Drainage Water Quality Impacts of Various In-field Nutrient Management Practices:

Agriculture Drainage Research and Demonstration Site – Gilmore City

Research focused on the effects of nitrogen (N) management on crop production and tile drainage water quality has been conducted in north-central Iowa near Gilmore City since 1989. The research site ag drainage well (ADW) includes 72 individually drained plots that are 50 feet wide and 125 feet long (Figures 1 and 2). Tile lines were installed at a depth of 3.5 feet spaced 25 feet apart. The center tile line from each plot is pump monitored continuously for drainage volume with a flow meter and a flow-proportional sample is passively collected for nitrate-nitrogen (nitrate-N) and dissolved phosphorus (P) analysis (Figure 3). Drainage flow is recorded and water samples are collected for analysis weekly. Soil types at ADW include Nicollet, Webster and Canisteo, all of which are clay loams. The 30-year average annual rainfall for ADW is 33.5 inches.

At ADW, multiple management practices have been examined for their impact on N and P loss and crop yield:

Crops: Corn-soybean, continuous corn, perennial forage

Management Practices: Cover crops, tillage, land use, N-fertilizer source/rate/timing

Figure 1. Aerial photo of 9.4-acre research site.

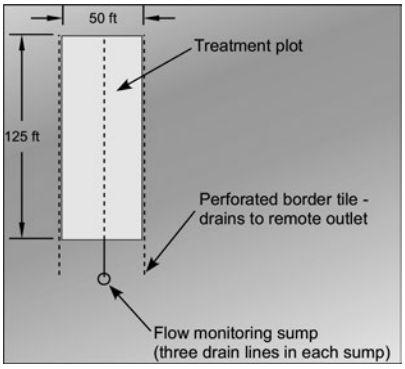

Figure 2. Schematic of plot drainage collection system.

Figure 3. Image of drainage volume and water quality monitoring setup at ADW.

Key Findings from 21 Years of Research (1989-2009):

- When N-fertilizer is applied at economic N-rates, the average concentration of nitrate-N in tile drainage ranged from 12 to 16 mg/L. (Drinking water standard is 10 mg/L) (Figure 4).
- When similar N-application rates to corn are used in 1) a corn-soybean rotation and 2) a continuous corn rotation, similar nitrate-N concentrations are observed in the tile drainage. When an additional 50 lbs N/acre are applied to continuous corn, however, nitrate-N concentrations are about 25 percent greater than the corn-soybean system.
- A fertilization rate of 120-160 lb-N/acre for a corn-soybean rotation allowed the corn to reach its yield potential.
- Over the long-term, approximately 10 inches of the annual 30 inches of precipitation exited through the tile drains. This resulted in an average nitrate-N loss of approximately 36 lb/acre through the drainage system with a 150-160 lb/acre N-fertilization rate to corn in a corn-soybean rotation. Due to weather conditions, the annual N-loss at this application rate varied from 0.9 lb/acre to 94 lb/acre (Figure 5).
- For a corn–soybean rotation with no N fertilizer applied there was still 15-20 lb N/acre lost through tile drains at nitrate-N concentrations of 6-8 mg/L.
- In general, concentration of nitrate in the tile drainage was similar for the corn and soybean phases of the corn-soybean rotation.

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- The nitrate concentration in tile drainage from treatments fertilized with liquid swine manure was similar to those treated with equal amounts of commercial fertilizer. Generally, the yields were improved using the swine manure.
- During the nine years that timing of fertilizer application was studied, there was little difference in the concentration or loss of nitrate between spring- and fall-applied N fertilizers.
- Use of a cover crop has the potential to reduce nitrate-N concentration in drainage water (Figure 6).
- Perennial land use (orchard grass and clover mix) has the potential to dramatically reduce nitrate-N concentrations in drainage water (Figure 6).
- Overall, long-term research has shown that nitrate-N concentrations generally exceeded 10 mg/L under a corn–soybean rotation when fertilized at common rates; even when no fertilizer is applied, there is loss of nitrate. Based on these studies, high nitrate-N levels are less about mismanagement of N-fertilizer and more a result of the land use and cropping practices.

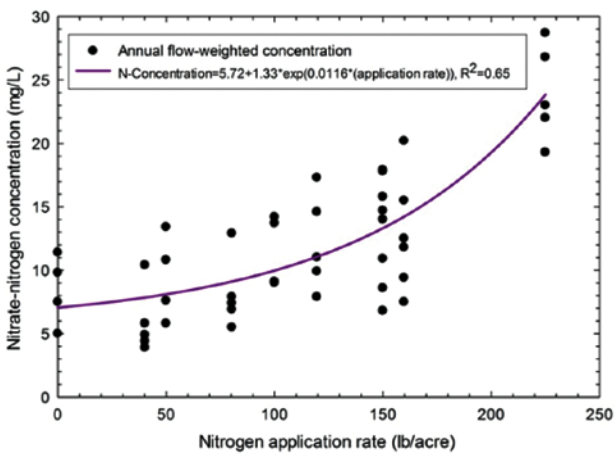

Figure 4. Overall nitrogen application rate effect on nitrate-N concentration for a corn-soybean rotation (1990-2004).

