Field Crops Research

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Timing of Nitrogen Supply to Corn from Spring Terminated Red Clover

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In a Nutshell

- Cultivation of cereal rye for cover crop seed offers the possibility of frost-seeding a legume into the standing rye crop in early spring, where the legume can produce biomass and fix N following rye harvest.
- Farmer-cooperators Tim Sieren and Dick Sloan grew corn in rotation following cereal rye frost-seeded with red clover and compared this to corn grown using synthetic N fertilizer applications.
- Tim and Dick invited Iowa State University graduate student Will Osterholz on to their farms to quantify N uptake by corn as well as two measures of N release from soil organic matter: net N mineralization and gross ammonification.

Key findings

- Red clover did not improve corn growth, N content or grain yield compared to synthetic N fertilizer.
- Soil N mineralization rates in August tended to be higher with red clover compared to synthetic N fertilizer, but differences were not statistically different.
- Fertilization with supplemental N at planting could provide corn with early season N before clover decomposition can provide sufficient N to the corn crop in late summer.

Project Timline:
2014-2015

Corn emerging through desiccated red clover (left) and in the synthetic N treatment at Dick Sloan's farm.

Background

Addition of an overwintering small grain mixed with a frost-seeded legume to corn-soy rotations may reduce N fertilizer requirements and mitigate negative environmental impacts of this cropping system. The small grain provides cover in the late fall to early spring period to reduce N losses, and the legume acts as an N source to the following corn crop.

Cultivation of cereal rye for cover crop seed offers the possibility of frost-seeding a legume into the standing rye crop in early spring, where the legume can produce biomass and fix N following rye harvest. Red clover is well adapted to frost-seeding into a small grain and can produce a large amount of biomass with significant N content following small grain harvest.

Farmer-cooperator Tim Sieren appreciates red clover's versatility and ability to be frost-seeded with a rye seed crop. "Red clover is a great cover crop to be able to grow in standing rye and wait for it to really come on strong after harvesting the rye," Tim says. "It's amazing how well it grows with competition from the rye crop." As a green manure cover crop, the clover biomass will decompose following termination, gradually releasing N during corn growth which could potentially replace part of the fertilizer required for corn. However, the rate and timing of N release will be important factors determining how well the red clover N is able to fulfill the corn's N requirement.

Soil N is constantly being transformed by microbes between organic N forms that are efficiently retained in soil but unavailable to plants and inorganic N forms that are readily taken up by plants but are vulnerable to movement into the surrounding environment (**Fig. 1**). Inorganic N, whether from synthetic N fertilizer or from soil organic N breakdown, is subject to several competing consumption processes: uptake by plants; uptake by soil microbes; or loss through leaching or gaseous losses. The balance of inorganic N supply and these competing consumption processes determines how fast and how much N could be made available for uptake by a crop.

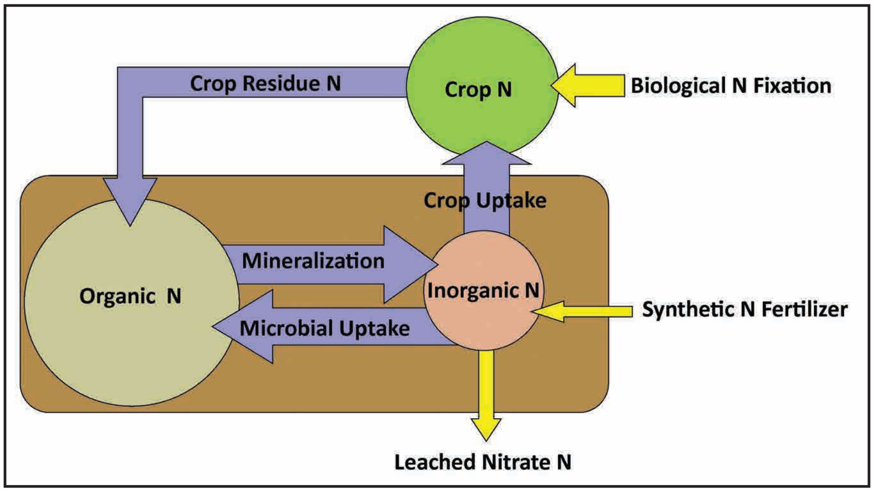

Figure 1. Generalized nitrogen cycle in an agricultural system. Circles represent N pools, and arrows represent flows into and out of pools.

