DRAINAGE MANAGEMENT AND NITROGEN LOSS

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Abstract

Nitrate-N loss through subsurface agricultural drainage is of local and regional concern in the Midwest. Good drainage and nitrogen management practices have the potential to reduce nitrate-N concentrations and loss from subsurface drainage systems. The five year (2005-2009) nitrogen management study in Pocahontas County, IA suggests that while fall application of fertilizer may result in higher nitrate-N concentrations than spring application during certain period of the growing season; overall, nitrogen application timing had no significant impact on nitrate-N concentration on an annual basis. Additionally, nitrogen loss was similar between two N application rates (75 lb/ac and 125 lb/ac). The three-year (2007-2009) drainage management study in Crawfordsville, IA suggests that the shallow and controlled tile systems could be used to decrease subsurface drainage and therefore reduce nitrate-N loss from drain water.

Introduction

Subsurface agricultural drainage has allowed for enhanced agricultural production in many areas of the world including the upper Midwest, United States. However, the presence of nitrate-nitrogen (nitrate-N) in subsurface drain water is a topic of intense scrutiny. Many studies have been done looking at ways to reduce nitrate-N in tile drainage (Baker et al., 1975; Baker and Johnson, 1981; Hanway and Laflen, 1974; Kanwar et al., 1988).With the growing concern for the health of the Gulf of Mexico (Mitsch et al., 2001; Rabalais et al., 1996), there is still a need to study and recommend drainage and nitrogen management practices that have the potential to reduce nitrate-N concentrations and loss through subsurface drainage systems. One practice is to apply the appropriate amount of nitrogen and previous work has found a relationship between nitrogen application rate and drain nitrate-N concentration (Figure 1). Another commonly discussed practice is to apply nitrogen in the spring as close to the time that the corn crop needs nitrogen as possible. Additional practices include management of the drainage system through drainage water management (controlled drainage) or shallower drain placement. Overall objectives of the drainage research group at Iowa State University are to study how drainage management and nitrogen management impact nitrogen loss from subsurface drainage systems.

Materials and Methods

Nitrogen Management Study Site: The study site is 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 0.14 ac plots, of which 32 were used for the study described within. Each plot is subsurface drained at a depth of approximately 3.5 ft with one drain down the center of the plot and a drain on each edge to eliminate lateral flow between plots. This setup resulted in a drain spacing of 25 ft.

Numerous application rates have been investigated at this site in the past; however the focus here is on application timing and two nitrogen rates. Nitrogen rates being investigated include 75 lb/ac and 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 late May to early June.

The center drain of each plot was monitored for flow and nitrate-N concentrations. Nitrate-N concentrations for each plot were weighted based off the amount of flow between sample dates and the annual flow to determine an average annual flow-weighted nitrate-N concentration to be used for comparison. Concentrations were also weighted with respect to monthly flow to evaluate monthly concentrations. Nitrate-N 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, a moderate to wet year, 2008, and another dry growing season in 2009. Subsurface drainage patterns followed precipitation patterns 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.

Treatments were statistically analyzed with the Statistical Analysis Software (SAS) package (version 9.1) using the Generalized Linear Model (GLM) procedure.

