HOW DO COVER CROPS, NITROGEN RATE, AND CROPPING SYSTEM AFFECT NITRATE LOSS IN TILE DRAINAGE WATER?

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ABSTRACT

A field research study was conducted on clay loam soil in Waseca Minnesota. The objectives were to quantify the effects and interactions of cover crops, nitrogen (N) fertilizer rates and cropping system on corn production and nitrate-N concentration and loss in tile drainage water. Cover crop treatments [cereal rye and a blend of annuals (oat, forage pea and radish)] were drilled soon after corn silage harvest each fall. Nitrogen treatments were split-applied at planting and V3 growth stage. Corn silage yields were not affected by cover crop treatments. Silage yield and quality were optimized at 180 lb N ac^{-1}. However, corn grain yields required more N, 220 or 260 lb ac^{-1}, to optimize production. Total annual tile drainage ranged from 7.3 inches in 2022 to 19.9 inches in 2024. Nearly all tile drainage occurred in spring months. Annual flow-weighted (FW) NO_3-N concentrations and losses were reduced by the cereal rye cover crop in 2 of 3 years. The reduction during those two years averaged 33%. The annual blend reduced FW NO_3-N concentrations in 1 of 3 years. Flow-weighted NO_3-N concentrations in tile water were 20% greater with 220 lb N ac^{-1} than with 180 lb N ac^{-1}, when averaged across cropping system and cover crop treatments. In 2 of 3 years FW NO_3-N concentrations were less with the corn grain cropping system than with corn silage systems. In all 3 years FW NO_3-N concentrations were numerically greatest with the corn silage no cover crop system. Nitrate-N concentrations in the control treatment, which received only 5 lb N ac^{-1} ranged from 1.9 and 3.6 mg L^{-1} among years, whereas the corn silage no cover crop treatment ranged from 10.7 to 25.8 mg L^{-1}. Seeding a cereal rye cover crop after silage harvest and applying 180 lb N ac^{-1} reduced nitrate loss in tile drainage water and optimized corn silage production in this study.

INTRODUCTION

Research has shown subsurface tile drainage systems deliver nitrate (NO_3^-) to surface waters and thereby degrade water quality (Randall and Mulla, 2001, Dinnes et al., 2002). The use of cover crops and applying appropriate rates of nitrogen (N) for corn are potential management strategies to reduce nitrate loads in tile drainage water. Research in Minnesota has shown cover crop establishment can be difficult (Strock et al., 2004), often producing minimal cover crop growth which results in less or inconsistent NO_3^- reduction in tile drainage water compared to other areas in the Midwest (Kaspar et al., 2007). Cover crop establishment after corn silage harvest in early September would allow more time for cover crop growth in the fall before soils freeze in Minnesota. Furthermore, a cover crop could protect the soil from erosion and potentially replenish carbon lost during the silage harvest which could improve soil health.

MATERIALS AND METHODS

A research experiment was initiated in 2021 on the drainage research facility at the Southern Research and Outreach Center. This facility has 36 tile drainage plots. Each plot measures 20 ft. by 30 ft. and has a separate drain outlet that is automated for flow measurement and sample collection. Eight treatments were comprised from a partial factorial combination of three management factors: corn crop system (corn for grain and corn for silage), cover crop use and N rate. Cover crop treatments included no cover crop, cereal rye with spring termination, and a blend of annuals (oat, forage pea and radish) with winter termination. Cover crops were only seeded in the corn silage system. Therefore, the four crop system treatments were corn for grain no cover crop (Gnc), corn for silage no cover crop (Snc), corn for silage with cereal rye cover (Srye) and corn for silage with annual blend cover (Sblend). Cover crop treatments were drilled soon after silage harvest at 60 lb ac^{-1} for cereal rye and 18, 8, and 1 lb ac^{-1} for oat, forage pea, and radish, respectively. Strip tillage was performed in the late fall each year with P, K and S fertilizer application in the strip. Corn was planted into the strips the following spring.

Nitrogen rates of 180 and 220 lb N ac^{-1} for continuous corn were compared across the four crop systems (Gnc, Snc, Srye and Sblend). Three additional N rate treatments were included in the corn grain system. A control, which received only 4.6 lb N ac^{-1} from starter fertilizer and 140 and 260 lb N ac^{-1}. These additional rates for corn grain production were used to determine the optimum N rate for corn each year. Nitrogen fertilizer was split-applied with 20 lb N ac^{-1} at planting and the remainder applied at V2 as urea ammonium nitrate (32-0-0) which was stream-injected between the rows.

Corn silage yields were measured from all treatments by hand harvesting, while corn grain yields from select treatments were harvested with a plot combine. Cover crop biomass yields were measured in the fall and prior to termination in spring. Treatments were arranged in split-plot design within a randomized complete block with four replications. All data were statistically analyzed using ANOVA with Proc mixed in SAS® (SAS 9.4, SAS Institute Inc., 2014. Cary, North Carolina) after examination of residuals, outliers and normality assumptions using Proc univariate in SAS.

