2021 and 2022 Drainage Water Quality Impacts of Agricultural Management Practices

Gabrielle Myers—graduate research assistant, Agricultural and Biosystems Engineering
Brian Dougherty—field agricultural engineer, ISU Extension and Outreach
Carl Pederson—agricultural specialist, Agricultural and Biosystems Engineering
Dan Andersen—associate professor, Agricultural and Biosystems Engineering
Ken Pecinovsky—farm superintendent
Raj Raman—Morrill Professor, Agricultural and Biosystems Engineering
Ken Moore—distinguished professor, Agronomy
Matt Helmers—professor, Agricultural and Biosystems Engineering; director, Iowa Nutrient Research Center

This study aims to evaluate the impact of manure application timing and different ground cover strategies on drainage water quality and crop yields. Treatment comparisons assess the effects of fall vs. spring-injected liquid swine manure, spring urea ammonium-nitrate (UAN) sidedress, and three different treatments with either annual or perennial cover crops. This information can be used to develop appropriate manure and cover crop practices to minimize nutrient loss 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 2020 at the Northeast Research Farm drainage water quality research site. All fall manure was injected with 30-in. spacing after soils had cooled to below 50°F. Comparisons in no-till corn-soybean rotation plots included fall manure, fall manure with cereal rye cover crop, spring manure, and spring UAN sidedress applications before corn. The cereal rye cover crop also was included in the soybean phase of the rotation. Plots received 150 lb. N/acre from injected liquid swine manure in the corn phase of the rotation. Spring UAN was applied at 150 lb. N/acre as a sidedress approximately four weeks after planting in system 1. No manure or commercial N was applied before soybean. The cereal rye cover crop was seeded with a no-till drill in the fall after manure injection at approximately 80 lb./acre. Spring termination of the cover crop was done with glyphosate approximately 10 days before corn planting and ±2 days of soybean planting.

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

System	Crop	Type of cover	Tillage	Application timing and nitrogen source	N application rate (lb./acre)
1	Corn Soybean	None None	No-till* No-till*	Spring UAN	150
2	Corn Soybean	None None	No-till* No-till*	Spring manure	150
3a	Continuous corn	None	Strip-till*	Fall manure	200
3b	Continuous corn	Early Interseed Cover	Strip-till*	Fall manure	200
4a	Continuous corn	Perennial Cover	Strip-till*	Fall manure	200
4b	Continuous corn twin 60 in.	Early Interseed Cover	Strip-till*	Fall manure	200
5	Corn Soybean	Cereal Rye Cereal Rye	No-till* No-till*	Fall manure Fall manure	150
6	Corn Soybean	None None	No-till* No-till*	Fall manure Fall manure	150

*System 1 was transitioned from conservation tillage to no-till in 2021. Systems 3a, 3b, 4a, and 4b were transitioned from conservation tillage to strip-till in 2021.
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.

Continuous corn plots were fall strip-tilled and received 200 lb. N/acre from fall-injected swine manure. Comparisons include a Kentucky bluegrass perennial groundcover (PGC) treatment, early interseed (~V5) multispecies cover crop in both 30-in. and twin 60-in. row spacings, and a no cover crop control. The twin rows were spaced 8 in. apart with a 52-in. gap in between. The Kentucky bluegrass cover (Midnight variety) was drill seeded at 17 lb./acre October 16, 2020. Table 2 shows the agronomic details for the multispecies cover crop mix, which varied between 2021 and 2022 based on availability.

Flow through each plot's center subsurface drainage tile was logged by a flow meter, and a weighted sample of flow events was automatically collected. If possible, flow meter values and water samples were collected weekly, then analyzed by Iowa State's Water Quality Research Lab for nitrate-N (nitrate + nitrite; cadmium reduction) and total reactive phosphorus concentrations (ascorbic acid reduction). Annual flow-weighted concentration values for each plot were calculated by summing the weekly loads of each nutrient and dividing by the total plot flows.

Results

Precipitation and Drainage. Table 3 gives the monthly precipitation for 2021 and 2022 compared with the 1976-2020 average. Total precipitation in both years was about 4 in. below the long-term average. The bulk of the precipitation in 2021 came after August, while most of the precipitation in 2022 came before September. The average monthly subsurface drainage flows for each year are shown in Table 4. Total drainage flow was higher in 2022 than in 2021. In 2021, most of the total flow was seen in the fall, while flow ceased after July in 2022.

Continuous corn yields and nutrient concentrations. Table 5 gives the yield results for continuous corn in 2021 and 2022. In both years, there were no statistical differences in corn yield in any treatments with 30-in. row spacing. Cover crop growth was minimal in the early interseed and perennial cover treatments with 30-in. row spacing, and the covers did not appear to affect corn yield. Cover crop growth was substantial in the twin-row 60-in. interseed plots. There also was a substantially lower yield in those plots in both years. When analyzing the aggregated annual data, the same relationship is seen with the twin-row 60-in. interseed treatment averaging ~39 bushels/acre lower than the control over both years. Yields were significantly lower in 2021 compared with 2022.