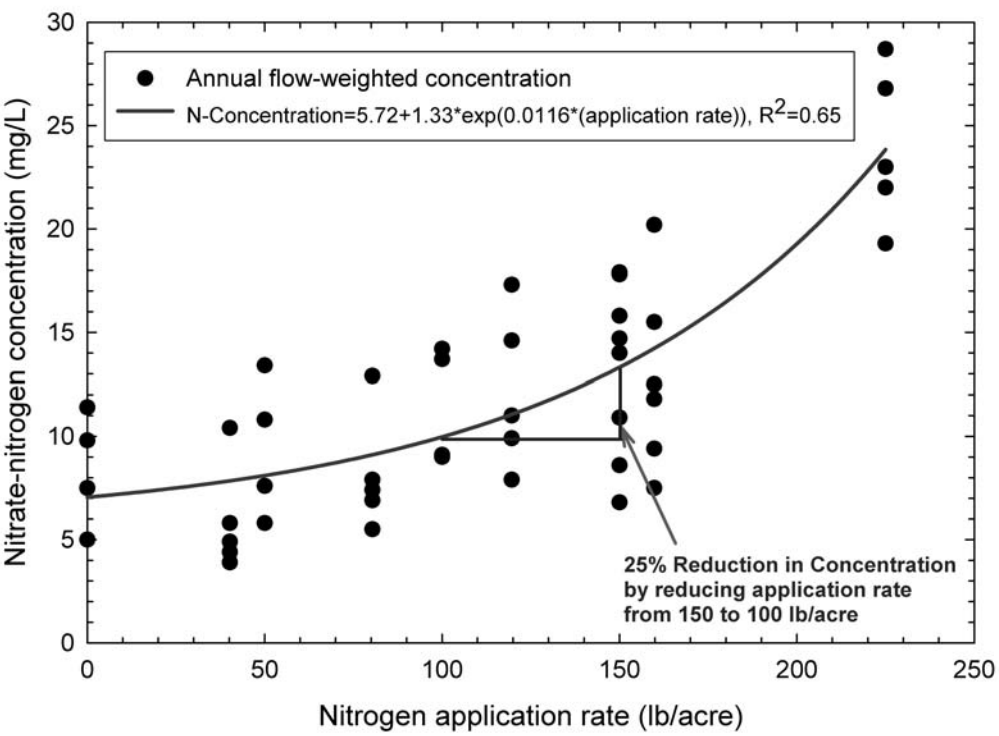

Figure 1. Overall Nitrogen Application Rate Effect on Nitrate-N Concentration for Corn-Soybean Rotation 1990-2004 (not all rates present in each year).

Drainage Management Study Site: Research is being conducted on modified drainage management systems on the Southeast Research Farm (SERF) in Crawfordsville, IA USA (41.19 N, 91.48 W). The site consists of Taintor (silty clay loam, fine, smectitic, mesic Vertic Argiaquolls) and Kalona (silty clay loam, fine, smectitic, mesic Vertic Endoaquolls) soils. The research site has 8 plots with two replications for each treatment (Figure 2). Individual plots range in size from approximately 3 to 6 ac in size for a total project area of 42 ac. Plots are split down the middle and cropped East to West in both corn and soybeans each year. The eight plots include two undrained plots and six plots consisting of:

- 2 plots with conventional drainage (4 ft. tile depth with 60 ft. spacing)
- 2 plots with shallow drainage (2.5 ft. tile depth with 40 ft. spacing)
- 2 plots with controlled (4 ft. tile depth with 60 ft. spacing with controls during the winter and summer and free flow during planting and harvesting).

Tiles lines are laid out in a North-South orientation with interior tiles being continuously monitored for flow rate with a V-notch weir and pressure transducer. Border tiles on each plot are to prevent flow from adjacent plots and these tiles are not monitored. The control gates for the controlled drainage plots are opened late April to early May prior to planting and closed after planting is completed generally in the 1st two weeks of June. Control gates are then reopened in early to mid-September prior to harvest and closed again after fall tillage is completed generally in early November. Data is collected from March through November to avoid freezing conditions. Treatments were statistically analyzed with the Statistical Analysis Software (SAS) package (version 9.1) using the Generalized Linear Model (GLM) procedure.

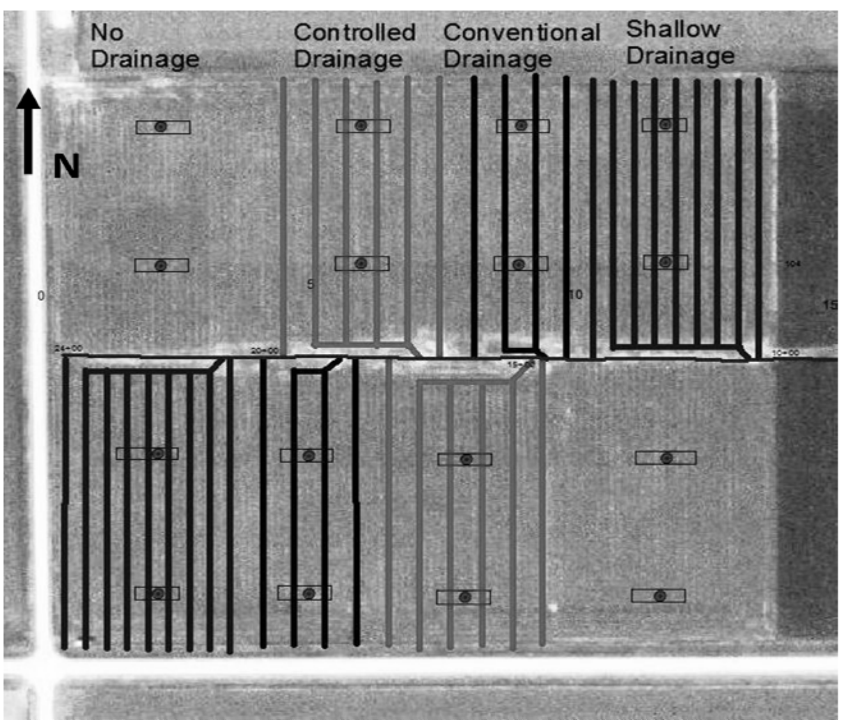

Figure 2. Aerial view of plots at the Crawfordsville, IA research site.

