Impact of 4R Management on Crop Production and Nitrate-Nitrogen Loss in Tile Drainage

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Introduction

Corn belt crop producers are increasingly challenged to maximize corn and soybean production while addressing the contributions farm practices make to the Gulf of Mexico hypoxia. Based on the need for nitrate-nitrogen (N) reductions to meet water quality goals, new management practices are needed to reduce nitrate-N losses at minimal cost and maximum economic benefits. This ongoing field research and demonstration project is evaluating various promising N management methods and technologies by documenting the nitrate-N export and crop yield from various systems. This is a summary of five years of crop yield data and four years of water quality data.

Materials and Methods

Funds provided by the Iowa State University Department of Agronomy Endowment helped instrument the site for replicated studies of drainage water quality in 2013. In 2014, the site was uniformly cropped, and the treatments were implemented for the 2015 growing season.

The site has 32 individual subsurface drained plots for drainage water quality evaluation. Drainage lines from individual plots are directed to separate sumps within culverts where drainage is diverted for sampling. Each treatment is replicated four times. Treatments consist of corn-soybean rotation with each phase of the rotation present each year. The four treatments are:

1. Fall (anhydrous ammonia with nitrification inhibitor N-serve), 135 lb N/acre
2. Spring (anhydrous ammonia with no nitrification inhibitor), 135 lb N/acre
3. Split N, with 40 lb/acre of urea 2 x 2 starter at planting plus remainder in-season Agrotain treated urea, 135 lb N/acre total
4. No nitrogen applied

Tile flow water samples are analyzed for nitrate-N concentration. Additionally, the project documents crop yield for each treatment.

Results and Discussion

Except for the early fall 2014 freezing conditions, which prevented fall anhydrous ammonia application (completed early spring 2015), agronomic operations were completed in a timely manner each year (Table 1). The 2015 year was characterized by greater than normal precipitation in late summer and fall, as well as a greater yearly precipitation than the 30-yr average (Cherokee, IA weather station about 10 miles south of the project site) (Table 2). The 2016 crop year also had more than the 30-yr average precipitation, with noticeably greater precipitation in April and September, which resulted in > 10 in. of average annual drainage (Table 3). The April precipitation delayed planting in 2016. The 2017 crop year had near normal precipitation in April and May, but much less than normal precipitation the rest of the year, resulting in

< 4 in. of drainage on average. Precipitation in 2018 was above normal in May, June, and September with the total being 5 in. above normal for the year. The wettest year of the study was 2019 with 10 in. above normal precipitation, and most of the rainfall was from May to September.

In 2015, there was a 40 bushels/acre corn yield increase with N application in Treatments 1–3 as compared with Treatment 4 where no N was applied (Table 4). In 2016, the corn yield increase with N application was greater than 50 bushels/acre. During both 2015 and 2016, no statistically significant corn yield differences were observed between the treatments where N was applied. In 2017, corn yield increase with Treatments 1 and 2 compared with no N application was more than 75 bushels/acre. Also, in 2017, there was a lower corn yield with the split N application compared with fall and spring ammonia timing. This was likely due to the limited precipitation after the sidedress N application and dry summer conditions (dry surface soil), which limited N movement into the soil and active corn root zone. In 2018, the split N application was timely with over an inch of precipitation a day after application. There was no statistically significant difference between the N application treatments in 2018, but all were significantly different compared with no N applied. In 2019, there were no differences among N treatments, and they were all 70 bushels/acre greater than the no N treatment. There were no statistical differences among the soybean yields in 2015, which would be expected based on the uniform previous site history, no treatments applied to soybean, and no prior-year N applications to corn. Soybean yields in 2016 were greater than 70 bushels/acre for all treatments and greater than 60 bushels/acre in 2017. In 2018, soybean yield had very little variability in treatments and was 70–72 bushels/acre. Soybean yield for 2019 was not different among treatments, but all were between 58 and 63 bushels/acre.

Annual flow-weighted nitrate concentration was statistically similar whether N fertilizer was applied in the fall with inhibitor or in the spring in all years except for 2018 (Table 5). The concentrations with split N were lower than fall-applied N all years except for 2017, and compared with spring-applied N, lower all years except 2018. There was no N applied to soybean, but in 2016 and 2018 (wet years) the concentrations with no N or split N applied to the prior corn crop still were lower than with the fall- or spring-applied N, i.e. those treatment effects carried into the soybean year. Annual nitrate load was lowest in 2017 from all plots due to low drainage in the dry year (Table 6). There were not many differences among treatments in nitrate-N load due to high plot-to-plot flow variability.

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Table 1. Dates of field operations for corn at the ISU Northwest Research Farm, Sutherland, IA.

