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Interaction of Winter Cereal Rye as Cover Crop and Manure Application on Soil Nitrate and Corn Yield

Abstract

Cover crops increased in acreage across the nation in the past several years as they provide many environmental benefits. Research reveals contradicting results of cover crop impact on corn yield and soil nitrate nitrogen. Investigation into high-carbon manure with winter rye as a cover crop supports previous research as inconsistencies were revealed during this two-year study as a potential interaction between a high-carbon manure source and corn grain yield resulted. Winter cereal rye and manure impacted nitrate soil levels and corn yield in specific years.

Introduction

The use of cover crops across the country increased 17% from 2017 to 2022 (Bowman and Morales, 2024). A few of the benefits of using cover crops include reductions of soil erosion, increasing water infiltration, reducing nutrient losses, and increasing soil organic matter. Inputs include seed, time and labor, planting, and termination, are costs associated with implementing a cover crop into a cropping system. Farmers continue to question the value of cover crops from an input and economic return to farm profitability. Nutrient cycling is one benefit that helps offset cover crop input costs as specifically, nitrogen can be put back into the soil and cropping system. Phosphorous and potassium nutrient recycling is another benefit with lower risk to leaching. One study found that a cereal rye cover crop reduced nitrate leaching by 32 to 42 percent over a three-year period (Satell et al., 1999). Reductions in nutrient leaching can reduce the fertilizer requirements in the year following the cover crop and protect ground and surface water quality (Cover Crop Resources, n.d.).

Groundwater contamination from nitrate nitrogen (NO_3^-) leaching in corn (*Zea mays* L.) production with coarse-textured soils poses an environmental concern (Struffert et al., 2016). Nitrate levels above the drinking water standard of 10 mg/l nitrate-N are considered a health risk to individuals (Staver and Brinsfield, 1990). Monitoring soil nitrate levels helps develop management strategies to reduce soil nitrate levels and potentially increase efficiency of nitrogen applications while limiting nitrate movement to groundwater. Nitrogen fertilizer contributes significantly to soil $N0_3^-$ contamination of groundwater (Redulla et al., 1996).

Consensus is lacking in the effect of cover crops on corn yield. Studies have shown decreases in corn yield when winter rye is used as a cover crop (Snapp and Surapur, 2018). Some studies show no effect or an increase in corn yield with winter rye in a cover crop system (Kravechenko et al., 2017). A Michigan study showed variable yields in cover crop-based systems that relied on reduced levels of chemical inputs (Kravechenko et al., 2017).

The use of cereal grain winter cover crops may offer an effective management alternative to more drastic measures, such as removing farmland from production or restricting N fertilization rates. Manure with a high carbon to nitrogen ratio may reduce corn yields while intercepting more nitrate and reducing nitrate leaching potential. Microbes decomposing cover crops attempt to maintain a 8:1 carbon to nitrogen ratio. If cover crop residue is low in nitrogen, microbes use more soil nitrogen to maintain the 8:1 C:N ratio (Cover Crop Resources, n.d.). Discussions with local corn growers, farmer-led organizations, conservation agencies, local elected officials, and business leaders revealed a need to address manure and nitrate management. Organizations and farmers were interested in the effect of cover crops and the interaction with manure with soil nitrate levels and corn grain yields.

Methods

The two-year study included three treatments which included winter cereal rye as the cover crop with no manure applied, winter cereal rye with manure applied, and no manure or winter cereal rye (untreated check). The treatments were replicated three times in a randomized complete block design. Location of the study was near New Auburn, Wisconsin on a Freeon sandy loam soil. The research area was in the same field each year with a different plot area and the previous year's crop being soybean.

Soil samples were taken from each plot prior to planting the cover crop in the fall and tested for soil nitrate levels at the 0 to 12 inch and 12 to 24 inch depths. Winter cereal rye was no-till drill planted at 2 bushels per acre in early November in 2022 and 2023 into recently harvested soybeans. Manure consisting of dairy calf manure with sawdust bedding was applied at 10 tons per acre one month following winter cereal rye planting. The carbon to nitrogen ratio of the manure was 100:1.

