elder	2016	1	0	25
Box Elder	2016	1	0	14.3
Box Elder	2017	1	0	28.4
Box Elder	2017	1	0	32.8
Cache	2014	1	0	31.5
Cache	2016	1	0	33.6
Cache	2017	1	0	36.5
Carbon	2016	1	0	22.1
Iron	2015	1	79	32.9
Iron	2016	1	0	29.8
Iron	2017	1	0	27.3
Millard	2016	1	0	31
Sevier	2014	1	0	21.5
Sevier	2015	1	0	28.9
Sevier	2017	1	0	28.3
Uintah	2014	1	0	26.8
Uintah	2015	1	0	22.6
Weber	2014	1	0	20.2
Weber	2015	1	0	34.3
Weber	2016	1	114	30.3
Weber	2017	1	0	30.6
Beaver	2016	2	0	32.3
Box Elder	2016	2	0	23
Box Elder	2017	2	0	25.7
Cache	2016	2	250	37.4
Cache	2017	2	0	30.6
Juab	2016	2	0	24.3
Sevier	2015	2	0	28.1
Sevier	2016	2	0	25.4
Uintah	2016	2	0	21

TABLE 5 Site history and management practices of alfalfa before it was terminated. Information was marked with a dash if the question was not applicable to the field or if the grower was not able to be contacted after the trial was ended.

Alfalfa Site History

ID	Block	Calendar Year	Year After Alfalfa	Alfalfa Fertilizer Program: What was applied?	Alfalfa Fertilizer Program: How much was applied?	Alfalfa Fertilizer Program: When was it applied?	Age of Alfalfa when killed	How was the stand killed	Killed in Fall or Spring	Stand Density of Alfalfa	Amount of regrowth
					kg ha^{-1}		Years				cm
1	Beaver	2017	1	11-52 and Sulfur	28 kg of 11-52 and 56 kg sulfur	November	9	Tillage	-----	Fair	0
2	Box_Elder	2017	1	Range lambs over winter	-----	Winter	8	Herbicide and Tillage	Spring	Poor	15.2
3	Box_Elder	2017	1	None	-----	-----	7	Tillage	Fall	Fair	2.5
4	Box_Elder	2017	2	P	84	Half in Fall, Half in Spring	5	Herbicide and Tillage	Fall	Fair	0
5	Cache	2017	1	Soil Test Recommendations		Spring	5	Herbicide and Tillage	Fall	Great	10.1
6	Cache	2017	2	-----	-----	-----	-----	-----	-----	-----	-----
7	Iron	2017	1	Manure	56 Mg ha^{-1}	Winter	5	Herbicide	Fall	Good	10.1
8	Sevier	2017	1	-----	-----	-----	-----	-----	-----	-----	-----
9	Weber	2017	1	-----	-----	-----	-----	-----	-----	-----	-----
10	Beaver	2016	1	11-52 and Sulfur	224 kg of 11-52 and 56 kg sulfur	November	8	Tillage	Fall	Fair	0
11	Beaver	2016	2	11-52	224 kg	November	10	Tillage	Fall	Fair	0
12	Box_Elder	2016	1	None	-----	-----	6	Tillage	Spring	Good	0
13	Box_Elder	2016	1	P	84	Half in Fall, Half in Spring	5	Herbicide and Tillage	Fall	Fair	0
14	Box_Elder	2016	2	P	84	Half in Fall, Half in Spring	5	Herbicide and Tillage	Fall	Fair	0
15	Cache	2016	1	P	56	Fall	3	Tillage	Fall	Good	0
16	Cache	2016	2	None	-----	-----	6	Herbicide and tillage	Fall	Fair	0
17	Carbon	2016	1	-----	-----	-----	-----	-----	-----	-----	-----
18	Iron	2016	1	Manure	-----	-----	6	Herbicide	Fall	Good	11.5
19	Juab	2016	2	-----	-----	-----	-----	-----	-----	-----	-----
20	Millard	2016	1	-----	-----	-----	-----	-----	-----	-----	-----
21	Sevier	2016	2	-----	-----	-----	-----	-----	-----	-----	-----
22	Uintah	2016	2	Vernal Blend	112		13	Tillage	Spring	Poor	0
23	Weber	2016	1	-----	-----	-----	-----	-----	-----	-----	-----
24	Beaver	2015	1	11-52	224 kg	November	10	Tillage	Spring	Poor	0
25	Box_Elder	2015	1	P	84	Half in Fall, Half in Spring	5	Herbicide and Tillage	Fall	Fair	0
26	Iron	2015	1	None	-----	-----	6	Herbicide	Fall	Good	11.5
27	Sevier	2015	2	-----	-----	-----	-----	-----	-----	-----	-----
28	Uintah	2015	1	Vernal Blend	112		13	Tillage	Spring	Poor	0
29	Weber	2015	1	-----	-----	-----	-----	-----	-----	-----	-----
30	Beaver	2014	1	11-52	224 kg	November	9	Tillage	Spring	Fair	0
31	Box_Elder	2014	1	None	-	-	6	Tillage	Fall	Poor	0
32	Cache	2014	1	-----	-----	-----	-----	-----	-----	-----	-----
33	Sevier	2014	1	-----	-----	-----	-----	-----	-----	-----	-----
34	Uintah	2014	1	-----	-----	-----	-----	-----	-----	-----	-----
35	Weber	2014	1	-----	-----	-----	-----	-----	-----	-----	-----
36	Sevier	2015	1	-----	-----	-----	-----	-----	-----	-----	-----