N availability is controlled by both the total size of the inorganic N pool in the soil as well as the flows of N into and out of this pool. Diversified cropping systems that utilize legumes as a major N source could maintain high rates of N cycling, producing a relatively consistent stream of inorganic N from a large organic N pool. Thus, including cereal rye/red clover in corn and soybean rotations could enhance both N mineralization and the N supply to a subsequent corn crop.

Table 1

Crop management in the two treatments at the two farms in 2014.

Farm	Treatment	Preceding crop	Red clover termination	Corn Planting	Pre-plant N rate (lb/ac)	Side-dress fertilization	Side-dress N rate (lb/ac)	Total N rate
Sieren	Red clover	Rye/red clover	April 23	May 6	23	--	0	23
	Synthetic N	Rye alone	--	May 6	113	June 12	77	190
Sloan	Red clover	Rye/red clover	May 18	May 21	27	--	0	27
	Synthetic N	Soybean/rye	--	May 21	27	June 14 & July 8	110	137

This project measured N availability in the corn year of rye/red clover-corn rotations on farms operated by Tim Sieren and Dick Sloan. These rotations were previously established by Tim and Dick as part of on-farm research trials in PFI's Cooperators' Program (Gailans and Sieren, 2014; Gailans et al., 2014). To complement those on-farm trials, Tim and Dick invited Iowa State University (ISU) graduate student Will Osterholz on to their farms to quantify N uptake by corn as well as two measures of N release from soil organic matter: net N mineralization and gross ammonification.

Methods

Research was conducted on Dick Sloan's farm near Rowley in Buchanan County in NE Iowa and Tim Sieren's farm near Keota in Washington County in SE Iowa. On both farms, the experimental treatments consisted of a diversified rotation with corn following cereal rye/red clover, and a corn crop that did not follow clover but which received synthetic N fertilizer within a conventional N fertilization strategy (**Table 1**). Red clover was frost-seeded into the standing cereal rye stand in April 2013. Cereal rye was harvested for grain in July, and the red clover grew as a cover crop/green manure until the following spring, when it was terminated with an herbicide prior to corn planting. The synthetic N fertilized treatments differed by farm. At the Sloan farm the synthetic N treatment was no-till corn following a year of soybean with a rye cover crop that was terminated May 18, 2014. At the Sieren farm the synthetic N corn followed cereal rye for grain and did not have a cover crop. Soil nitrogen levels in all treatments were measured using the Late Spring Nitrate Test (LSNT), and synthetic N fertilizer was side-dressed on the synthetic N corn only using the results of the LSNT (Blackmer et al., 1997).

The farms employed side-by-side strips between 300 and 750 ft in length to compare treatments. The Sieren farm employed 4 randomized replicates of the treatments, while the Sloan farm had a single side-by-side comparison of the treatments along a ~1300 ft strip. In order to increase confidence in our results, Dick and Will divided the single comparison at the Sloan site into 4 ~325 ft strips. The sampling scheme thus entailed sampling 4 replicates of 2 treatments at 2 sites, for a total of 16 experimental units for each of the measurements.

Two indicators of soil N cycling, net N mineralization and gross N mineralization, were measured in a laboratory at ISU. Soil samples, taken to a one-foot depth, were collected on both farms on August 4-5, 2014. Net N mineralization measurements followed a 7-day anaerobic incubation technique (Bundy and Meisinger, 1994). Potentially mineralizable N (PMN) is a measure of the accumulation of ammonium (NH_4^+) over a 7-day period in an anaerobic (saturated) soil sample. Gross ammonification rates were made using the ^{15}N pool dilution technique (Hart et al., 1994), where gross ammonification rate measures the rate at which organic nitrogen is broken down to ammonium (NH_4^+). Nitrogen cycling rates were scaled up assuming a soil bulk density of 1.35 g/cm^{-3}.

Nitrogen uptake in the corn crop was measured by sampling corn plants at two dates: at the time of soil sampling in early

August and after crop reached maturity on September 24 (Sieren) and October 28, 2014 (Sloan). Corn was separated into grain and stover, and analyzed for biomass and N content by drying, weighing, and submitting samples to the Iowa State Soil and Plant Analysis Laboratory. Plant mass and N content were scaled up to a per acre basis using plant populations of 28,700 plants/ac at Sloan's farm and 28,900 plants/ac at Sieren's, which were determined by comparing sampled yield to actual harvested yield. Red clover biomass and N content was measured in spring before termination.