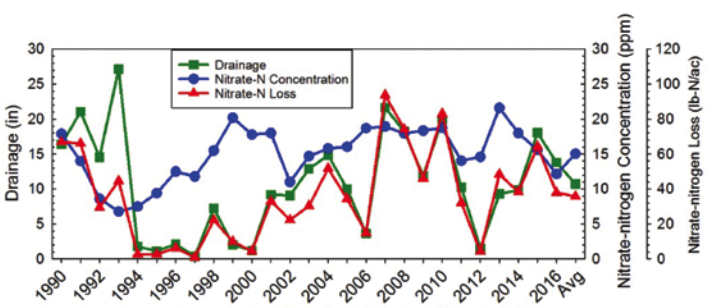

Figure 5. Comparison of drainage volume, nitrate-N concentration and nitrate-N loss for the 150-160 lb N/acre fertilization rate to corn in a corn-soybean rotation from 1990 to 2016.

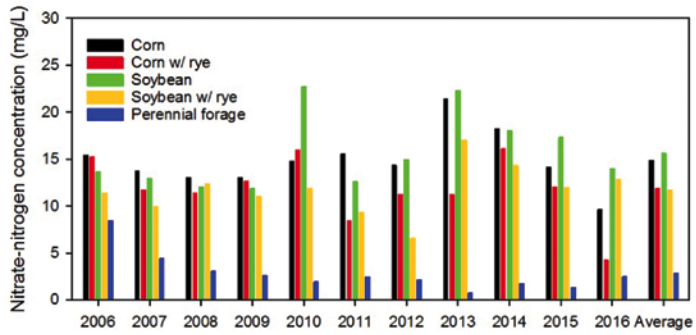

Figure 6. Impact of cover crop and land use on flow-weighted nitrate-N concentration from 2006 to 2016.

Key Findings from 5 Years of Research (2011-2015):

From 2011-2015, treatments focused on:

1. Cereal rye winter cover crop vs. no rye (with and without tillage)
2. Conventional tillage (fall chisel plow with spring cultivation) vs. no-till
3. Nitrogen timing and source (2011-2014)
   a. Fall vs. spring vs. late season sidedress with 150 lb N/acre aqua-ammonia
   b. Aqua-ammonia vs. urea vs. poly-coated urea with a spring application of 150 lb N/acre

General findings:

- Most drainage and nitrate loss at ADW occurs in the spring, due to the timing of rainfall. Over five years, tile drainage ranged from 43 percent of annual rainfall in 2011 to 4 percent in 2012.
- For all treatments, the highest nitrate-N concentration in the tile drainage was found in 2013, which was a year with a wet spring following a drought year (2012).
- In general, concentration of nitrate in the tile drainage was similar for the corn and soybean phases of the corn-soybean rotation.

Cereal rye cover crop versus no cover crop:

- Rye biomass production was on average 125 lbs/acre before corn planting. Before soybean planting, biomass production was greater at 544 lbs/acre due to an average extra 25 growing days. Due to cooler temperatures at ADW, rye biomass production was generally lower than in studies in central Iowa, where rye biomass ranged from 892 to 1,685 lb/acre.

- Rye was drill-seeded after harvest (and after fall tillage in plots with tillage) at a rate of 90 lb/acre from 2010 to 2014 for the 2011 to 2015 crop years.

- Annual subsurface drainage was not significantly impacted by cover crops, though there were minimal (5-10 percent) reductions in drainage volume over the five year period in conventional tillage systems. In no-till systems, rye reduced drainage by 5 percent in the corn phase.

- Over five years, rye significantly reduced the annual nitrate-N load in the conventional tillage system, on average, by 13.6 lb/acre in the corn phase and by 13.0 lb/acre in the soybean phase (Figure 7).

- Over five years, within the conventional tillage systems, rye reduced the average annual flow-weighted nitrate-N concentration in the tile drainage compared to the system without rye. In the corn phase this nitrate-N concentration was 11.4 mg/L with rye and 16.2 mg/L without rye. In the soybean phase these values were similar at 11.8 mg/L and 15.8 mg/L.

- Rye did not have an impact on nitrate-N load in the no-till systems, likely because the no-till systems at ADW had already experienced a significant impact of nitrate-N load reduction compared to the conventional tillage system.