Table 2. Multispecies cover crop mix and approximate seeding rates drill interseeded on June 8, 2021 and June 17, 2022.

Species	2021 seeding rate, lb./acre	2022 seeding rate, lb./acre	Species	2021 seeding rate, lb./acre	2022 seeding rate, lb./acre
Sunn Hemp	3.1	3.1	Phacelia (Super Bee)	2.1	2.1
Cowpeas (CatJang black)	5.1	5.1	Brown Mustard (Kodiac)	1.2	1.2
Yellow blossom sweet clover	1.4		Rapeseed (Trophy)	1.0	1.0
Buckwheat (Mancan)	5.1	5.1	Hairy Vetch (MT)	3.4	3.4
Annual Ryegrass (Tam Tbo)	3.1	3.1	Total	25.5	24.1

*System 1 was transitioned from conservation tillage to no-till in 2021. Systems 3a, 3b, 4a, and 4b were transitioned from conservation tillage to strip-till in 2021. 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 3. Precipitation (inches) during the 2021 and 2022 growing seasons.

	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Total
2021	0.63	3.48	1.42	2.53	10.58	1.61	4.50	2.02	26.77
2022	3.62	4.10	5.22	2.55	6.74	1.03	0.75	2.02	26.03
1976-2020 average	3.68	4.52	5.47	4.57	4.67	3.56	2.68	1.74	30.89

Table 4. Average drainage flow (inches) in 2021 and 2022.

	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2021	0.16	0.12	0.07	0.16	0.00	0.00	0.20	0.23	1.30	0.04	2.29
2022	0.14	1.15	2.12	1.22	1.05	0.00	0.01	0.00	0.00	0.00	5.68

Table 5. Continuous corn yield for the 2021 and 2022 crop years.

	2021	2022	2021 + 2022 Avg
System	**Continuous corn yield, bushels/acre**		
3a -Fall manure	228a	205a	216a
3b - Fall manure + 30" early interseed cover	223a	205a	214a
4a -Fall manure + perennial cover	217a	209a	213a
4b - Fall manure + 60 in. Early interseed cover	174b	181b	177b

Yields with the same letter within year are not significantly different.

Drainage water nitrate-N and TRP concentrations for continuous corn are shown in Table 6. Flow-weighted average nitrate-N concentrations were significantly higher in 2022 compared with 2021. In 2021, a significant difference between the twin-row 60-in. interseed plots and the other three treatments was detected. No statistical differences between treatments were seen for nitrogen in 2022. Phosphorus concentrations were significantly higher in 2022 than in 2021 in the continuous corn plots. The twin-row 60-in. interseed treatment was significantly higher than the 30-in. interseed treatment when flow-weighted average TRP data was analyzed over both years. However, when years were analyzed separately, no statistical differences between treatments were detected in either year.

Rotated corn yields and nutrient concentrations. Table 7 gives the treatment effects on corn yield in corn-soybean rotation for 2021 and 2022. Again, yields were higher in 2021 than in 2022. In 2021, the cereal rye cover crop treatment had a significantly lower yield (-18 bushels/acre) than the no cover crop comparison, and the spring UAN sidedress treatment had a significantly lower yield (-13 bushels/acre) than the spring manure comparison. In 2022, both spring nitrogen fertilizer treatments out-yielded both fall fertilizer treatments. Across both years, the cereal rye cover crop treatment and the fall manure comparison did not differ statistically, and the spring UAN and spring manure treatments did not differ.

Table 8 summarizes the subsurface nitrate-N and TRP concentration data for 2021 and 2022 in the rotated corn plots. Flow-weighted average nitrate-N concentrations in 2022 (16.7 mg N/L) were significantly higher than in 2021(5.43 mg N/L), but concentrations did not differ between treatments when analyzed across both years. In 2021, there were no significant differences in flow-weighted average nitrate-N concentrations between treatments. In 2022, flow-weighted average nitrate-N concentrations in the spring manure treatment were significantly lower than in the other three treatments. Flow-weighted average TRP concentrations were not significantly different between years or treatments when analyzed over the two years or by each year separately.

Table 6. Continuous corn subsurface drainage nitrate-N and TRP concentrations for 2021 and 2022.