Data analysis was performed by Will Osterholz using JMP Pro 10 (SAS Institute, Cary NC). Analysis of variance was used to compare treatments and sites, and repeated measures were used for the plant sample data from two dates. Least square means were used to calculate site and treatment averages and standard errors.

Results and Discussion

Total rainfall during the period of April 1-September 30, 2014 at Tim Sieren's farm was 33.8 in. compared to the 120-year average of 23.1 in. at Washington, Iowa (12 miles from Tim's) (Iowa Environmental Mesonet, 2014). For that same period, total rainfall at Dick Sloan's was 25.9 in. compared to the long-term average of 24.8 in. at Independence, Iowa (11 miles from Dick's) (Iowa Environmental Mesonet, 2014). Rainfall in July and August at Dick's, however, was approximately 60% of the long-term average (5.4 vs. 8.8 in.).

Red clover biomass

At Tim Sieren's, the above ground red clover biomass averaged 5,210 lb/ac prior to termination in Spring 2014, with a total N content of 113 lb N/ac. At Dick Sloan's, clover was sampled in Fall 2013 only, prior to a killing frost. Aboveground biomass averaged 6,670 lb/ac with a total N content of 176 lb N/ac.

Corn biomass and N content

Over the two sampling dates both corn biomass (**Fig. 2**) and corn N content (**Fig. 3**) were greater in the synthetic N strips compared to the red clover strips at both farms. Similarly corn grain yield was greater in the synthetic N corn compared to the corn following red clover (**Table 2**), which suggests that corn following red clover experienced N limitation. Yield results presented in an earlier PFI research report from the same trial at Tim Sieren's farm supports this hypothesis. This earlier report considered an additional treatment where the corn following red clover received 100 lb N/acre in June (this treatment was not included in the current study). Tim found corn from this treatment was able to yield ~30 bu/ac greater than the corn following red clover without supplemental fertilizer, suggesting N limitation in the corn following clover without N (Gailans and Sieren, 2014).

Table 2

Corn yields in the two treatments at the two farms in 2014.

Farm	Treatment	Corn yield (bu/ac)
Sieren	Red clover	150
	Synthetic N	199
Sloan	Red clover	127
	Synthetic N	179

Figure 2

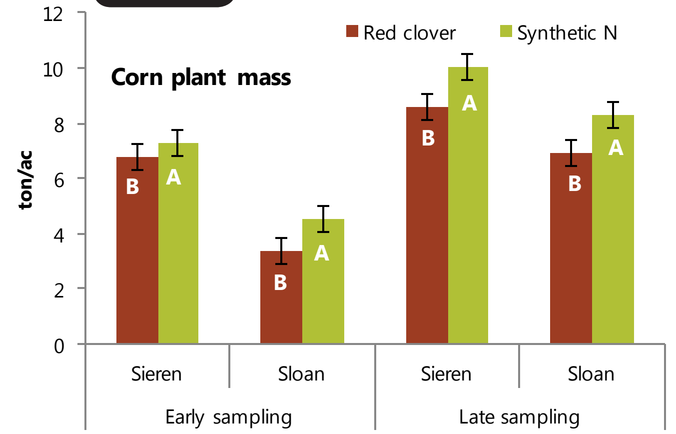

Figure 2. Corn plant biomass. Early sampling was first week of Aug. and late sampling was in late Sept. (Sieren) or Oct. (Sloan). The statistical analysis showed that sites were different (Sieren > Sloan) and the dates were different (Late sampling > Early sampling). By farm and sampling date, columns with different letters are significantly different. Error bars represent standard error of the mean.