Both years, spring fertility applications included 120 pounds/acre diammonium phosphate (18-46-0) and 85 pounds/acre potash (0-0-60) at planting as a starter fertilizer in a 2" x 2" band placement. Winter rye was terminated with glyphosate herbicide at 32.0 ounce/acre rate on May 8, 2023 and May 19, 2024. Corn was then planted no-till into soybean residue on thirty-inch spacing. Corn was planted May 15, 2023 and May 29, 2024. Corn planting population was 31,200 seed per acre with the starter fertilizer application.

Summer nitrogen application included broadcast sidedress nitrogen in late June 2023 and 2024 using a mix of ammonium sulfate and urea (46-0-0) to apply 98 pounds/acre actual nitrogen (70 pounds/acre ammonium sulfate + 180 pounds/acre urea).

Soil analysis was conducted for soil nitrate (NO_3^-) levels during fall, spring and summer. Fall nitrate soil samples were taken after corn harvest. Spring samples were taken in mid-May and summer samples in late-June. Routine soil samples were taken at the start of the project in mid-November 2022 to obtain a baseline for manure application rates and results are displayed in Table 1. Corn harvest was completed in October 2023 and November 2024. Corn yield and moisture measurements were recorded and yield adjusted for moisture to 14.5%.

Results

Table 1. Routine soil sample results.

Soil pH	Organic Matter (%)	P_2O_5 (ppm)	$K_2 0$ (ppm)
6.4	2.3	33	107

The data in Table 2. indicate winter rye plus manure yielded significantly more than the untreated check (P=0.05 and P=0.10) in 2023. Winter rye was not significantly different from the untreated check or the winter rye plus manure treatment (P=0.05 and P=0.10). Soil nitrate levels were higher in the fall in the check than in the winter rye or winter rye plus manure treatments indicating potential use of nitrate by cover crop treatments.

Table 2. Fall 2022 and 2023 soil nitrate levels (ppm) and corn grain yield.

Treatment	Fall 2022 Total NO_3^- 0-24 in	Spring 2023 Total NO_3^- 0-24 in	Summer 2023 Total NO_3^- 0-24 in	Fall 2023 Total NO_3^- 0-24 in	Fall 2023 Corn Yield bu/acre
Check	10.8[a]	7.7[b]	9.3[a]	11.4[a]	119.4[bc]
Winter rye	11.2[a]	8.5[b]	6.5[c]	10.1[b]	126.7[ab]
Winter rye + Manure	11.7[a]	9.0[a]	5.8[c]	10.2[b]	132.5[a]

Analysis of variance (ANOVA) p=0.05. Means followed by same letter do not significantly differ.

Table 3 shows that in 2023 winter rye plus manure had significantly lower corn yield compared to check (P=0.05 and P=0.10). Winter rye was not significantly different from the other two treatments (P=0.05 and P=0.10). Soil nitrate levels were higher in the check in spring and summer but lower in the fall compared to the winter rye or winter rye plus manure treatments indicating potential tie up of nitrogen by the winter rye and high-carbon source manure. Individual treatment effect on corn yield is represented in Figure 1 for 2023 and Figure 2 for 2024.

Table 3. Fall 2023 and 2024 soil nitrate levels (ppm) and corn grain yield.

Treatment	Fall 2023 Total NO_3^- 0-24 in	Spring 2024 Total NO_3^- 0-24 in	Summer 2024 Total NO_3^- 0-24 in	Fall 2024 Total NO_3^- 0-24 in	Fall 2024 Corn Yield bu/acre
Check	10.9[a]	8.6[a]	9.3[a]	7.7[b]	162.1[a]
Winter rye	12.5[a]	5.7[b]	6.5[b]	8.5[a]	157.9[ab]
Winter rye + Manure	12.1[a]	6.8[b]	5.8[b]	9.0[a]	147.8[bc]

Analysis of variance (ANOVA) p=0.05. Means followed by same letter do not significantly differ.

