Impact of Fertilizer Application Timing on Drainage Nitrate Levels

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Abstract
Nitrate loss from drainage systems in Iowa and other upper Midwestern states is a concern relative to local water supplies as well as the hypoxic zone in the Gulf of Mexico. As a result, there is a need to quantify how various nitrogen management practices impact nitrate loss. One practice that is commonly mentioned as a potential strategy to reduce nitrate loss is to vary fertilizer application timing and specifically apply nitrogen as close to when the growing crop needs it as possible. At a site in Gilmore City, Iowa, a number of fertilizer timing and rate schemes within a corn soybean rotation were used to study the impacts on nitrate leaching. Timing schemes include nitrogen application in the fall and an early season sidedress in the spring with each scheme having four replicates for both corn and soybeans. Fertilizer application rates investigated are 84 and 140 kg/ha (75 and 125 lb/ac) in the fall and 84 and 140 kg/ha (75 and 125 lb/ac) in the spring. The timing and rates have been practiced since 2005 with contrasting weather conditions each year. Overall, an annual basis there was not significant differences in nitrate concentrations or loss exiting the drainage system between the application rates or between the fall and spring application. In addition, there was not a yield penalty to the corn crop when fertilizer as applied in the fall versus the spring.

Keywords
Subsurface drainage, nitrate, application rate, corn, soybean

Disciplines
Agriculture | Bioresource and Agricultural Engineering

Comments
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Impact of Fertilizer Application Timing on Drainage Nitrate Levels

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Introduction

Subsurface agricultural drainage has allowed for enhanced agriculture production in many areas of the world including the upper Midwest, United States. However, the presence of nitrate in subsurface drain water is a topic of intense scrutiny. Many studies have been done looking at ways to reduce nitrates (Baker et al., 1975; Baker and Johnson, 1981; Hanway and Laflen, 1974; Kanwar et al., 1988) in reaction to human health concerns and the growing concern for the health of the Gulf of Mexico (Mitsch et al., 2001; Rabalais et al., 1996). As a result there is a need to study and recommend nitrogen management practices that have the potential to reduce nitrate concentrations and loss through subsurface drainage systems. One commonly discussed practice is to apply nitrogen in the spring as close to the time that the corn crop needs nitrogen as possible. The objectives of this study were to evaluate timing and rate of nitrogen application on nitrate leaching and crop yield.

Materials and Methods

The study site was in Garfield Township in Pocahontas County, Iowa. Soils are of the Nicollet-Webster-Canisteo (clay loam) series with average slope around 1%. The site is divided up into 78 separate 0.5 ha plots, of which 32 were used for this study. Each plot is subsurface drained at a depth of approximately one meter with one drain down the center of the plot and a drain on each edge to eliminate horizontal nitrate transfer between plots. This setup resulted in a drain spacing of 7.6 m.

Numerous application rates have investigated at this site in the past; however the focus here is on application timing. Nitrogen rates being investigated include 84 kg ha\(^{-1}\) (75 lb/ac) and 140 kg ha\(^{-1}\) (125 lb/ac). Each rate was applied during the corn year of a corn-soybean rotation either in the fall or spring with four replicates per rate per application time. These treatments, and the plots associated with them, did not change during the study duration. Fall fertilizer application consisted of injecting aqua ammonia in mid to late November of each year while spring fertilization occurred just after crop emergence in mid May to early June.

The center drain of each plot was monitored for flow and nitrate concentrations. Nitrate concentrations for each plot were weighted based off the amount of flow during the sampling event and the annual flow to determine an average annual flow-weighted nitrate concentration to be used for comparison. Concentrations were also weighted with respect to monthly flow to evaluate monthly concentrations. Nitrate samples were collected in all years regardless of crop. Data presented here show results from the corn year, the soybean year, and the full rotation.

Climatic conditions over the study period included two relatively dry years, 2005 and 2006, a wet year, 2007, and a moderate to wet year, 2008. Subsurface drainage patterns followed precipitation pattens in almost all cases. The first year of the study, 2005, is considered an adjustment period, as other nutrient application rates were applied prior to this study. This year will be included for reference; however, results from this year are not considered in evaluating the overall treatment impacts.

Statistics were completed with the Statistical Analysis Software (SAS) package (version 9.1) using the Generalized Linear Model (GLM) procedure.

Results

When all plots are considered together, there is a trend of increasing nitrate concentrations when annual drainage volume decreases. This phenomenon has been shown previously in
Lucey and Goolsby (1993) and suggests nitrate storage in the soil profile during dry years. Wet years provide dilution and leaching, which drops the observed concentrations.

Looking at individual treatments from 2005 to 2008, no strong statistical difference is found in resulting subsurface drain water from different nitrogen application timing schemes (Table 1 and Table 2). When removing the adjustment year, 2005, and investigating individual months, five months emerge as being significant at the alpha = 0.1 level and one month at the alpha = 0.05 level (Figure 1). Although only a few points, these observations suggest fall application of fertilizer may be slightly “riskier” than spring application. However, any significance is lost when looking at treatments on an annual basis.