Figure 3

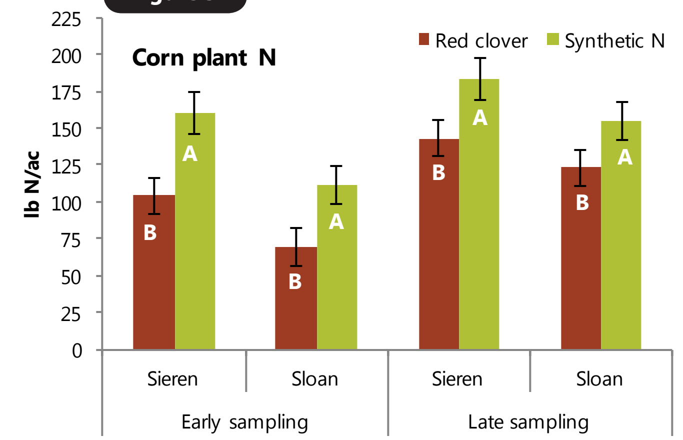

Figure 3. Total corn plant N content. Early sampling was first week of Aug. and late sampling was in late Sept. (Sieren) or Oct. (Sloan). The statistical analysis showed that sites were different (Sieren > Sloan) and the dates were different (Late sampling > early sampling). By farm and sampling date, columns with different letters are significantly different. Error bars represent standard error of the mean.

Red clover prior to chemical termination in May at Dick Sloan's farm.

The corn plant N content results (**Fig. 3**) suggest that reduced corn yield following red clover may be due to limitations in plant N supply early in the growing season N. Between the two sampling dates (Aug. – Oct.), the increase in corn total N between early August and October was possibly greater in the corn following red clover compared to the synthetic N corn at both farms, although this was not statistically significant (**Table 3**). This result suggests that the red clover treatment was able to provide available N to the corn late in the growing season as the red clover was decomposed and N was released. Growing red clover before corn has been shown to replace a significant portion of the N fertilizer needed by a following corn crop when the clover was terminated by plowing in the fall or the spring in northeast Iowa (Liebman et al., 2012). Previous findings at Tim Sieren's showed that the red clover was able to replace at least 43 lb N/acre when chemically terminated prior to planting corn (Gailans and Sieren, 2014).

Soil N cycling

Soil N cycling was assessed in early August at both farms. Both gross ammonification rate and potentially mineralizable N measurements provide an estimate as to the amount of soil N becoming plant-available on a daily basis and are expressed as lb N/ac/day. Gross ammonification was >2x higher at Sieren's compared to Sloan's farm, which may have been caused by greater precipitation and soil moisture at Sieren's enhancing the breakdown of red clover biomass. The N cycling measurements were not statistically significantly between the red clover and synthetic N treatments, due in part to high variability in the measurements (**Figs. 4** and **5**). While the N mineralization rates in the red clover treatments tended to be higher than in the synthetic N treatments, the differences were not large enough to provide support for the hypothesis that red clover treatment would enhance soil N mineralization rates. The results do suggest, however, that any reductions in yield in the corn following red clover (**Table 2**) are not due to lack of soil N later in the summer. Rather, N limitation likely occurs early in the growing season before the decomposition of the clover biomass can release substantial plant available N. "Even though clover biomass seemed to contain plenty of nitrogen to grow a crop of corn," Dick notes, "the timing of its availability in the soil to the corn crop [late in the season] in my experience means I expect to provide additional N fertilizer to the corn."

Management that attempts to address early season N limitation following spring-killed red clover may help overcome the corn yield hit observed in these on-farm trials (and those documented by farmer-cooperators in Gailans and Sieren [2014] and Gailans et al. [2014]). Vyn et al. (2000) observed in Ontario, Canada that the corn yield response to N fertilizer may have been greater in spring-killed red clover compared to autumn-killed red clover, suggesting that N fertilization is particularly important when a red clover cover crop is killed shortly before corn planting. Building on the insights of this on-farm study, it may very well be that earlier fertilization with supplemental N, possibly at corn planting, could provide corn with early season N during the period of N limitation before clover decomposition can provide sufficient N to the corn crop in late summer.

Table 3

Change in total plant N between the early and late sampling times for both treatments at both farms.