RESULTS AND DISCUSSION

Cover Crop

Cover crop species significantly affected biomass production in 1 of 2 fall harvests (Table 1). The annual blend had 230 lb dry matter (DM) ac^{-1} while cereal rye had only 92 lb DM ac^{-1} in the fall of 2023. The lack of a difference in rye biomass from fall of 2021 to spring of 2022 was not related to poor spring growth as rye height in the spring was about 2X greater than in the fall. It was due to stand loss in wheel tracts and strip-till zones. Rye growth increased dramatically from fall of 2023 to spring of 2024. A very dry fall in 2022 limited establishment and growth, so no fall data was collected. The C:N ratio was greater with rye than blend in the fall of 2021.

Table 1. Cover crop dry matter yield and C:N ratio as affected by cover crop species.

Cover	Timing of cover crop biomass harvest					
Crop	Fall '21	Spring '22	Fall '22	Spring '23	Fall '23	Spring '24
	Biomass yield, lb of dry matter ac^{-1}					
Cereal rye	296	296	ND	28	92 b	676
Blend	255	ND	ND	ND	230 a	ND
	C:N ratio of biomass					
Cereal rye	11.4 a	12.4	ND	9.8	9.6	10.4
Blend	10.2 b	ND	ND	ND	9.1	ND

ND, no data collected

Corn Grain Yield

In all three years corn grain yields increased numerically as N rate increased (Table 2). In 2023 and 2024 grain yields were statistically similar with 220 and 260 lb N ac^{-1}. A wet spring delayed planting, and was followed by a dry summer which reduced corn yields in 2023. However, weather, delayed planting and N loss likely contributed to reduced yields in 2023.

Table 2. Corn grain yields as affected by nitrogen rate.

	Corn grain yield		
Nitrogen rate	2022	2023	2024
lb ac^{-1}	bu ac^{-1}		
4.6	60 c	48 d	84 d
140	189 b	137 c	180 c
180	194 b	150 b	204 b
220	201 b	158 ab	223 a
260	218 a	163 a	227 a

Corn Silage Yield

In all three years corn silage yields were not affected by main effect of N rate (Table 3). In 2024 silage yields were greater with silage crop systems than with the corn grain system. However, a significant interaction between crop system and N rate showed in the corn grain system, silage yields were less with 180 lb N ac^{-1}. These data show regardless of cover crops 180 lb N ac^{-1} was sufficient to optimize corn silage yield in silage crop systems. Whereas in the corn grain system, grain yields required 220 lb N

ac^{-1} or more in all three years and corn silage yield required 220 lb N ac^{-1} in 1 of 3 years. Like corn grain yields, silage yields were reduced in 2023.

Table 3. Slage yields as affected by crop system, cover crops and N rates.

Crop system treatments			Silage yield		
Corn for	Cover crop	N rate	2022	2023	2024
			Tons dry matter ac^{-1}		
Grain	None	180	8.17	6.85	8.22 c†
Grain	None	220	8.45	6.73	9.13 b
Silage	None	180	9.03	7.13	9.59 ab
Silage	None	220	8.89	6.74	9.19 b
Silage	Cereal rye	180	9.11	7.29	9.84 a
Silage	Cereal rye	220	8.95	7.30	9.48 ab
Silage	Blend	180	9.09	6.92	9.25 ab
Silage	Blend	220	9.07	7.30	9.17 b
Crop system effects					
Grain, no cover			8.31	6.79	8.68 B
Silage, no cover			8.96	6.93	9.39 A
Silage, rye			9.03	7.29	9.66 A
Silage, blend			9.08	7.11	9.21 A
Nitrogen rate effects					
180 lb N ac^{-1}			8.85	7.05	9.23
220 lb N ac^{-1}			8.84	7.02	9.24
Interaction effects					
Pr. > F			0.751	0.385	0.052

† Yields followed by different letters within a column are significantly different.

Nitrate Concentration in Tile Drainage Water

When averaged across N rates in 2022, annual flow-weighted (FW) NO_3-N concentrations were greater with Snc than with Srye and Sblend (Table 4). Srye had 36% lower NO_3-N concentrations than did Snc. In 2023 annual FW NO_3-N concentrations were less with the corn grain system (Gnc) than with silage systems (Snc, Srye and Sblend). The rye cover crop was not effective at sequestering N from the soil in 2023, likely due to poor rye growth. In 2024 annual FW NO_3-N concentrations were less with the Gnc and Srye systems than with Snc and Sblend. Rye reduced NO_3-N concentration in 2024, especially during the high tile flow interval of April-June. However, rye was less effective at reducing NO_3-N concentrations later in the growing season (Figure 1). When averaged across crop systems, 220 lb N ac^{-1} had greater annual FW NO_3-N concentrations than 180 lb N ac^{-1} in all three years of the study.

Nitrate-N concentrations in the control were much less than in N fertilized treatments in 2024 (Table 1), which was like previous years (previous years not shown). The Gnc and Srye systems had similar NO_3-N concentrations in April but Srye was greater during other months. These seasonal differences could result from N being released from the cereal rye during the growing season or greater mineralization and less immobilization of N in the silage system than with the corn grain system. The Snc and Sblend systems had similar NO_3-N concentrations in April and June but Snc was greater in May while Sblend was greater in July.