	2021		2022		2021 + 2022 Avg.	
System	N FWA*, mg N/L	P FWA**, µg P/L	N FWA, mg N/L	P FWA, µg P/L	N FWA, mg N/L	P FWA, µg P/L
3a -Fall manure	5.6a	12a	19.5a	6a	12.5a	9a,b
3b - Fall manure + 30 in. early interseed cover	4.3a	7a	17.4a	6a	10.8a,b	6b
4a -Fall manure + perennial cover	5.0a	10a	15.1a	7a	10.0a,b	8a,b
4b - Fall manure + 60 in. early interseed cover	2.6b	11a	17.2a	10a	10.0b	11a

Concentrations with the same letter within year and nutrient are not significantly different at the $P \leq 0.05$.
N FWA: Nitrite + Nitrate annual flow-weighted average N concentration
P FWA: TRP annual flow-weighted average P concentration

Table 7. Corn yield in corn-soybean rotations for the 2021 and 2022 crop years.

	2021	2022	2021 + 2022 Avg
System	**Continuous corn yield, bushels/acre**		
1- Spring UAN	228a	205a	216a
sidedress	226b	240a	232a
2- Spring manure	239a	226a	232a
5- Fall manure +	174b	181b	177b
rye cover	223b	192b	208b
6- Fall manure	241a	204b	223a,b

Yields with the same letter within year are not significantly different at $P \leq 0.05$.

Table 8. Rotated corn subsurface drainage nitrate-N and TRP concentrations for 2021 and 2022.

	2021		2022		2021 + 2022 Avg.	
System	N FWA*, mg N/L	P FWA**, µg P/L	N FWA, mg N/L	P FWA, µg P/L	N FWA, mg N/L	P FWA, µg P/L
1- Spring UAN sidedress	6.2a	8a	18.0a	5a	12.1a	7a
2- Spring manure	6.4a	24a	11.1b	5a	8.7a	15a
5- Fall manure + rye cover	3.5a	6a	19.3a	7a	11.4a	7a
6- Fall manure	5.7a	8a	18.4a	7a	12.1a	7a

Concentrations with the same letter within year and nutrient are not significantly different at the $P \leq 0.05$.
N FWA: Nitrite + Nitrate annual flow-weighted average N concentration.
P FWA: TRP annual flow-weighted average P concentration.

Soybean yields and nutrient concentrations. Soybean yields are presented in Table 9. In 2021, the cereal rye cover crop treatment had a significantly lower yield than the no cover crop comparison. System 1 also had a lower yield than systems 2 and 6 in 2021. System 1 was transitioned from conservation tillage to no-till in 2021, which may have contributed to the yield reduction. In 2022, System 1 out-yielded the cereal rye cover crop system. Across both years, the only treatment difference seen is the cereal rye cover crop system yielding significantly lower than its no cover crop comparison by ~4.2 bushels/acre.

Table 10 shows the subsurface nitrate-N and TRP flow-weighted average concentrations for 2021 and 2022. Again, nitrate-N concentrations were lower in 2021 (7.19 mg N/L) than in 2022 (9.84 mg N/L), although the difference is less pronounced than in the corn plots. When data was analyzed over the two years, System 1 had significantly higher flow-weighted average nitrate-N concentrations than the other three systems. This relationship was seen in 2021. In 2022, system 1 again had higher nitrate-N concentrations than the other three systems. There was no difference between the spring and fall manure treatments or the cereal rye cover crop and its comparison, system 6, but the cereal rye cover crop treatment had significantly lower nitrate-N concentrations than system 2 in 2022. Flow-weighted average TRP concentrations did not statistically differ between years or treatments when data was analyzed across both years or separately in the soybean plots.

Table 9. Soybean yield for the 2021 and 2022 crop years.

	2021	2022	2021 + 2022 Avg
System	**Continuous corn yield, bushels/acre**		
1	69.6b	77a	73.3a,b
2	74.9a	75a,b	74.5a,b
5- Rye cover	71.5b	71b	71.2b
6	75.3a	76a,b	75.4a

Yields with the same letter within year are not significantly different at P ≤ 0.05.

Table 10. Rotated corn subsurface drainage nitrate-N and TRP concentrations for 2021 and 2022.

	2021		2022		2021 + 2022 Avg	
System	N FWA*, mg N/L	P FWA**, µg P/L	N FWA, mg N/L	P FWA, µg P/L	N FWA, mg N/L	P FWA, µg P/L
1	10.1a	5a	14.7a	7a	12.4a	6a
2	5.9b	10a	10.1b	17a	8.0b	14a
5- Rye cover	5.9b	25a	6.4c	5a	6.2b	15a
6	6.8b	13a	8.2b,c	5a	7.5b	8a

Concentrations with the same letter within year and nutrient are not significantly different at the P ≤ 0.05.
N FWA: Nitrite + Nitrate annual flow-weighted average N concentration
P FWA: TRP annual flow-weighted average P concentration

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Figure 1. Putting water drainage metering pumps into water quality plot sump sites.