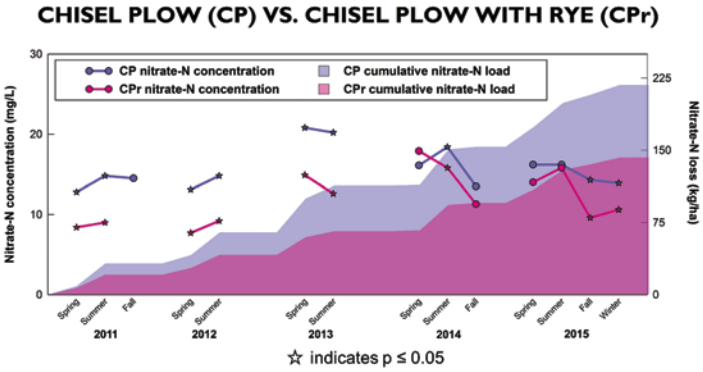

Figure 7. Tile drainage concentration and nitrate-N load by year and season for conventional tillage systems with a rye cover crop (CPr) and without (CP) rye averaged over the corn-soybean phases.

No-till versus conventional tillage:

- Subsurface drainage volume was not significantly impacted by no-till.

- Over five years, no-till reduced the annual nitrate-N load compared to the conventional tillage system, on average, by 10.7 lb/acre in the corn phase and 12.5 lb/acre in the soybean phase (Figure 8).

- Over five years, no-till reduced the annual flow-weighted nitrate-N concentration compared to the conventional tillage system in both the corn and soybean phases (10.9 versus 16.2 mg/L in the corn phase and 12.1 versus 15.8 mg/L in the soybean phase).

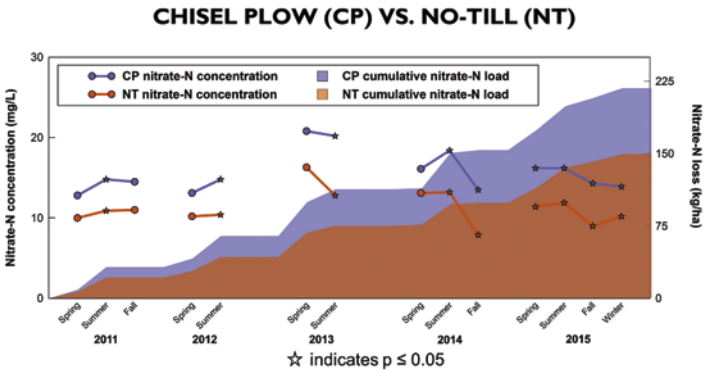

Figure 8. Tile drainage concentration and nitrate-N load by year and season for conventional tillage (CP) and no-till (NT) systems averaged over the corn-soybean phases.

N-fertilizer timing and source:

- Over four years (2011-2014), the average annual drainage volume was similar among N-timing and source treatments within both the corn and soybean phases and ranged from 5.9 inches to 8.0 inches.

- The four-year average corn and soybean yields were similar among all treatments (Figure 9).

- This study showed limited impact of N-application timing on nitrate concentrations in drainage. However, when averaged over the corn-soybean rotation nitrate-N concentrations tended to be lower in the sidedress treatment.

- The four-year average flow-weighted nitrate-N concentration (Figure 9) was significantly higher in the fall application treatment (18.6 mg/L) compared to the sidedress treatment (13.7 mg/L) in the corn phase. In the soybean phase, the fall application treatment for the previous crop (12.3 mg/L) was lower than the spring application to the previous crop (16.9 mg/L). Averaged over both the corn and soybean phases, the four-year average nitrate-N concentration was similar among the spring (17.1 mg/L), fall (15.3 mg/L) and sidedress (14.7 mg/L) treatments.

- The use of poly-coated urea as a source of nitrogen fertilizer showed some potential to reduce nitrate concentrations in subsurface drainage.

- Over the four years, averaged over the corn-soybean rotation, the flow-weighted nitrate-N concentration (Figure 9) was similar between the poly-coated urea (15.0 mg/L), urea (17.2 mg/L) and aqua-ammonia (17.1 mg/L) treatments, however it was significantly lower with poly-coated in 2011.

