Effect of Manure Application Timing and Cover Crops on Nitrogen and Phosphorus Leaching 2016–2020

RFR-A2072

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Introduction

The primary objective of this study is 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 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, Nashua, Iowa, drainage water quality research site. Early fall manure, early fall manure with cereal rye cover crop, and late fall manure applications prior to corn were compared in a corn-soybean rotation. The cover crop also was included in the soybean phase of the rotation. In continuous corn, late fall manure with and without Instinct II® nitrification inhibitor, late fall manure with a gypsum application of 1 ton/acre in the fall of 2015 and 2017, and spring manure were compared. The early fall manure with and without cover crop and late fall manure treatments were no-till, and the rest of the treatments received tillage. All rotated corn plots received 150 lb N/acre from liquid swine manure or spring UAN side-dress (System 1 only). Continuous corn plots received 200 lb N/acre from liquid swine manure. No manure or commercial N is applied prior to soybean. 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 is seeded with a no-till drill in the fall after manure injection. Spring termination of the cover crop is 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 2020 growing seasons. Precipitation was much greater than the 30-yr average for both 2016 and 2018. Precipitation in 2018 was the highest since recordkeeping began at the farm in 1976. Total precipitation in both 2017 and 2019 was close to the 30-yr average. The 2020 crop year was drier than average, with drought conditions in July and August.

Nitrate-N concentrations. Table 3 shows annual and 5-yr average flow-weighted nitrate-N concentrations in drainage water for 2016 through 2020. In the corn phase of corn-soybean rotations, the early fall manure treatment with no cover crop had significantly higher 5-yr average nitrate-N concentrations compared with the other treatments. The cover crop led to significantly lower 5-yr average nitrate-N concentrations in both corn and soybean relative to the no cover treatment. There were minimal differences in nitrate-N concentrations in the continuous corn plots. Spring manure resulted in significantly lower annual nitrate-N concentration compared with late fall manure in 2017, but there was no difference in the other years. The nitrification inhibitor did not reduce nitrate-N concentrations compared with no inhibitor.

Table 4 shows 5-yr 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 rotations, 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 were generally highest in the second quarter (April-June) and lowest in the fourth quarter (October-December).

Total N loss. Nitrate-N loss from the drainage system in lb/acre is shown in Table 5. Drainage N loss is primarily driven by precipitation patterns, whereas nitrate-N concentrations in the water are more consistent over time. In 2016 and 2018, total precipitation was substantially higher than normal (Table 2). This led to much higher loss of N compared with 2019 and 2020, when precipitation and drainage were normal to below normal and N losses were much lower. There were few statistically significant differences between treatments due to high plot-to-plot variability in drainage flow. The cereal rye cover crop reduced total N loss by about 14 lb/acre per year in corn and 7 lb/acre per year in soybean, though this was not statistically significant at $P = 0.05$.

Total reactive phosphorus concentrations. Table 6 shows the annual average flow-weighted total reactive phosphorus (TRP) concentrations in drainage water for 2016 through 2020 in µg/L. The cereal rye cover crop did not significantly affect TRP leaching. The only significant differences between any of the systems on an annual basis occurred in continuous corn plots in 2019, when TRP levels were elevated relative to other years. This is almost entirely attributed to a peak in drainage flow in late May 2019. Systems 4a and 4b in particular had higher TRP concentrations, likely due to substantially higher soil P test levels in those two systems relative to the others. Higher levels in 2019 could also be due to manure being applied in spring 2019 rather than fall 2018. It should be noted these TRP concentrations are generally very low (1 µg = 0.001 mg). Many of the water samples analyzed for TRP were below the detection limit of the analysis equipment. The results suggest that none of the treatments had a significant effect on TRP leaching, and loss of dissolved P in drainage water is minimal 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 7. 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/acre prior to corn and 58 lb/acre prior to soybean. 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.

Acknowledgements

Funds to conduct this research were provided by the Iowa Pork Producers Association and Calcium Products for the gypsum treatment.