Considering nitrate concentrations from each rotation (2006 to 2008) (Figure 2), there are no statistical differences between either nitrogen application timing or application rate. This is observed because flow weighted nitrate concentrations coming from the drain in the soybean year of each treatment are, for all practical purposes, the same between treatments. No statistical differences are shown in nitrate loss either (Figure 3).

There is some evidence, although not significant, that drain nitrate concentrations in the soybean year are lower when fertilizer was applied the previous year in the fall. This could be due to more leaching in the spring of the corn year, uptake of nitrogen by the corn, and more time available for denitrification.

### Table 1. Annual subsurface flow weighted nitrate concentrations in the corn year of the rotation for 84 kg ha⁻¹ and 140 kg ha⁻¹. Significance is within each year only.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Nitrate N (mg/L) p=0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005</td>
</tr>
<tr>
<td>Fall 84</td>
<td>14.5a</td>
</tr>
<tr>
<td>Spring 84</td>
<td>13.5a</td>
</tr>
<tr>
<td>Fall 140</td>
<td>14.5a</td>
</tr>
<tr>
<td>Spring 140</td>
<td>18.1a</td>
</tr>
</tbody>
</table>

Note: means with the same letter within years (i.e., within columns) are not significantly different at p = 0.05.

### Table 2. Annual subsurface flow weighted nitrate concentrations in the soybean year of the rotation for 84 kg ha⁻¹ and 140 kg ha⁻¹. Significance is within each year only.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Nitrate N (mg/L) p=0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005</td>
</tr>
<tr>
<td>Fall 84</td>
<td>17.8a</td>
</tr>
<tr>
<td>Spring 84</td>
<td>18.8a</td>
</tr>
<tr>
<td>Fall 140</td>
<td>13.5a</td>
</tr>
<tr>
<td>Spring 140</td>
<td>17.0a</td>
</tr>
</tbody>
</table>

Note: means with the same letter within years (i.e., within columns) are not significantly different at p = 0.05.
Figure 1. Monthly drain nitrate response to fertilizer application timing for 2006, 2007, and 2008. The symbols represent significance where † denotes alpha = 0.10 and * denotes alpha = 0.05.
There was little consistently significant differences in crop yields between treatments (Table 3 and Table 4) except that in 2007 the spring-140 treatment had statistically lower corn yield than the fall-140 treatment. This is likely a result of dry conditions after spring application in 2007.
Following nitrogen application in June of 2007 there was little rain at the project site until August 2007 which may have limited movement of the nitrogen down to the primary root zone for the growing corn crop and resulted in less access to the applied nitrogen. Overall, the results indicate limited yield impact due to timing of nitrogen application or, in this study, application rate during the years of this study.

Table 3. Corn yields for the 84 kg ha⁻¹ and 140 kg ha⁻¹ nitrogen application rates. Significance is within each year only.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (kg/ha)</th>
<th>p=0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005</td>
<td>2006</td>
</tr>
<tr>
<td>Fall 84</td>
<td>9792a</td>
<td>8662a</td>
</tr>
<tr>
<td>Spring 84</td>
<td>10168a</td>
<td>9289a</td>
</tr>
<tr>
<td>Fall 140</td>
<td>10294a</td>
<td>9227a</td>
</tr>
<tr>
<td>Spring 140</td>
<td>10859a</td>
<td>8976a</td>
</tr>
</tbody>
</table>

Note: means with the same letter within years (i.e., within columns) are not significantly different at p = 0.05.

Table 4. Soybean yields for the 84 kg ha⁻¹ and 140 kg ha⁻¹ nitrogen application rates. Significance is within each year only.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (kg/ha)</th>
<th>p=0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005</td>
<td>2006</td>
</tr>
<tr>
<td>Fall 84</td>
<td>3362a</td>
<td>2892b</td>
</tr>
<tr>
<td>Spring 84</td>
<td>3430a</td>
<td>3699a</td>
</tr>
<tr>
<td>Fall 140</td>
<td>3228a</td>
<td>3362b</td>
</tr>
<tr>
<td>Spring 140</td>
<td>3295a</td>
<td>3228b</td>
</tr>
</tbody>
</table>

Note: means with the same letter within years (i.e., within columns) are not significantly different at p = 0.05.

Conclusion

There were no statistically significant differences in drain nitrate concentrations due to application of fertilizer in the fall versus the spring when considering annual flow weighted nitrate concentrations. However, during some of the spring months there were significantly greater monthly nitrate concentrations from the fall nitrogen application treatments indicating fall application of fertilizer may be slightly “riskier” than spring application. Findings from this study are consist with other studies at this project site (Lawlor et al., 2004) but differ from studies in Minnesota that found greater nitrate leaching with fall application in some years (Randall and Vetsch, 2005 and Randall et al., 2003). Likely the largest factor when looking at fertilizer application timing is when precipitation and associated nitrate loss occurs.

Acknowledgements

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References