TABLE 6 Site information from the research sites. Information was marked with a dash if the question was not applicable to the field or if the grower was not able to be contacted after the trial was ended.

Corn Site History

ID	Block	Corn Hybrid	Corn Planter used	Seeding rate Seeds ha^{-1}	Date corn was planted	N normally applied to corn (kg/ha)	Herbicides applied to corn	irrigation	Insect and disease issues Yes or No	Which pest	How they were delt with
1	Beaver	Dekalb 4415 RIB	White	96,371	7-May-17	-----	Round up - 16 oz acre	Pivot	No	-----	-----
2	Box_Elder	Dekalb 48-12 98 day	Case	83,545	12-May-17	-----	Round up - 22 oz. per acre	Furrow	No	-----	-----
3	Box_Elder	Dekalb 7001 120 day	Case	83,545	13-May-17	-----	Round up - 22 oz. per acre	Furrow	No	-----	-----
4	Box_Elder	Dekalb 52-61	Case 1235	88,958	May-17	252	Round Up - 1 qt per acre, Banvil - 4 oz per acre	Furrow	Yes	Spider Mites	Onager
5	Cache	Wolf River Valley 3396 FL 95 day	John Deere Max Emerge	86,487	12-May-17	196	Surpass - 2 pt / ac	Pivot	No	-----	-----
6	Cache	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
7	Iron	NK 29T	John Deere	98,000	10-May-17	None	Round up	Pivot	No	-----	-----
8	Sevier	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
9	Weber	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
10	Beaver	Deklab	White	95,135	7-May-16	336	Round up - 16 oz acre	Pivot	Yes	Ground Squirls	Baiting and Fumigating
11	Beaver	Dekalb 4415 RIB	White	96,371	7-May-16	336	Round up - 16 oz acre	Pivot	Yes	Ground Squirls	Baiting and Fumigating
12	Box_Elder	Dekalb 67-86	John Deere JD 71	-	May-16	Manure	-----	Furrow	No	-	-
13	Box_Elder	Dekalb 52-61	Case 1235	88,958	May-16	252	Round Up - 1 qt per acre, Banvil - 4 oz per acre	Furrow	Yes	Spider Mites	Zeal
14	Box_Elder	Dekalb 52-61	Case 1235	88,958	May-16	280	Round Up - 1 qt per acre, Banvil - 4 oz per acre	Furrow	Yes	Spider Mites	Zeal
15	Cache	Mycogin 106 day	Case Airseeder	88,200	May-16	-	Round-up	Furrow	Yes	Spider Mites	Oberon - Spray plane
16	Cache	Croplan 90 day	John Deere 1700 Airseeder	85,750	Apr-16	224	Glyphosphate - Atrazine	Furrow	No	-----	-----
17	Carbon	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
18	Iron	NK 29T	John Deere	98,000	14-May-16	None	Round up	Pivot	No	-----	-----
19	Juab	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
20	Millard	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
21	Sevier	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
22	Uintah	Mycogen 101 day	John Deere 7100	85,750	15-Jun-16	112	Round up	Pivot	No	-----	-----
23	Weber	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
24	Beaver	Mycogen 101 day	John Deere 7000	101,313	6-May-15	168	Round up - 16 oz acre	Pivot	No	-----	-----
25	Box_Elder	Dekalb 52-61	Case 1235	88,958	May-16	252	Round Up - 1 qt per acre, Banvil - 4 oz per acre	Furrow	Yes	Spider Mites	Zeal
26	Iron	NK 29T	John Deere	98,000	14-May-16	None	Round up	Pivot	No	-----	-----
27	Sevier	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
28	Uintah	Mycogen 101 day	John Deere 7100	85,750	10-Jun-15	112	Round up	Pivot	No	-----	-----
29	Weber	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
30	Beaver	Dekalb	John Deere 7000	101,313	12-May-14	168	Round up - 16 oz acre	Pivot	No	-----	-----
31	Box_Elder	Dekalb 67-86	John Deere JD 71	-	May-14	Manure	-----	Furrow	Yes	Spider Mites	None
32	Cache	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
33	Sevier	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
34	Uintah	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
35	Weber	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
36	Sevier	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