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

System	Application timing and nitrogen source	Crop	Tillage	N application rate (lb/ac)
1	Spring UAN sidedress	Corn	Chisel plow	150
		Soybean	Field cultivate	-
2	Early fall manure	Corn	No-till	150
		Soybean	No-till	-
3a	Late fall manure + Instinct II®	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	-

Table 2. Precipitation (in.) during the 2016 through 2020 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
2020	1.53	5.36	6.95	1.96	1.48	5.41	1.64	1.47	25.80
1986-2015 avg.	3.88	4.44	5.40	4.75	4.37	2.64	2.47	1.75	29.70

Table 3. Annual and 5-yr average flow-weighted nitrate-N concentrations in 2016 through 2020 (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											
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
2020	15.1a	14.6a	15.8a	13.8a	12.9a	8.2b	6.3b	7.4b	13.3ab	11.0b	11.4ab	14.5a
5-yr Avg	**12.4b**	**19.2a**	**13.0b**	**14.5b**	**11.4a**	**8.6b**	**6.2c**	**8.8b**	**15.0a**	**13.5a**	**14.0a**	**14.8a**

[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 five years (2016-2020) 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	9.3b	17.4a	12.7b	10.9b	12.1a	8.9b	7.3b	9.3ab	14.6a	11.4a	12.5a	13.6a
Apr-Jun	13.3c	23.9a	16.5bc	17.9b	13.6a	10.0b	7.2c	10.0b	17.9a	15.3a	17.3a	19.8a
Jul-Sep	13.0ab	16.1a	11.6b	14.8ab	9.7a	7.5b	5.5c	7.9b	15.4a	14.5a	13.7a	13.8a
Oct-Dec	8.3ab	9.3a	4.7b	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, 5-yr average, and total nitrate-N loss via drainage water in 2016 through 2020 (lb/acre).[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
	Nitrate-N loss, lb/acre											
2016	29.5b	72.5a	40.9ab	60.0ab	25.8ab	31.9ab	21.0b	51.0a	59.5a	61.6a	70.5a	62.4a
2017	17.8b	38.5a	20.6ab	51.6ab	17.3a	31.1a	14.3a	28.5a	34.9a	23.7a	36.0a	34.3a
2018	30.3a	58.7a	46.1a	46.2a	26.2a	19.1a	18.8a	37.1a	43.2a	37.1a	43.7a	33.0a
2019	5.7a	11.2a	8.1a	14.5a	5.4a	13.5a	10.4a	11.8a	7.9a	6.3a	7.9a	7.0a
2020	13.4a	29.7a	25.9a	24.9a	20.4a	11.1ab	8.4b	15.9ab	16.5a	13.5a	15.4a	16.2a
5-yr avg.	**19.4b**	**42.1a**	**28.4ab**	**39.4a**	**19.0ab**	**21.3ab**	**14.6b**	**28.9a**	**32.4a**	**28.5a**	**34.7a**	**30.5a**
5-yr total	**96.8**	**210.7**	**141.6**	**197.3**	**95.1**	**106.7**	**72.9**	**144.3**	**162.0**	**142.3**	**173.6**	**152.8**

[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 6. Annual and 5-yr average flow-weighted total reactive phosphorus concentrations in 2016 through 2020 (ug/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 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
2020	3a	6a	9a	27a	4a	17a	3a	5a	5a	6a	6a	27a
5-yr avg	**13a**	**20a**	**12a**	**15a**	**6b**	**19a**	**10ab**	**11ab**	**14b**	**12b**	**33ab**	**38a**

[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 7. 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	2548	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	-	1526	2.74	0.27	2.55	42.0	4.2	39.3
Soybean	10/10/16	4/17/17	In band	2490	4.48	0.49	3.81	111.1	12.4	95.6
Soybean			Between band	1117	4.18	0.43	3.43	46.9	4.8	38.6
Corn			-	1559	3.05	0.37	2.82	49.0	5.8	44.1
Soybean	10/26/17	5/7/18	In band	3121	4.78	0.44	3.88	147.8	13.4	118.9
Soybean			Between band	3160	3.41	0.31	2.92	108.2	9.8	92.5
Corn			-	2805	3.02	0.37	3.11	84.7	10.3	87.4
Soybean	11/2/18	5/2/19	-	1650	4.05	0.38	3.19	66.7	6.2	52.7
Corn		5/6/19	-	1186	5.71	0.48	3.62	67.7	5.7	43.0