Effect of Manure Application Timing and Cover Crops on Nitrogen and Phosphorus Leaching in 2016–2019

RFR-A1966

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Introduction

The primary objective of this study was to evaluate the impact of various cropping and nutrient management systems on drainage water quality and crop yields. Treatment comparisons evaluate the impact of liquid swine manure application timing, nitrification inhibitor with late fall swine manure application, cereal rye cover crop, and gypsum application. This information can be used to develop appropriate manure and nutrient management practices to minimize water contamination potential and enhance the use of swine manure as a nutrient resource.

Materials and Methods

Table 1 lists the treatments established on 36 one-acre plots in the fall of 2015 at the Northeast Research Farm drainage water quality research site. Early fall manure, early fall manure with cereal rye cover crop, and late fall manure applications prior to corn are compared in a corn-soybean rotation. The cover crop also is included in the soybean phase of the rotation. In continuous corn, late fall manure with and without a nitrification inhibitor, late fall manure with a gypsum application of one ton/acre in the fall of 2015 and 2017, and spring manure are compared. The early fall manure with and without cover crop and late fall manure treatments are no-till and the rest of the treatments receive tillage. All rotated corn plots received 150 lb N/acre from liquid swine manure or spring UAN side-dressed (System 1 only). Continuous corn plots received 200 lb N/acre from liquid swine manure. No manure or commercial N was applied prior to soybean in any of the treatments. Phosphorus was applied to System 1 at rates of 46, 75, and 65 lb P_2O_5/acre in the fall of 2016, 2017, and 2018, respectively. System 5 received a P application of 46 lb P_2O_5/acre in the fall of 2016. No commercial P was applied to any of the other treatments. The cereal rye cover crop was seeded with a no-till drill in the fall after harvest and manure injection. Spring termination of the cover crop was done with glyphosate approximately 10 days prior to corn planting and ±2 days of soybean planting.

Results and Discussion

Precipitation. Table 2 gives the monthly precipitation for the 2016 through 2019 growing seasons. Precipitation was much greater than the 30-yr average for both 2016 and 2018. Growing season precipitation in 2018 was the wettest since recordkeeping began at the farm in 1976. Total precipitation in both 2017 and 2019 was close to the 30-yr average.

Nitrate-N concentrations. Table 3 shows annual and 4-yr average flow-weighted nitrate-N concentrations in drainage water for 2016 through 2019. In the corn phase of corn-soybean plots, the early fall manure treatment with no cover crop had significantly higher 4-yr average nitrate-N concentrations compared with the other treatments. The cover crop led to significantly lower nitrate-N concentrations in three out of the four years in the corn phase. In the soybean phase, the cover crop treatment had significantly lower concentrations in all years compared with the other treatments. There were minimal differences in nitrate-N concentrations in the continuous corn plots. The nitrification inhibitor did not reduce nitrate-N concentrations compared with no inhibitor, and the gypsum application did not reduce nitrate-N concentrations compared with no gypsum.

Table 4 shows 4-yr (2016–2019) average quarterly flow-weighted nitrate-N concentrations in drainage water. There was no flow in January and minimal flow in February due to frozen soil conditions. In the corn phase of corn-soybean plots, the early fall manure treatment with no cover crop had significantly higher nitrate-N concentrations compared with the other treatments in the first two quarters of the year. In soybean, the cover crop treatment had significantly lower concentrations from April through December. On a quarterly basis, there were no significant differences in the continuous corn treatments. Nitrate-N concentrations peaked in the second quarter in all treatments except the cover crop treatment in soybean.

Total reactive phosphorus concentrations. Table 5 shows the annual average flow-weighted total reactive phosphorus (TRP) concentrations in drainage water for 2016 through 2019. In 2016, annual average TRP concentrations ranged from 4 to 27 μg/L. In 2017, concentrations ranged from 3 to 29 μg/L. Concentrations in 2018 ranged from 6 to 33 μg/L. There were no statistically significant differences between any of the systems on an annual basis. Averaged over four years, there was a significant difference between treatments in the soybean phase of the corn-soybean rotations. However, it should be noted these concentrations are very low (1 μg equals 0.001 mg) and many of the TRP results were below the detection limit of the analysis equipment. The results suggest none of the treatments had a significant effect on TRP leaching. The low concentrations show there is minimal TRP leaching at this location.

