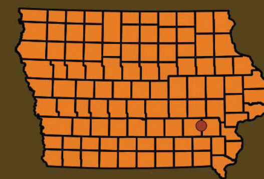
Field Crops Research



Nitrogen Replacement Value of Red Clover

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http://bit.ly/pfi_fieldcrops

In a Nutshell

- Extending and diversifying a crop rotation to include a small grain presents farmers with the opportunity to also include a forage legume that could possibly reduce the need for synthetic N fertilizer.
- Cooperator Tim Sieren grew corn in rotation following cereal rye frost-seeded with red clover and corn in rotation following cereal rye alone.
- Tim also applied a low and high N rate to the corn following rye + red clover and the corn following rye alone.

Key Findings

- Corn following rye and red clover and receiving 100 lb N/ac yielded the same as corn following rye alone that received 143 and 190 lb N/ac.
- This was enough of a reduction in applied N to significantly reduce the amount of money Tim spent on N fertilizer per bushel of corn produced.

Project Timeline
2013-2014

Corn emerges through a mat of cereal rye and red clover residue at Tim Sieren's Green Iron Farms.

Background

Farmers intent on replacing expensive, synthetically-derived forms of plant nutrients for crop production have often looked to include forage legume species such as alfalfa, red clover or hairy vetch in their crop rotations. These legumes are often established with a small grain species such as oats, wheat or rye in the growing season preceding corn production. After the small grain is harvested in July, the legume grows for the remainder of the season, overwinters, greens up the following spring and is finally terminated prior to planting corn.

A potential benefit of using these biological forms of N is the alignment of soil N availability with the period of rapid N uptake in the corn's lifecycle. As the legume decomposes during the season, N slowly becomes plant-available. Synthetic N fertilizer, on the other hand, becomes readily plant-available shortly following application. Better aligning soil N availability with crop uptake during the season reduces the susceptibility for N to be leached from the soil with ground water (Dinnes et al., 2000). Research across the Corn Belt has shown red clover to replace between 90-185 lb N/ac of applied N fertilizer for corn production (Vyn et al., 2000; Liebman et al., 2012; Gaudin et al., 2013).

The objective of this research project was to quantify the agronomic and economic effect on corn production by replacing applied N fertilizer with a red clover cover crop that had been frost-seeded into winter cereal rye the previous growing season. Comparisons are made between corn that was preceded in rotation by either cereal rye + red clover or cereal rye alone that received 'low' and 'high' rates of applied N fertilizer.

Method

This research project was conducted by Tim Sieren of Green Iron Farms near Keota in Washington County in southeast Iowa. Green Iron Farms is a small, diversified row crop-livestock family farm.

Treatments included two cropping systems (cereal rye + red clover followed by corn and cereal rye alone followed by corn) and two N rates (low and high) particular to each cropping system. The treatments were replicated four times in randomized strips running the length of a field. Cereal rye was drilled following corn harvest in 2012. Crop management is listed in **Table 1**. Corn was managed under no-till conditions and all strips received a banded fertilizer prior to corn planting at a rate of 40 gal/ac. The anhydrous ammonia applied in the Rye alone treatments was accompanied by 1 qt/ac of N-Serve®.

Red clover was terminated with a combination of glyphosate (32 oz/ac), ammonium sulfate (2 lb/ac), Trizmet II (2 qt/ac), metachlor (0.5 qt/ac), and 2,4-D (0.5 pt/ac). All strips were sprayed with the recommended rate of glyphosate on June 13, 2014 to control weeds.

Soil nitrate concentration was determined to a depth of 12 in. by collecting soil samples according to protocols for the late-spring soil nitrate test (Blackmer et al., 1997) when corn was six to eight inches tall on June 2, 2014.

Stalk samples were collected for nitrate concentration analysis on September 24, 2014.

Corn was harvested from all strips on October 24, 2014 and corrected for 15.5% moisture.

Data were analyzed using JMP Pro 10 (SAS Institute Inc., Cary, NC) and yield comparisons employ least squares means for accuracy. Statistical significance is determined at $P \leq 0.05$ level and means separations are reported using Tukey's Least Significant Difference (LSD).

Results and Discussion

Total rainfall during the period of April 1-September 30, 2014 at Green Iron Farms was 33.8 in. compared to the 120-year average of 23.1 in. at Washington, Iowa (12 miles from Green Iron Farms) (Iowa Environmental Mesonet, 2014).

Prior to termination on April 23, 2014, average red clover aboveground biomass among those strips was 5,210 lb/ac. With an N concentration of 2.2%, the aboveground biomass contained 113 lb N/ac. The C:N ratio of the aboveground biomass was 17, which falls within the range suitable for microbial decomposition and release of N given ideal conditions (Sullivan, 2003).

Soil nitrate concentrations when corn was six to eight inches tall are provided in **Table 2**. This stage of development in the corn lifecycle marks the beginning of the period of rapid N uptake from the soil (Blackmer et al., 1997). Soil nitrogen in the nitrate form is readily available for plant uptake. There was no difference among the treatments in the of soil nitrate in the soil at this point in the growing season.

