COVER CROPS AND N CYCLING IN NORTH DAKOTA CROPPING SYSTEMS

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ABSTRACT

Cover crops have proven effective in reducing wind and water erosion, improving soil health, and capturing excess N in the fall to prevent leaching. Although the benefits of cover crops to soil health are widely reported, their impact on the yield of the following crops is not clear. The purpose of this North Dakota study was to determine the impact cover crops have on the yield of following corn (*Zea Mays L.*) and wheat (*Triticum aestivum L.*) crops along with quantifying nitrogen pools in the soil. Following barley (*Hordeum vulgare L.),* cover crops were no-till seeded at three eastern North Dakota sites in 2021 and 2022. Prior to frost termination, above-ground cover crop biomass ranged from 660 to 2,600 lb ac^{-1} across locations. The following spring, corn grain was planted into cover crop and no-cover crop treatments and fertilized with five N rates (0 to 160 lb N ac^{-1}) in a randomized complete block design with a split-plot arrangement. The following year, wheat was planted on these sites and fertilized with the same N rates. After corn and wheat harvest, grain yield was determined and soil samples were taken to a depth of 2 ft and analyzed for NO_3-N, NH_4-N, and non-exchangeable NH_4-N. The cover crop had no significant impact on corn or wheat yield; however, it did appear the cover crop had an impact on the wheat yield response to N. The total known available N (TKAN, sum of preplant soil NO_3-N, N credits, and fertilizer N) needed to reach maximum yield in the no cover crop treatments was greater than the amount of N needed in the wheat grown two seasons following the cover crop, indicating a potential second-year credit from cover crops may be attainable in these environments.

INTRODUCTION

Cover crops provide environmental benefits by reducing N leaching and may also provide productivity and economic benefits if retained N becomes available to subsequent cash crops (Hughes and Langemeier, 2020). However, studies relating the use of cover crops to following crop yield have had highly variable results. Some studies show the use of cover crops improve the following crop yield (Reinbott et al., 2004; Andraski and Bundy, 2005; Blanco-Canqui et al., 2012), while other studies show the opposite, mixed, or neutral effects (Kuo and Jellum, 2000; O'Reilly et al., 2012; Berti et al., 2017; Ruark et al., 2018; Andersen et al., 2020; Leiva, 2020; Franzen et al., 2023). The impact of cover crops on yield of the following crop is not clear, indicating N from cover crop biomass does not consistently become available the following growing season. The purpose of this study was to determine the impact fall cover crops have on the yield of the subsequent crops of corn and wheat and soil NO_3-N, NH_4-N, and non-exchangeable NH_4-N.

MATERIALS AND METHODS

Site Description and Experimental Design

This experiment was conducted from 2021 to 2023 at three non-irrigated locations in eastern North Dakota, near Valley City (46.880486N, 97.913760W), Logan Center (47.791001N, 74 97.775661W), and Gardner (47.175694N, 96.920118W). The sites were all managed under no-tillage practices and were planted with a cover crop following small grains the year prior to the establishment of this project. Gardner and VC had been under no-till management for >6 years at the inception of this study, LC <6 years.

Two of the locations in this study were a continuation of a two-row malting barley N rate experiment established in the spring of 2021 at VC and LC (Goettl et al., 2024). The barley study consisted of five N fertilizer rates ranging from 0 to 160 lbs N ac^{-1}. An additional site, Gardner, was included in the analysis for this study. Wheat was grown at the Gardner site in 2022, prior to cover crop establishment, and fertilized with 80 lbs N ac^{-1}. Following small grain harvest at each site, a mixed species cover crop was seeded. The cover crop mix consisted of 2 lbs ac^{-1} forage radish, 2 lbs ac^{-1} brown flax, and 30 lbs ac^{-1} faba bean at LC and VC. At the Gardner site 30 lbs ac^{-1} oat, 2 lbs ac^{-1} forage radish, and 2 lbs ac^{-1} brown flax was planted. Following the cover crop, corn was planted the subsequent spring with wheat following the second year. Cover crop above-ground biomass was collected in the fall prior to the first killing frost averaging 1,123, 2,877, and 1,912 lbs ac^{-1}, Gardner, LC, and VC site respectively.

The experiments were arranged as a randomized complete block design with a split-plot arrangement. Cover crop versus no cover crop was the main-plot treatment and N rate was the sub-plot treatment. Blocks were replicated three times at Gardner and five at VC and LC. Nitrogen fertilizer treatments applied to the subsequent corn and wheat crops were 0, 40, 80, 120, and 160 lbs N ac^{-1}.