Results

Nitrogen Management Study Site: Looking at individual treatments from 2005 to 2009, no statistical differences were found in nitrate-N concentrations in subsurface drain water from the different nitrogen application timings (Table 1 and Table 2). When removing the adjustment year, 2005, and investigating individual months, four months emerge as being significant at the p = 0.1 level and one month at the p = 0.05 level (Figure 2). 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. Nitrate-N loss from subsurface drain water also varies from year to year due to the variation in annual precipitation and the resulting drainage, as illustrated for spring nitrogen application with a 125 lb/ac rate (table 3).

Table 1. Annual subsurface flow weighted nitrate-N concentrations in the corn year of the rotation for 75 lb/ac and 125 lb/ac. Significance is within each year only.

Treatment		Nitrate-N (mg/l)			
	2005	2006	2007	2008	2009
Fall 75	14.5a	17.3a	10.6b	15.7a	10.8a
Spring 75	13.5a	18.3a	10.0b	14.5a	11.2a
Fall 125	14.5a	16.0a	13.8a	14.9a	11.2a
Spring 125	18.1a	15.1a	13.8a	13.0a	13.0a

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-N concentrations in the soybean year of the rotation for 75 lb/ac and 125 lb/ac. Significance is within each year only.

Treatment		Nitrate-N (mg/l)			
	2005	2006	2007	2008	2009
Fall 75	17.8a	10.4a	11.1a	9.5a	11.9a
Spring 75	18.8a	12.0a	13.5a	9.7a	11.8a
Fall 125	13.5a	14.0a	11.6a	11.5a	10.9a
Spring 125	17.0a	14.9a	12.9a	12.1a	11.9a

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

Table 3. Precipitation, drainage, and NO_3-N loss during March through November for 125 lb/ac spring application.

	Precipitation (inch)	Drainage (inch)	Nitrate-N loss (lb/ac)
2005	22.3	5.5	23.1
2006	21.2	4.2	13.6
2007	33.3	14.6	45.2
2008	32.0	13.9	40.8
2009	26.1	8.2	34.1