	2015	2016	2017	2018	2019
Fall NH_3 + N-Serve application	4/18/2015	11/10/2015	11/16/2016	11/6/2017	11/16/2018
Spring NH_3 application	4/18/2015	4/12/2016	4/12/2017	4/29/2018	4/22/2019
Planting date	5/18/2015	5/19/2016	5/6/2017	5/9/2018	5/7/2019
Urea starter banded at planting	5/18/2015	5/19/2016	5/6/2017	5/9/2018	5/7/2019
Agrotain treated urea sidedress	7/18/2015	7/14/2016	7/6/2017	7/3/2018	7/15/2019
Harvest	10/18/2015	10/29/2016	10/24/2017	10/4/2018	10/16/2019
Sulfur application		11/3/2016			
Planting population (seeds/acre)	34,000	34,000	35,077	35,077	35,077
Corn hybrid	Pioneer P0453	AgriGold 6267VT2RIB	Pioneer P0157AMX	Legend 9701	Wyfells W2506RIB

Table 2. Monthly precipitation from 2015 to 2019 at the ISU Northwest Research Farm, Sutherland, IA.

	Precipitation (in.)					
Mo.	2015	2016	2017	2018	2019	30-yr avg. precip. at Cherokee, IA (in.)
Jan	0.1	0.2	1.0	0.7	0.1	0.6
Feb	0.0	0.4	0.8	0.8	2.0	0.6
Mar	0.6	2.1	1.4	2.0	3.2	1.9
Apr	3.1	5.2	3.2	1.5	3.5	3.1
May	3.5	3.5	3.0	4.4	6.7	3.9
Jun	2.6	1.8	1.9	6.3	4.2	5.0
Jul	6.8	3.9	1.3	3.1	6.6	3.9
Aug	6.1	3.2	4.3	4.2	3.2	3.7
Sep	2.8	7.5	2.3	8.2	4.7	3.5
Oct	1.9	3.5	3.3	2.1	4.0	2.1
Nov	4.9	1.8	0.2	1.2	1.6	1.5
Dec	1.8	1.0	0.2	1.5	1.3	0.9
Total	34.1	34.0	22.9	36.0	41.0	30.7

Table 3. Drainage in inches by treatment from 2015 to 2018 at the ISU Northwest Research Farm, Sutherland, IA.

	Corn				Soybean			
Nitrogen management for corn	2015	2016	2017	2018	2015	2016	2017	2018
Fall NH_3 (with inhibitor)	7.2	6.5	4.9	6.4	3.9	12.5	2.0	11.0
Spring NH_3 (no inhibitor)	5.7	7.7	3.8	8.2	5.1	10.4	2.1	8.0
Split N	6.9	8.5	4.3	4.3	5.1	12.4	2.0	11.0
None	6.7	10.4	4.1	9.4	6.1	10.0	2.7	8.1

Table 4. Corn and soybean yields for 2015 - 2019 (bu/ac) at the ISU Northwest Research Farm, Sutherland, IA.

Nitrogen management for corn	Corn					Soybean				
	2015[1]	2016	2017	2018	2019	2015	2016	2017	2018	2019
Fall NH_3 (with inhibitor)	221a*	198a	203a	200a	214a	62	74	62	70	58
Spring NH_3 (no inhibitor)	223a	200a	203a	195a	216a	64	75	67	71	62
Split N	224a	196a	181b	205a	207a	64	72	66	70	59
None	183b	141b	125c	107b	137b	61	74	64	72	63

[1]Early fall 2014 freezing conditions prevented fall anhydrous ammonia application (completed early spring 2015).
*Means with the same letter in the same column are not significantly different, P = 0.05. There were no significant differences among soybean yields.
Yields are reported at 15.5% moisture for corn and 13% moisture for soybean.

Table 5. Annual flow-weighted nitrate-N concentration (mg/L) from 2015 to 2018 at the ISU Northwest Research Farm, Sutherland, IA.

Year	Corn				Soybean			
	Fall NH_3 (with inhibitor)	Spring NH_3 (no inhibitor)	Split N	None	Fall NH_3 (with inhibitor)	Spring NH_3 (no inhibitor)	Split N	None
2015	15.9a*	15.9a	12.1bc	9.3c	13b	13.5ab	12.2b	12.5b
2016	13.2a	13a	10.4bc	10bc	13.9a	14a	11.2b	9.2c
2017	13.2ab	13.8a	9.7bcd	11.9abc	8.9cd	12.2abc	8.6cd	5.7d
2018	11.5a	9.6b	9.8b	7c	11.6a	11.2a	8.7b	6.5c

*Means with the same letter in the same row are not significantly different, P = 0.05.

Table 6. Annual nitrate-N load (lb/ac) from 2015 to 2018 at the ISU Northwest Research Farm, Sutherland, IA.

Year	Corn				Soybean			
	Fall NH_3 (with inhibitor)	Spring NH_3 (no inhibitor)	Split N	None	Fall NH_3 (with inhibitor)	Spring NH_3 (no inhibitor)	Split N	None
2015	24.4a*	18.8ab	16.9ab	15ab	10.2b	14.2ab	13.4ab	16.3ab
2016	17.5b	21.5ab	19.5ab	21.9ab	37.8a	31.7ab	30ab	20.9ab
2017	13.3a	9.0ab	8.3ab	8.7ab	4.2b	5.5ab	3.8b	3.2b
2018	15ab	17.8ab	9.1b	14.3ab	29.1a	19.4ab	21ab	11.6b

*Means with the same letter in the same row are not significantly different, P = 0.05.