REFERENCES

Aflakpui, G. K. S., Vyn, T. J., Hall, M. R., Anderson, G. W., & Swanton, C. J. (1993). Effect of tillage on nitrogen response in corn (Zea mays L.) after established alfalfa (Medicago sativa L.). *Canadian Journal of Plant Science, 73(1)*, 73-81. doi: 10.4141/cjps93-010.

Cela, S., Santiveri, F., & Lloveras, J.. (2011). Optimum nitrogen fertilization rates for second-year corn succeeding alfalfa under irrigation. *Field Crops Research, 123 (2)*, 109-116. doi: 10.1016/j.fcr.2011.05.003.

Coombs, C., Lauzon, J. D., Deen, B. & Van Eerd, Laura L. (2017). Legume cover crop management on nitrogen dynamics and yield in grain corn systems. *Field Crops Research, 201,* 75-85. doi: https://doi.org/10.1016/j.fcr.2016.11.001.

Ferguson, B. J., & Mathesius, U. (2003). Signaling Interactions During Nodule Development. *Journal of Plant Growth Regulation, 22*, 47-72.

Fernandez, A. L., Fabrizzi, K. P., Tautges, N. E., Lamb, J. A., & Craig C. Sheaffer. (2017). Cutting management and alfalfa stand age effects on organically grown corn grain yield and soil N availability. *Renewable Agriculture and Food Systems*, 1-11. doi: 10.1017/S1742170517000394.

Fox, R.H., & Piekielek, W.P. (1988). Fertilizer N equivalence of alfalfa, birdsfoot trefoil, and red clover for succeeding corn crops. *Journal of Production Agriculture, 1(4),* 313-317.

Holmgren, L., & Pace, M.. (2015). Costs and Returns for Irrigated Roundup Ready Silage Corn, Box Elder County. https://extension.usu.edu/newsletters/files/uploads/2015_Budgets/Silage_Corn_15 edit3-10.pdf: USU Extension Publication.