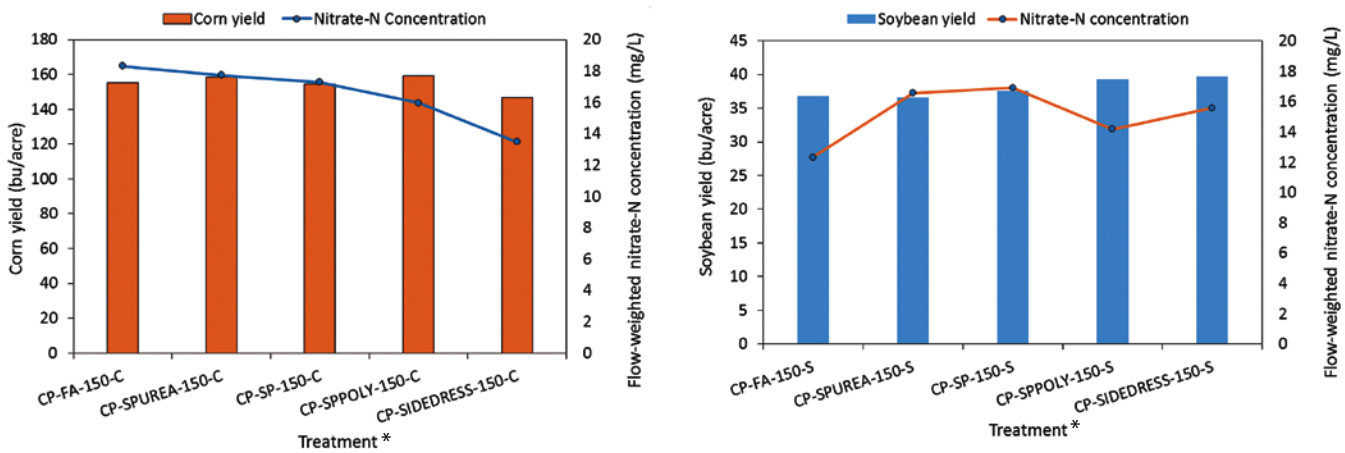

Figure 9. Four-year average corn and soybean yield (bars) with average annual flow-weighted nitrate-N concentrations (points) for each treatment.

*CP-FA-150-C(S) – fall application of aqua-ammonia, CP-SPUREA-150-C(S) – spring application of urea, CP-SP-150-C(S) – spring application of aqua-ammonia, CP-SPPOLY-150-C(S) – spring application of poly-coated urea, CP-SIDEDRESS-150-C(S) – late season sidedress of aqua-ammonia.

Ongoing Research and Preliminary Findings:

Treatments were changed in the fall of 2015 and current treatments are listed in Table 1.
This research is studying the impacts of:

1. Cereal rye winter cover crop vs. no rye (with and without tillage)
2. Conventional tillage (fall chisel plow with spring cultivation) vs. no-till (with and without rye)
3. Timing of N-application and use of nitrification inhibitor

Table 1. Treatments at ADW for crop years 2016-2017.

Treatment Number*	Tillage	Cover Crop	Nitrogen Application Time	Nitrogen Application Rate (lb/acre)
1,2	Conventional tillage	–	Fall – Anhydrous Ammonia	150
3,4	Conventional tillage	–	Fall – Anhydrous with N inhibitor	150
5,6	Conventional tillage	–	Spring - Anhydrous	150
7,8	Conventional tillage	Rye planted into standing corn and beans and tilled prior to planting of cash crop in Spring	Spring - Anhydrous	150
9,10	No-till	–	Spring - Anhydrous	150
11,12	No-till	Rye planted into standing corn and beans	Spring - Anhydrous	150
13,14	Conventional tillage	–	Spring – Anhydrous with N inhibitor	150
15,16	Conventional tillage	–	Spring - Anhydrous Ammonia with UAN sidedress	150 (100 as AA)
17	Kura clover - Corn	–	Spring	150
18	Orchardgrass + Red/ Ladino clover	–	–	no fertilizer

* Within the corn and soybean rotation treatments, odd numbers are soybean and receive no nitrogen.

Preliminary findings:

- Rye biomass production was greatest in 2016 compared to each year in the 2011-2015 rye study (331 lbs/acre on average before corn planting and 2,175 lbs/acre on average before soybean planting). This was due to the early (September 2015) interseeding which allowed for better rye establishment in the fall.
- Corn yield in the no-till system was significantly reduced (176 bu/acre) compared to the conventional tillage system (197 bu/acre).
- Corn yield was not significantly different in the conventional tillage system with rye (184 bu/acre) compared to the conventional tillage system without rye. Yield was not impacted by the rye cover crop in the no-till systems (176 bu/acre in both no-till with rye and no-till without rye).
- Soybean yield was similar between all tillage and rye treatments.
- In 2016, rye and no-till continued to reduce nitrate-N concentration in drainage. In the corn phase, the nitrate-N concentrations were greatest in the conventional tillage system without rye (9.6 mg/L) followed by the no-till system without rye (6.9 mg/L), the no-till system with rye (6.6 mg/L) and finally the conventional system with rye (4.3 mg/L).
- In the soybean phase, similar results were found: 13.9 mg/L for conventional tillage, 12.8 mg/L for conventional tillage with rye, 11.2 mg/L for no-till and 7.3 mg/L for no-till with rye.

Acknowledgements

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