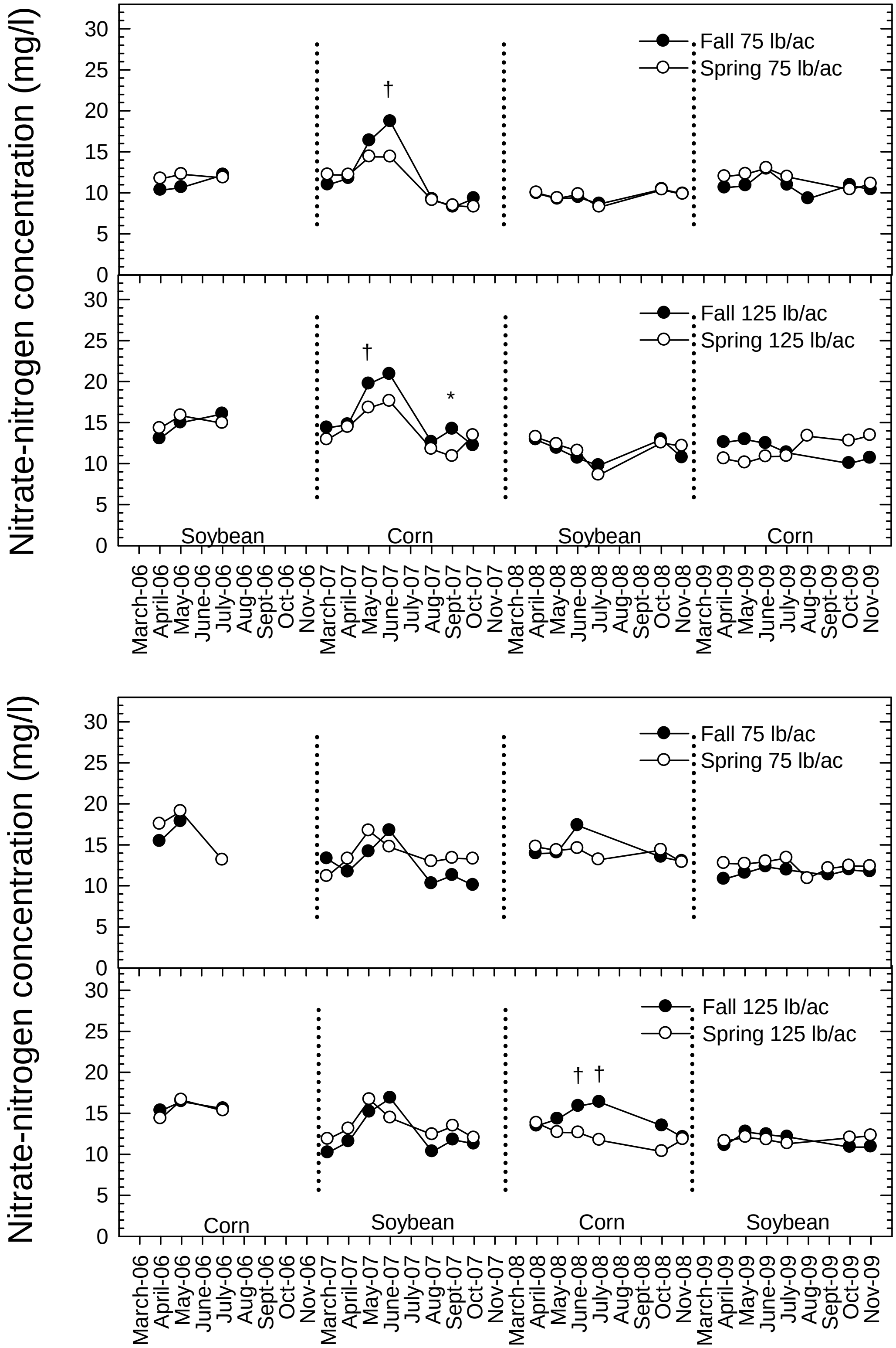

Figure 2. Monthly drain nitrate-N response to fertilizer application timing for 2006, 2007, 2008 and through August of 2009. The symbols represent significance where † denotes p = 0.10 and * denotes p = 0.05.

Drainage Management Study Site: Monthly and annual drainage in the conventional tile plots is noticeably higher than drainage from the shallow and controlled tile systems (Table 4 and 5). Averaging treatments over the three year study period, accounting for annual variation, shows an increase in drainage volume from the conventionally drained plots.

Table 4. Monthly drainage (inch) from the 3 treatments. North and South plots averaged. Conv is conventional drainage, CD is controlled drainage, and SH is shallow drainage. Unavailable data is indicated with NA. Monthly means within years with a different letter are significantly different (p=0.05). Only months with significant differences are indicated.

	Monthly subsurface drainage (inch)								
	2007			**2008**			**2009**		
Month	**Conv**	**CD**	**SH**	**Conv**	**CD**	**SH**	**Conv**	**CD**	**SH**
January	NA	NA	NA	0.0	0.0	0.0	0.3	NA	0.2
February	NA	NA	NA	0.1	0.0	0.0	0.2	0.0	0.0
March	NA	NA	NA	0.0	0.6	0.0	2.0	0.9	1.9
April	0.0	0.0	0.0	2.4ab	3.0a	1.4b	1.8a	1.5ab	0.4b
May	1.2	2.2	1.3	6.8	5.8	3.0	3.4ab	4.0a	1.9b
June	3.9	2.7	3.3	3.7	1.3	1.2	5.4	2.5	3.4
July	0.1	0.1	0.1	0.7	0.0	0.0	1.9	0.8	1.3
August	1.7	0.8	1.3	0.0	0.0	0.9	3.1a	1.6b	1.4b
September	0.0	0.0	0.0	2.2	1.9	0.9	0.0	0.1	0.0
October	1.6a	1.2b	1.2b	0.2a	0.0b	0.1b	5.0a	2.5b	2.5b
November	0.0	0.0	0.0	0.3	0.0	0.0	0.1	0.0	0.1
December	1.7	NA	NA	NA	NA	NA	NA	NA	NA

Table 5. Annual drainage (inch) from the three treatment types. North and South plots averaged. Means within years or for the 3-yr average with a different letter are significantly different (p=0.05).

	Drainage (inch)			
Treatment	2007	2008	2009	3-Year Average
Conventional	10.1a	12.1a	23.2a	15.1a
Controlled	7.1a	9.1ab	14.0a	10.0b
Shallow	7.1a	5.6b	13.1a	8.6b

Summary

The nitrogen management study suggests that fall application of fertilizer may result in higher nitrate-N concentrations than spring application during certain periods of the growing season. However, nitrogen application timing had no significant impact on nitrate-N concentration on an annual basis. The drainage management study suggests that the shallow and controlled tile systems could be used to decrease subsurface drainage compared to the conventional drainage systems and as a result reduce nitrate-N loss from drain water. Additionally, a major factor in nitrate-N loss is the year to year variability in weather conditions. To meet societal demands for reduced export of nitrate-N to downstream waterbodies will take a combination of in-field and end-of-pipe technologies.

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