Cover crop growth. Spring rye cover crop biomass, nutrient uptake, and planting and sampling dates for 2016 through 2019 crop years are shown in Table 6. Rye biomass was sampled in and between the swine manure injection bands in the soybean residue plots in 2016 through 2018. Uptake of N, P, and K was considerably greater in the manure injection bands compared with between the injection bands in those three years. Four-yr average N uptake in aboveground biomass averaged about 95 lb N/acre prior to corn and 58 lb N/acre prior to soybeans. Biomass growth and nutrient uptake in 2019 did not differ between manured plots and those receiving no manure, possibly due to late application of manure and no cover crop growth in fall 2018.

Soil nitrate-N and Bray-1 P data. Tables 7 and 8 show 3-yr average (2016 through 2018) soil nitrate-N and Bray-1 P concentrations, respectively, from deep core samples taken after fall harvest. There were no substantial differences in nitrate-N between treatments at any depth. Bray-1 P levels were substantially higher to a depth of 12 inches in Systems 4a and 4b. These plots have a much longer history of swine manure application relative to the other treatments. Table 8 shows subsoil is very low in P, which may partly explain the low TRP loss with tile drainage. The water quality results observed were reasonable given the soil profile nitrate-N and P data in Tables 7 and 8.

Acknowledgements

Funds to conduct the research are being provided by the Iowa Pork Producers Association and from Calcium Products for the gypsum treatment.

Table 1. Experimental treatments for Nashua manure management and water quality study beginning fall 2015.[1]

System	Application timing and nitrogen source	Crop	Tillage	N application rate (lb/ac)
1	Spring UAN	Corn	Chisel plow	150
	-	Soybean	Field cultivate	-
2	Early fall manure	Corn	No-till	150
	-	Soybean	No-till	-
3a	Late fall manure + Instinct	Continuous corn	Chisel plow	200
3b	Spring manure	Continuous corn	Chisel plow	200
4a	Late fall manure	Continuous corn	Chisel plow	200
4b	Late fall manure + gypsum	Continuous corn	Chisel plow	200
5	Early fall manure	Corn + rye cover	No-till	150
	-	Soybean + rye cover	No-till	-
6	Late fall manure	Corn	No-till	150
	-	Soybean	No-till	-

[1]Phosphorus fertilizer is applied as needed according to soil testing to Systems 1, 2, 5, and 6. Potassium is applied as needed according to soil testing to all systems.

Table 2. Precipitation (in.) during the 2016 through 2019 growing seasons.

	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Total
2016	2.34	3.04	11.62	6.05	7.32	14.91	2.32	1.32	48.92
2017	4.31	4.79	5.15	8.35	1.75	2.25	4.86	0.37	31.83
2018	2.81	6.26	9.73	2.9	10.2	14.58	3.78	2.03	52.29
2019	3.77	6.32	2.89	3.46	2.50	3.94	5.20	2.15	30.23
1986-2015 avg.	3.88	4.44	5.40	4.75	4.37	2.64	2.47	1.75	29.70

Table 3. Annual flow-weighted nitrate-N concentrations in mg/L for 2016 through 2019.[1]

System	1	2	5	6	1	2	5	6	3a	3b	4a	4b
Crop	Corn	Corn	Corn	Corn	Soy	Soy	Soy	Soy	CC	CC	CC	CC
	Flow weighted nitrate-N concentration, mg/L											
2016	12.0c	20.5a	11.3c	15.7b	11.4a	10.9a	6.7b	12.0a	21.6a	22.0a	21.1a	20.7a
2017	13.2c	27.2a	12.0c	20.1b	12.6a	9.5ab	4.9c	8.7b	18.3a	14.7b	17.1a	18.2a
2018	10.5a	12.3a	11.9a	11.2a	9.5a	7.2bc	5.6c	8.3ab	10.9a	9.4a	11.0a	9.8a
2019	11.2b	21.5a	14.1b	11.8b	10.8a	7.5b	7.6b	7.5b	10.7a	10.3a	9.4a	10.8a
4-yr Avg	**11.7b**	**20.4a**	**12.3b**	**14.7b**	**11.1a**	**8.8b**	**6.2c**	**9.1b**	**15.4a**	**14.1a**	**14.6a**	**14.9a**

[1]Concentrations with the same letter within year are not significantly different at P = 0.05. Corn, soybean, and continuous corn were evaluated separately.