Stalk nitrate concentrations just after the corn had reached physiological maturity ("black layer") are shown in **Table 3**. Across all preceding crop-N rate combinations, stalk nitrate concentrations fell into the "low" category (Blackmer and Mallarino, 1996). This signifies that the corn in all treatments could have received and used more N to ensure maximum yield potential. The likely cause for these "low" values was the predominantly wet conditions; in 2014 precipitation at the farm exceeded the long-term average by 10.7 in. The additional rain and subsequent wet conditions likely caused N to leach from the soil before uptake by the corn.

Corn yields are provided in **Figure 1**. Yields from both Rye alone treatments and the Rye-clover + 100 lb N/ac treatment were statistically equivalent. Yields from these three treatments were greater than the 10-year corn yield average for Washington County of 163 bu/ac (USDA-NASS, 2014).

As no difference was detected between the Rye-clover + 100 lb N/ac and Rye alone + 143 lb N/ac treatments (as well as no difference between the Rye alone + 190 lb N/ac and Rye alone + 143 lb N/ac treatments), we can assess the fertilizer

Table 1

Crop management among the treatments

Treatment	Cereal rye planting rate & date	Red clover broadcast rate & date	Cereal rye harvest	Red clover sampling & termination	Corn planting	Pre-plant fertilizer rate (lb/ac)	Side-dress N rate	Total N rate
Rye-clover + Low N	120 lb/ac on Oct. 20, 2012	14 lb/ac on April 4, 2013	July 16, 2013	April 23, 2014	May 6, 2014	23 lb N, 50 lb P, 75 lb K, 15 lb S, 0.3 lb B, 0.5 lb Zn as starter fertilizer	-	23 lb N/ac
Rye-clover + High N	120 lb/ac on Oct. 20, 2012	14 lb/ac on April 4, 2013	July 16, 2013	April 23, 2014	May 6, 2014	23 lb N, 50 lb P, 75 lb K, 15 lb S, 0.3 lb B, 0.5 lb Zn as starter fertilizer	77 lb N/ac as UAN (32%)	100 lb N/ac
Rye alone + Low N	120 lb/ac on Oct. 20, 2012	-	July 16, 2013	-	May 6, 2014	113 lb N, 50 lb P, 75 lb K, 15 lb S, 0.3 lb B, 0.5 lb Zn as starter fertilizer and anhydrous ammonia	30 lb N/ac as UAN (32%)	143 lb N/ac
Rye alone + High N	120 lb/ac on Oct. 20, 2012	-	July 16, 2013	-	May 6, 2014	113 lb N, 50 lb P, 75 lb K, 15 lb S, 0.3 lb B, 0.5 lb Zn as starter fertilizer and anhydrous ammonia	77 lb N/ac as UAN (32%)	190 lb N/ac

Table 2

Soil nitrate concentrations at 12 in. depth and soil N contents as affected by preceding crop and rate of N applied.

Preceding crop and N rate	Soil nitrate concentration (ppm)[a]	Soil N content (lb N/ac)[b]
Rye-clover + 23 lb N/ac	18 a	144
Rye-clover + 100 lb N/ac	18 a	144
Rye alone + 143 lb N/ac	19 a	152
Rye alone + 190 lb N/ac	21 a	168

[a] Values followed by the same letter are not significantly different at $P \leq 0.05$. LSD = 13 ppm.
[b] After Blackmer et al. (1997).

Table 3

Stalk nitrate concentrations in corn just after physiological maturity as affected by preceding crop and rate of N applied.

Preceding crop and N rate	Stalk nitrate concentration (ppm)[a]	Interpretation[b]
Rye-clover + 23 lb N/ac	30 a	Low
Rye-clover + 100 lb N/ac	20 a	Low
Rye alone + 143 lb N/ac	20 a	Low
Rye alone + 190 lb N/ac	31 a	Low

[a] Values followed by the same letter are not significantly different at $P \leq 0.05$. LSD = 31 ppm.
[b] After Blackmer and Mallarino (1996).

Figure 1

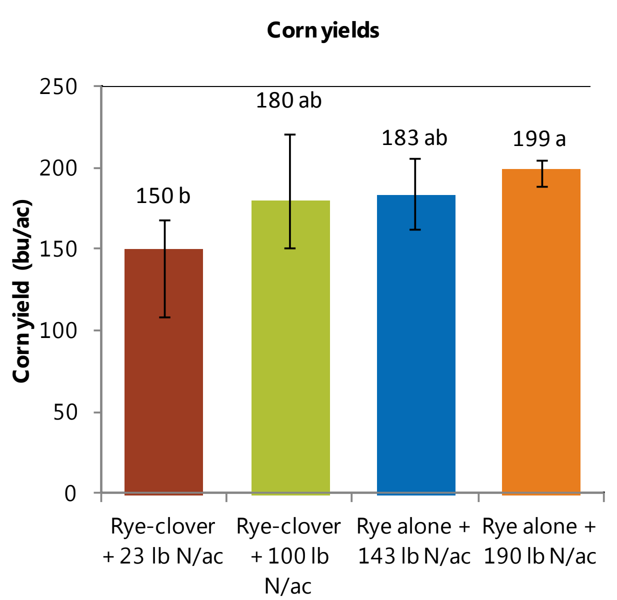

Figure 1. Corn yields from strips harvested on October 24, 2014. Mean values above each column followed by the same lower-case letter are not significantly different (LSD = 41 bu/ac). Black bars represent the maximum and minimum yields observed for each treatment.