Crop Management

At all of the three locations, corn was no-till planted in 30-in rows. Wheat was sown the cropping year following corn in 7.5-in rows at LC and VC. Seeding rates, cultivars, starter fertilizer, and pest management were determined and executed by the cooperating farmers in accordance with local production practices.

At the time of planting, N fertilizer was hand-broadcast applied to the N treatments using SUPERU as the fertilizer N source. SUPERU is a urea-based (46% N) fertilizer treated with *dicyandiamide* and *N-(n-butyl) thiophosphoric triamide*. (Koch Agronomic Services LLC, 2019)

Data Collection and Analysis

After harvest, corn grain weights were adjusted to the standard moisture content of 15.5% and wheat to 13.5% for yield calculations. Soil samples were collected from the 0-24 in depth in the spring prior to corn and wheat planting and fertilization, and again following crop harvest. These samples were immediately air dried before being analyzed for NO_3-N, NH_4-N, and non-exchangeable NH_4-N. NO_3-N and NH_4-N analyses were carried out by Agvise Laboratories (Northwood, ND). Non-exchangeable NH_4-N was determined using a modified sodium tetraphenylboron method (Cox et al., 1996; J. Breker, personal communication, July 7, 2022).

Data analysis was performed using JMP Pro 17 (SAS Institute, Cary, NC). Analysis of variance (ANOVA) was carried out as a randomized complete block design with a split-plot arrangement. Regression analysis was performed using JMP Pro 17 Nonlinear Modeling. Corn and wheat response to N was determined using total known available N (TKAN) (Franzen, 2023; Goettl et al., 2024) and maximum return to N methods (Sawyer and Nafziger, 2005). TKAN is calculated as the sum of preplant soil NO_3-N, prior crop N credits, no-tillage N credits, and amount of fertilizer N applied. Tillage and prior crop N credits were assessed as reported in Franzen (2023). To compare yield response to TKAN relative yield was used; relative yield was calculated by dividing the maximum yielding experimental unit at each site by yield of each experimental unit (Raun et al., 2011; Franzen et al., 2021; Goettl et al., 2024). Mean separation was performed using Student's T for comparing two means or Tukey's Procedure for comparing three or more. Analysis of wheat yield and N data during the wheat year at the Gardner site is not included in this manuscript. Data in this study was considered statistically significant at p=.05.

RESULTS AND DISCUSSION

Grain Yield and Quality

In the first cropping season following the cover crop, corn grain yield was not impacted by the presence of the cover crop (Table 1). However, corn yield did show a significant response to N fertilizer rate, as expected. When also considering TKAN and relative yield (Figure 1a), yield response was not significantly different between the cover crop treatments. The similarity of yield response to TKAN in both the cover crop and no cover crop treatment indicates no contribution or detraction of crop available N impacting corn yield following a cover crop, which is not unexpected based on previous research (Pantoja et al., 2015; Andersen et al., 2020; Leiva, 2020). Without a differing relationship between following corn yield and TKAN between previous cover crop and no cover crop in this study, it appears N sequestered in cover crop biomass is not becoming available to the subsequent crop in this environment, as also noted by (Andersen et al., 2020; Leiva, 2020).

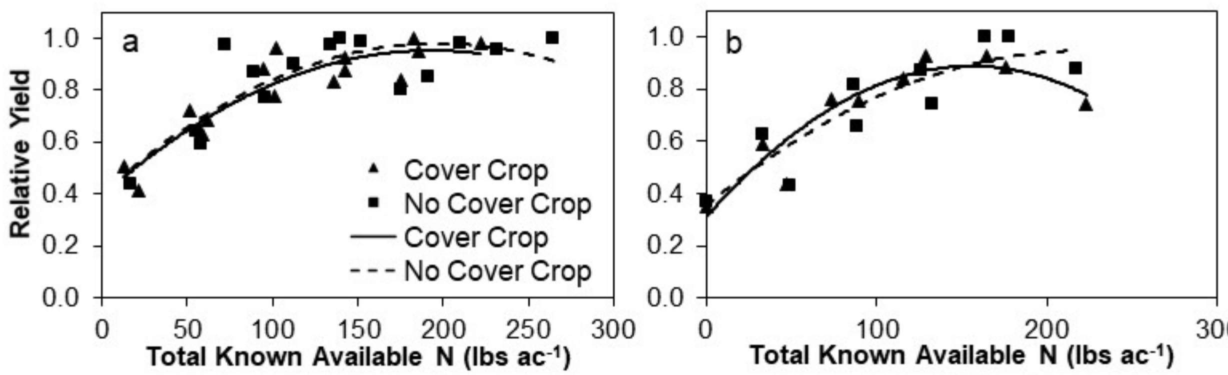
Similar to the corn yield response, wheat planted two crop years following a fall cover crop showed a significant response to N fertilizer rate, but no response to cover crop treatment at the LC and VC sites (Table 1). With increasing N fertilizer rate, not only did yield increase, but grain protein content showed a positive response (Table 1).