Table 4. Annual nitrate-N concentrations as affected by crop systems, cover crops and N rates.

	Nitrate-N concentration		
Treatment main effects	2022	2023	2024
	------------	mg L^{-1}	-----------
Crop system effects			
Grain, no cover	8.9 ab	8.1 b	13.9 b†
Silage, no cover	10.7 a	13.0 a	25.8 a
Silage, rye	6.8 c	12.1 a	17.7 b
Silage, blend	8.5 bc	12.2 a	25.1 a
Nitrogen rate effects			
180 lb N ac^{-1}	7.8 b	10.5 b	19.0 b
220 lb N ac^{-1}	9.7 a	12.2 a	22.3 a
Interaction effects			
Pr. > F	0.485	0.608	0.541

† Yields followed by different letters within a column are significantly different.

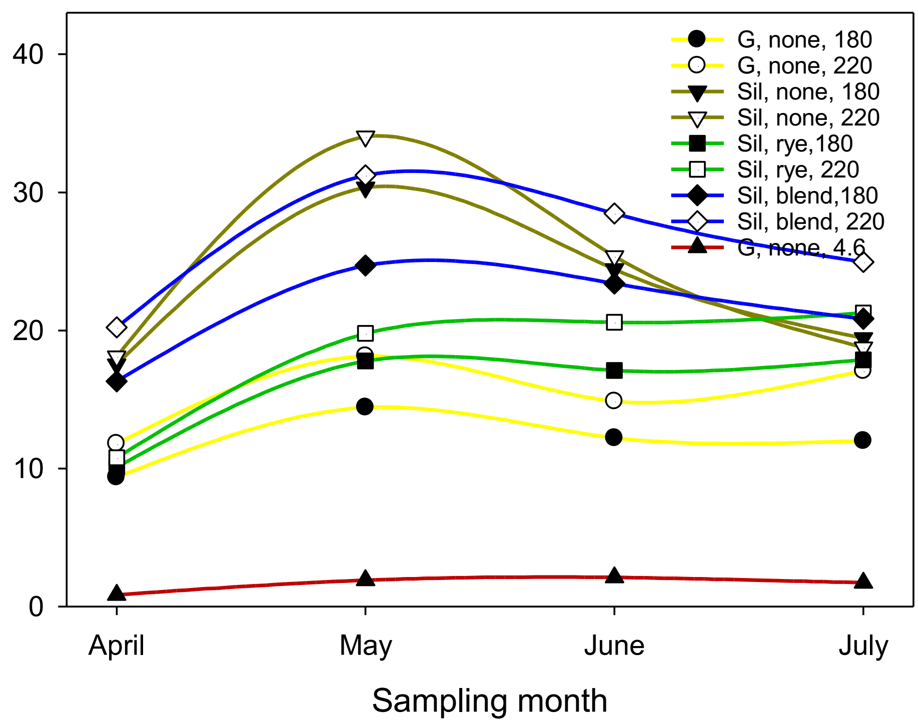

Figure 1. Effects of crop system, cover crops and N rates on monthly nitrate-N concentrations in tile drainage water in 2024.

The rapid increase in NO_3-N concentration from April to May is very interesting since most of the N fertilizer was applied at the V2 growth stage on 7 June 2024 (Figure 1). This suggests the increase in NO_3-N concentration in tile drainage water in May resulted from NO_3-N remaining in the soil from the previous year (2023 had a summer drought) or a flush of N from mineralization in May.

CONCLUSION

Greater N rates were needed to optimize corn grain yield than corn silage yield in this 3-year study. Seeding cover crops after corn silage harvest in September had no effect on corn silage yields. The corn grain and silage yield responses to N rate observed in this study may the result of cooler soils due to greater residue cover in the corn grain system which could reduce N mineralization of SOM and increase N immobilization of fertilizer and soil derived N. Nitrate concentrations in tile drainage water can be reduced in corn silage systems by applying an MRTN rate of N fertilizer (180 lb N ac^{-1}) and seeding a cereal rye cover crop after harvest. These data suggest nitrate concentrations and losses in tile drainage water may be greater in corn silage systems than in corn grain systems.

REFERENCES

Dinnes, D.L., D.L. Karlen, D.B. Jaynes, T.C. Kaspar, J.L. Hatfield, T.S. Covlin and C.A. Cambardella. 2002. Nitrogen management strategies to reduce nitrate leaching in tile-drained Midwestern Soils. Agron. J. 94:153-171.

Kaspar, T.C., D.B. Jaynes, T. Parkin, and T. Moorman. 2007. Rye Cover Crop and Gamagrass Strip effects on nitrate concentration and load in tile drainage. https://doi.org/10.2134/jeq2006.0468 J. Environ. Qual. 36(5):1503-11.

Randall, G.W., and D.J. Mulla. 2001. Nitrate nitrogen in surface waters as influenced by climatic conditions and agricultural practices. J. Environ. Qual. 30:337–344.

Strock, J.S., P.M. Porter, and M.P. Russelle. 2004. Cover crop to reduce nitrate loss through subsurface drainage in the northern Corn Belt. J. Environ. Qual. 33:1010-1016.