Farm	Treatment	Early sampling	Late sampling	Change
		-------- Plant N (lb/ac) --------		
Sieren	Red clover	104	143	39
	Synthetic N	160	183	23
Sloan	Red clover	69	123	54
	Synthetic N	111	155	44

Figure 4

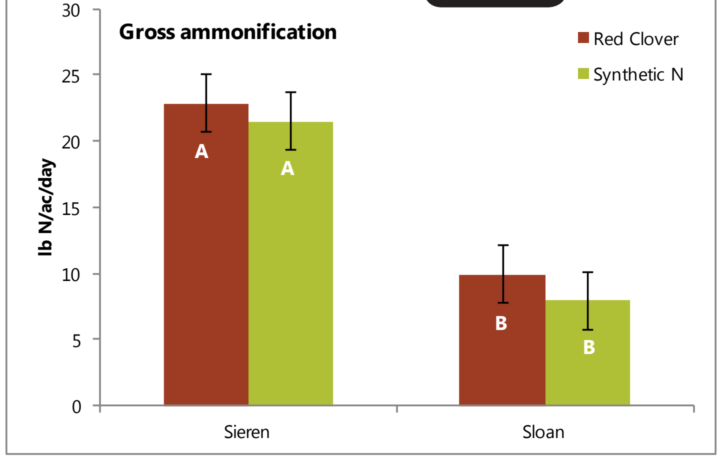

Figure 4. Gross ammonification rate is a measure of the rate at which organic nitrogen is broken down to ammonium (NH_4^+), and this rate was measured once during the first week of Aug. 2014. Gross ammonification was significantly different between the two sites (Sieren farm > Sloan farm), but did not differ by the treatment. Error bars represent standard error of the mean, and letters represent statistically different groups.

Figure 5

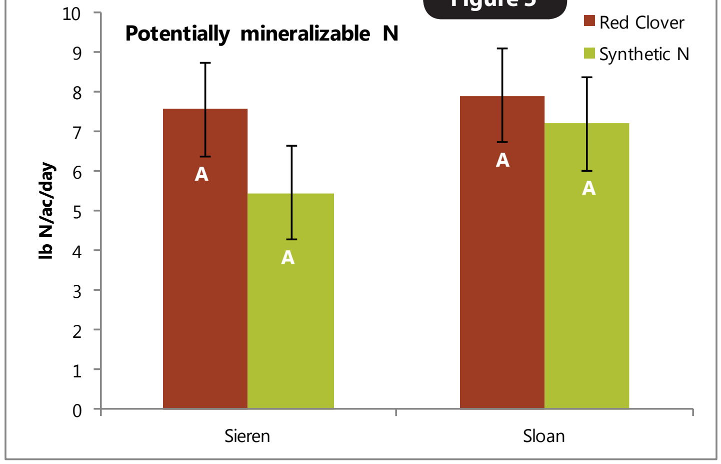

Figure 5. Potentially mineralizable N (PMN) is a measure of the accumulation of NH_4^+ over a 7-day period in an anaerobic (saturated) soil sample. PMN was not significantly different between the two sites or the two treatments. Error bars represent standard error of the mean, and letters represent statistically different groups.

Conclusions and Next Steps

The findings presented above supplement previous findings reported by PFI farmer-cooperators, Tim Sieren and Dick Sloan, in Gailans and Sieren (2014) and Gailans et al. (2014). Spring terminated red clover did not significantly enhance N cycling in a succeeding corn crop on the two cooperating farms. Corn yields in this study were less when following a spring terminated red clover cover crop compared to corn fertilized with synthetic N. Corn plant N results, however, suggest that the decomposing red clover was able to provide significant late season N to the corn. Conceivably, moderate fertilization at corn planting could enable the young corn crop to overcome early season N limitation and enhance corn yields following red clover.

Conducting research like this has been rewarding for Tim: "This project gave me the confidence to measure and use the fertilizer value that cover crops can provide As a result of this project, I've been planting different cover crops to find out what characteristics they might have that could add even more value to my rotations than red clover. I'm learning that there are other cover crops that work better with row crop rotations, and I'm still learning all their characteristics. It gives me more tools in my toolbox for profitable crop production, and red clover will always be one of those tools, in the right situation. And I'm improving my conservation efforts as well as protecting the environment as an added bonus."

With further adjustments of agronomic practices, spring terminated red clover could prove to be a successful strategy to reduce synthetic N fertilizer requirements and N losses while still maintaining high yields in a following corn crop.

Dick is looking ahead to potential future on-farm research trials: "I think there are a number of valuable clues from this research that will help us refine our management of the clover to corn rotation. For instance, since the nitrogen availability to the corn plant comes later perhaps we need to kill the clover in the fall (I have found it difficult to kill in the spring). I would consider setting up a trial to compare fall terminated clover to spring terminated clover."

Both Tim Sieren and Dick Sloan established red clover with a cereal rye seed crop the previous year.

Acknowledgements

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