Unlike the corn relative yield response to TKAN (Figure 1a) where response curves for both cover crop and no-cover crop treatments follow similar quadratic shapes and have similar agronomic N rates, the wheat response to TKAN indicates differing responses to cover crop treatments (Figure 1b). Whereas maximum wheat yield for the cover crop treatments was attained at 162 lbs N ac^{-1}, maximum yield on the non-cover crop treatment was attained at 235 lbs ac^{-1}, based on the quadratic regression. North Dakota N rate studies carried out from 1969-2019 indicate the TKAN needed to attain maximum yield averages 220 lbs ac^{-1} across all productivity levels and varying management practices in eastern North Dakota.

Table 1. Mean corn grain yield following fall-seeded cover crops and wheat yield and protein content planted following the corn in eastern North Dakota.

		Corn[a]	Wheat[b]	
Effect	**Variable**	**Yield**	**Yield**	**Grain Protein**
		lbs ac^{-1}	lbs ac^{-1}	%
Cover Crop	No Cover Crop	110 a	50 a	14.2 a
	Cover Crop	101 a	49 a	13.7 a
N-Rate (lbs ac^{-1})	160	117 a	61 a	16.4 a
	120	118 a	61 a	15.4 a
	80	112 a	55 a	14.1 ab
	40	101 ab	44 ab	12.3 b
	0	80 b	26 b	11.4 b

[a]Sites were located near Logan Center, Valley City, and Gardner, North Dakota.
[b]Sites were located near Logan Center and Valley City, North Dakota.
Note: Means with the same letter within the same effect are not significantly different at the .05 probability level.



Treatment	Corn **Equation**	**r^2**	Wheat **Equation**	**r^2**
Cover Crop	y=0.400+0.005x-1.156×$10^{-5}x^2$	0.84	y=0.307+0.007x-1.927×$10^{-5}x^2$	0.89
No Cover Crop	y=0.398+0.005x-1.185×$10^{-5}x^2$	0.67	y=0.354+0.005x-9.487×$10^{-6}x^2$	0.81

Figure 1. Relative corn grain yield (a) following fall cover crop and no cover crop treatments and subsequent wheat yield (b) following the corn compared to total known available soil N at sites in eastern North Dakota.

Based on the historical wheat response to N in North Dakota and current recommendations, the TKAN rate for maximum yield on non-cover cropped treatments is near what is expected. The cover cropped treatment, however, appears to demand a lower TKAN rate to attain maximum yield (Figure 1b) indicating a potential contribution of N from the to the system not recognized in the constituents of TKAN calculation or by N fertilizer rate alone. The contribution of N is only recognized two years following cover crop growth and termination, a phenomenon also noted in North Dakota by Franzen, (2022). Additionally, the yield contribution may be from non-N-related cover crop benefits, such as increased snow capture during the winter prior to wheat planting, which was not measured in this study.

Nitrogen Pools

Soil N concentrations in the fall following cover crop termination showed a significant decrease in NO_3-N in the cover cropped treatments at two of the three sites (50 lbs N ac^{-1} lower in LC and 17 lbs N ac^{-1} lower in Gardner), NH_4-N and non-exchangeable NH_4-N showed no significant change, however. Soil samples collected in the fall following corn harvest and the spring prior to wheat harvest indicated no statistical differences in concentration of NO_3-N, NH_4-N, or non-exchangeable NH_4-N for either cover crop treatment at all sites. Soil NO_3-N levels did show a significant interaction with applied N fertilizer rate in the fall following corn and again following wheat cultivation.

CONCLUSION

Although cover crops were shown to decrease residual NO_3-N in soil thereby decreasing the risk of leaching, the results of this study align with previous work indicating N sequestered in cover crop biomass does not become available the subsequent cropping season. Although a yield benefit from the cover crop was not seen, it is important to note a decrease in yield was not noted, either. Planting a cover crop for soil health and environmental-service benefits did not come at a detriment to the following corn crop. In the second year following cover cropping practices, no yield benefit was realized; however, it does appear the cover crop has an impact on N response two cropping seasons following its growth. The lower N demand of the crop two years following a cover crop indicates a potential second-year credit from cover crops may be attained. Although the source of the N credit cannot be determined by the present study, future long-term studies should be carried out to determine the magnitude of this occurrence.

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