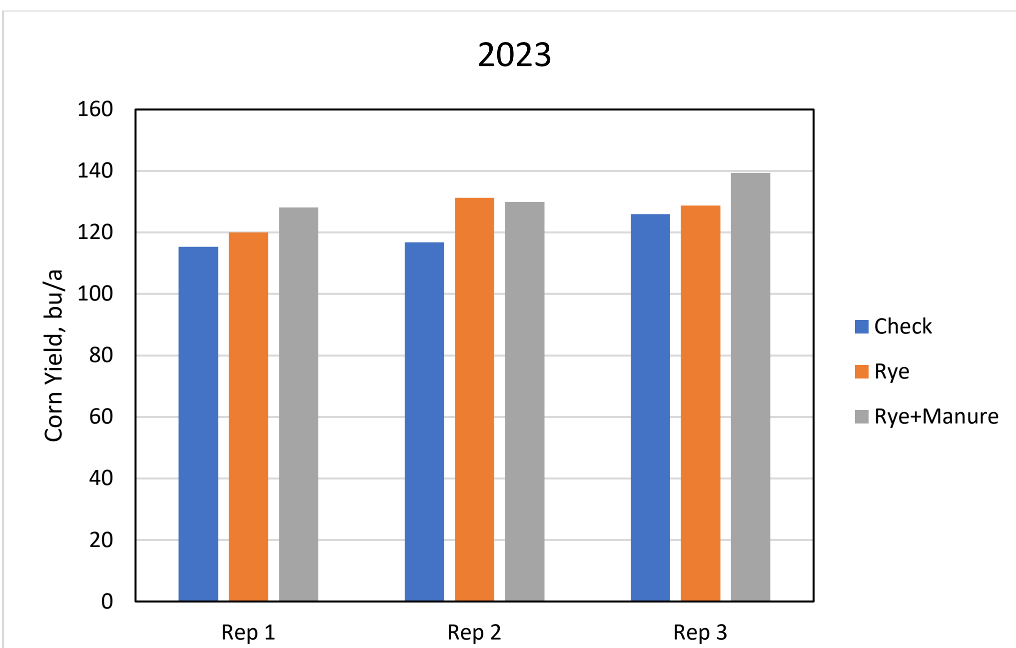

Figure 1. Corn grain yield from individual treated plots in 2023.

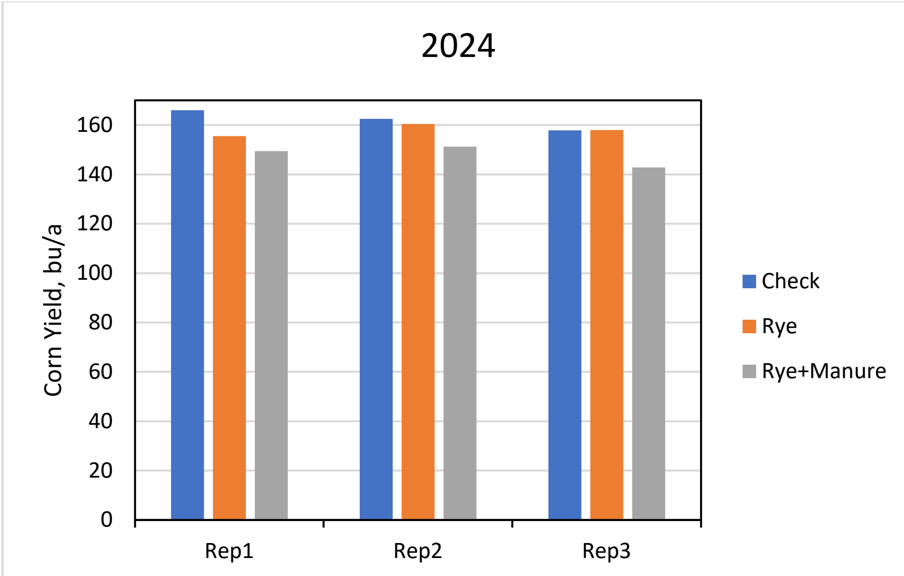

Figure 2. Corn grain yield from Individual treated plots in 2024.

Discussion

Higher soil nitrate levels in summer and fall 2023 and the spring and summer in 2024 in the untreated check compared to the rye plus manure treatment may have resulted from an interaction with the high-carbon manure application in the rye plus manure treatment. The introduction of rye itself or with manure reduced nitrate levels in four of the eight timings indicating rye is assisting in removal of nitrate nitrogen. Higher corn yields observed in the rye and rye plus manure treatments in 2023 indicate the potential for more nitrate to be available for the growing crop. Lower overall nitrate in 2024 is reflective of excessive rainfall in 2024.

Conclusions

Inconsistencies with the rye plus manure treatment over the two years indicate a potential interaction between a high-carbon manure source and corn grain yield. Having winter cereal rye in the crop system appears to lower soil nitrate levels while not lowering grain yields. More research is needed on the interaction of winter cereal rye and high-carbon manure applications over a longer study period.

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