Table 4. Quarterly flow-weighted nitrate-N concentrations averaged over four years (2016-2019) in mg/L.[1]

System	1	2	5	6	1	2	5	6	3a	3b	4a	4b
Crop	Corn	Corn	Corn	Corn	Soy	Soy	Soy	Soy	CC	CC	CC	CC
	Flow weighted nitrate-N concentration, mg/L											
Jan-Mar	9.1b	19.8a	12.9b	11.4b	11.7a	9.2a	7.8a	9.9a	18.3a	13.9a	14.7a	16.1a
Apr-Jun	13.4c	26.4a	17.0bc	19.0b	14.0a	10.5b	7.4c	10.7b	19.5a	16.6a	19.1a	21.6a
Jul-Sep	11.3bc	15.8a	10.5c	14.0ab	8.9a	7.3a	5.3b	8.0a	14.5a	13.8a	13.1a	12.4a
Oct-Dec	8.3ab	9.3a	4.9b	9.3a	7.1a	7.1a	5.2b	7.1a	9.1a	7.4a	9.1a	5.4a

[1]Concentrations on an annual basis with the same letter are not significantly different at P = 0.05. Corn, soybean, and continuous corn were evaluated separately.

Table 5. Annual flow-weighted total reactive phosphorus concentrations in ug/L for 2016 through 2019.[1]

System	**1**	**2**	**5**	**6**	**1**	**2**	**5**	**6**	**3a**	**3b**	**4a**	**4b**
Crop	**Corn**	**Corn**	**Corn**	**Corn**	**Soy**	**Soy**	**Soy**	**Soy**	**CC**	**CC**	**CC**	**CC**
	Flow weighted TRP concentration, ug/L											
2016	9a	7a	11a	9a	4a	27a	5a	17a	8a	6a	10a	16a
2017	4a	29a	4a	5a	5a	3a	7a	5a	4a	5a	7a	7a
2018	6a	10a	11a	11a	9a	30a	13a	9a	10a	8a	36a	33a
2019	42a	46a	26a	23a	9a	20a	24a	17a	42b	36b	107a	105a
Average	**15a**	**23a**	**13a**	**12a**	**7b**	**20a**	**12ab**	**12ab**	**16a**	**14a**	**40a**	**40a**

[1]Concentrations with the same letter within year are not significantly different at P = 0.05. Corn, soybean, and continuous corn were evaluated separately.

Table 6. Cereal rye cover crop aboveground biomass and N, P, and K uptake.

Residue	Plant date	Sample date	Sample location	Biomass, dry lb/ac	N %	P %	K %	N lb/ac	P lb/ac	K lb/ac
Soybean	10/7/15	4/14/16	In-band	2,548	4.72	0.51	3.25	120.4	12.9	83.1
Soybean			Between band	826	4.02	0.33	2.50	33.3	2.8	20.6
Corn	10/21/15	4/25/16	-	1,526	2.74	0.27	2.55	42.0	4.2	39.3
Soybean	10/10/16	4/17/17	In band	2,490	4.48	0.49	3.81	111.1	12.4	95.6
Soybean			Between band	1,117	4.18	0.43	3.43	46.9	4.8	38.6
Corn			-	1,559	3.05	0.37	2.82	49.0	5.8	44.1
Soybean	10/26/17	5/7/18	In band	3,121	4.78	0.44	3.88	147.8	13.4	118.9
Soybean			Between band	3,160	3.41	0.31	2.92	108.2	9.8	92.5
Corn			-	2,805	3.02	0.37	3.11	84.7	10.3	87.4
Soybean	11/2/18	5/2/19	-	1,650	4.05	0.38	3.19	66.7	6.2	52.7
Corn		5/6/19	-	1,186	5.71	0.48	3.62	67.7	5.7	43.0

Table 7. Three-yr (2016-2018) average fall soil nitrate-N at different depths.

	1	2	3a	3b	4a	4b	5	6
Sample depth	Fall soil nitrate-N, mg/kg							
0-6 in.	16	18	17	18	19	15	18	19
6-12 in.	9	9	13	9	11	11	9	8
12-24 in.	6	7	5	6	7	5	6	6
24-36 in.	4	4	3	4	4	3	3	4
36-48 in.	3	3	3	3	3	2	2	3

Table 8. Three-yr (2016-2018) average fall Bray-1 P at different depths.

	1	2	3a	3b	4a	4b	5	6
Sample depth	Bray-1 P, mg/kg							
0-6 in.	14	43	37	33	117	140	19	29
6-12 in.	4	11	7	8	26	39	4	6
12-24 in.	3	3	4	3	5	5	3	3
24-36 in.	5	3	5	3	4	7	2	3
36-48 in.	6	5	6	3	6	8	5	4