James, D. W., & Topper, K. F.. (1989). *Utah Fertilizer Guide*.

Lawrence, J. R., Ketterings Q. M., & Cherney J. H. (2008). Effect of Nitrogen Application on Yield and Quality of Silage Corn after Forage Legume-Grass. *Agronomy Journal 100 (1*), 73-79.

Lowther, W. L., & Loneragan, J. F.. (1968). Calcium and Nodulation in Subterranean Clover (Trifolium subterraneum L.). *Plant Physiology 43 (9)*, 1362-1366.

Malhi, S. S., Johnston, A. M., Loeppky, H., Vera, C. L., Beckie, H. J., & Bandara, P. M. S. (2007). Immediate Effects of Time and Method of Alfalfa Termination on Soil Mineral Nitrogen, Moisture, Weed Control, and Seed Yield, Quality, and Nitrogen Uptake. *Journal of Plant Nutrition 30(7)*, 1059-1081.

Marschner, H. (1995). Mineral Nutrition of Higher Plants. Academic Press. London; San Diego. pp. 206-209.

NRCS. (1979). Guide to Texture by Feel | NRCS Soils. accessed March 05. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054311.

Rice, W. A., Penney, D. C., & Nyborg, M. (1977). Effects of Soil Acidity on Rhizobia Numbers, Nodulation and Nitrogen Fixation By Alfalfa and Red Clover. *Canadian Jornal of Soil Science 57 (May*), 197-203.

Riedell, W. E. (2014). Nitrogen Fertilizer Applications to Maize After Alfalfa: Grain Yield, Kernel Composition, and Plant Mineral Nutrients. *Journal of Plant Nutrition 37 (12),* 2026-2035.

Sims, J. R., & Jackson, G. D. (1971). Rapid Analysis of Soil Nitrate with Chromotropic Acid1. *Soil Science Society of America Journal, 35(4)*, 603-606. doi: 10.2136/sssaj1971.03615995003500040035x.

Stanger, T. F., & Lauer, J. G. (2008). Corn Grain Yield Response to Crop Rotation and Nitrogen over 35 Years. *Agronomy Journal, 100 (3)*, 643-650. doi: 10.2134/agronj2007.0280.

Tang, C., Hinsinger, P., Drevon, J. J., & Jaillard, B. (2001). Phosphorus Deficiency Impairs Early Nodule Functioning and Enhances Proton Release in Roots of M*edicago truncatula* L.Phosphorus Deficiency Impairs Early Nodule Functioning and Enhances Proton Release in Roots of Medicago truncatula L. *Annals of Botany 88 (1)*, 131-138.

Vilsack, T., & Clark, C. Z.F.. (2014). 2012 Census Volume 1, Chapter 1: State Level Data. edited by National Agricultural Statistics Service USDA.

Yost, M. A., Russelle, M. P., & Coulter, J. A. (2013). Nitrogen Requirements of First-Year Corn following Alfalfa Were Not Altered by Fall-Applied Manure. *Agronomy Journal, 105*, 1061-1069.

Yost, M. A., Coulter, J. A., & Russelle, M. P. (2013). First-Year Corn after Alfalfa Showed No Response to Fertilizer Nitrogen under No-Tillage. *Agronomy Journal 105(1)*, 208-214. doi: 10.2134/agronj2012.0334.

Yost, M. A., Morris, T. F., Russelle, M. P., & Coulter, J. A. (2014). Second-Year Corn after Alfalfa Often Requires No Fertilizer Nitrogen. *Agronomy Journal 106 (2)*, 659-669. doi: 10.2134/agronj2013.0362.

Yost, M. A., Russelle, M. P., Coulter, J. A., Schmitt, M. A., Sheaffer, C. C. & Randall, G. W. (2015). Stand Age Affects Fertilizer Nitrogen Response in First-Year Corn following Alfalfa. *Agronomy Journal 107(2)*, 486-494. doi: 10.2134/agronj14.0493.