replacement value (FRV) of the clover (143 – 100 = 43 lb N/ac). This 43 lb N/ac is conceivable as previous work in Iowa found the FRV of red clover to corn to range from 90-185 lb N/ac (Liebman et al., 2012). That study, however, involved corn grown under fall and spring tillage and the present study involved no tillage. The red clover at Tim's in the present study contained 113 lb N/ac in aboveground shoots and leaves the fall prior to corn being grown. A portion of this N became plant-available through microbial decomposition and offset the greater amount of N fertilizer applied to the corn in the Rye alone treatments.

A closer look at the range in corn yields observed for each of the treatments (black bars in **Figure 1**) suggests that yields resulting from the Rye-clover treatments were more variable than those from the Rye alone treatments. The ranges for the Rye alone + 190 lb N/ac and Rye alone + 143 lb N/ac treatments (16 and 44 bu/ac, respectively) were less than those observed for the Rye-clover + 100 lb N/ac and Rye-clover + 23 lb N/ac treatments (70 and 59 bu/ac, respectively). One strip in the Rye-clover + 100 lb N/ac treatment yielded 221 bu/ac and this was the high strip yield for the entire experiment.

Economic considerations

Economic considerations of the preceding crop and N rate combinations are presented in **Table 4**. Tim provided the prices he paid for the liquid starter fertilizer, anhydrous ammonia, N-Serve®, and UAN (32%). The total cost of the N applied for each treatment is presented as well as the amount spent on applied N per bushel of corn produced. Tim spent the most per bushel in the Rye alone + 190 lb N/ac treatment and the least in the Rye-clover + 23 lb N/ac treatment. Nearly $0.20 more was spent on N per bushel of corn produced in the Rye alone + 190 lb N/ac treatment compared to the Rye-clover + 100 lb N/ac treatment, yet yields were not significantly different (**Figure 1**).

Table 4

Costs associated with the treatments. Amount of each source of N applied is listed in Table 1

Preceding crop and N rate	Cost of N applied at planting[a] ($/ac)	Cost of additive[b] ($/ac)	Cost of side-dress N[c] ($/ac)	Total cost of N ($/ac)	Average amount spent on N per bu corn[d] ($/bu)
Rye-clover + 23 lb N/ac	$4.83	--	--	$4.83	$0.03 c
Rye-clover + 100 lb N/ac	$4.83	--	$47.69	$52.52	$0.29 b
Rye alone + 143 lb N/ac	$34.43	$13.00	$16.89	$64.95	$0.35 b
Rye alone + 190 lb N/ac	$34.43	$13.00	$47.69	$95.75	$0.48 a

[a] The liquid starter applied to the whole field was quoted at $0.21/lb N. Anhydrous ammonia applied to the Rye alone treatments was quoted at $660/ton.
[b] N-Serve® quoted at $13.00/qt, applied at 1 qt/ac with the anhydrous ammonia in Rye alone treatments.
[c] UAN (32%) was quoted at $350/ton.
[d] Calculated as the total cost of N divided by the corn grain yield from each strip for each treatment. Values followed by the same lower-case letter are not significantly different (LSD = $0.06/bu).

Conclusion

Tim Sieren assessed yields of corn grown in rotation with cereal rye that he raises for cover crop seed by looking at two kinds of systems: those that relied mostly on synthetic N and those that relied mostly on biologically-derived N. In the systems that relied on synthetic N, Tim applied a low (143 lb N/ac) and high (190 lb N/ac) rate of N fertilizer to his corn, mostly in the form on anhydrous ammonia at the time of corn planting. In the systems that relied on biologically-derived N, Tim applied two rates of N fertilizer (23 and 100 lb N/ac) to his corn but also frost-seeded red clover, a forage legume, with his rye the year prior that acted as a cover crop and green manure crop.

Based on his results, Tim was able to reduce applied N by 43 lb N/ac and still see top yields when he grew corn after the Rye-clover pairing. This reduction in applied N fertilizer also significantly reduced his expenses on applied N by $0.06/bu corn produced.

Based on these results, farmers looking to reduce reliance on applied, synthetic N should consider implementing a small grain coupled with a forage legume like red clover into their crop rotations.

Cereal rye frost seeded with red clover at Tim Sieren's Green Iron Farms.

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