ASSESSING CORN RESPONSE TO COVER CROPS AND NITROGEN FERTILIZATION IN A NO –TILL, THREE-YEAR ROTATION IN NORTHEAST KANSAS

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ABSTRACT

As industry initiatives and government programs begin funding and incentivizing climate-smart agricultural practices, more farmers in the great plains region may be interested in incorporating cover crops into their rotations. Annual yield data can aid in understanding how cover crops impact cash crop productivity in this region. A long-term cover crop experiment in northeast Kansas was established in 2007 based on a wheat – corn – soybean rotation to determinate the effect of cover crops and nitrogen (N) rates on subsequent crop growth and yield. Treatments included different cover crops (cereal rye, crimson clover, a mix of cereal rye and crimson clover, and a diverse seven species mix) and control treatments (chemical fallow, double-crop soybean), planted in late summer after wheat harvest, and five N rates (0, 40, 80, 160, 240 lb/ac). Yield responded differently across cover crops treatments, nitrogen rates and years. In both the 2021 and 2022 growing seasons, corn after chemical fallow and double-crop soybeans had the highest yields with lower N rates (80 and 160 lb/ac), and corn following cereal rye and the cereal rye-crimson clover mix had the lowest yields overall. Nitrogen fertilizer replacement values of each cover crop treatment and double-crop soybeans were determined by solving the quadratic equation model of the chemical fallow treatment yield response to nitrogen fertilizer application rate. These replacement values were negative for most cover crop treatments, with values for the double-crop soybean being the least negative. Overall, nitrogen availability for plant uptake was reduced by the presence of a cover crop, and additional applied nitrogen was necessary for these treatments to reach baseline levels. Decreased precipitation during critical growing periods in 2022 exacerbated the negative yield response following the cereal rye cover crop monoculture and mix compared to 2021. Incorporating cover crops before corn can be done in Kansas, but additional nitrogen may need to be applied to recover what was lost from cover crops. Moisture is also a concern in this region, and cover crops can take up early season moisture leaving little for the germination of the cash crop in a dry year. Alternatively, a double-crop soybean would minimally impact subsequent corn yields and may offer both ground cover and an additional cash crop between wheat harvest and corn planting. In conclusion, cover crops may be implemented in northeast Kansas, but producers will need to consider additional N inputs and current moisture conditions when deciding whether or not to plant covers in a given year.

INTRODUCTION

Cover crops may benefit no-till agricultural systems in a variety of ways including physical protection from erosion and organic matter production. Species with low carbon (C) to nitrogen (N) ratios can release N for the subsequent cash crop (Lu, Y. et al 2000). Because legume cover crops fix their own N, and grass cover crops can scavenge N from deeper in the soil profile, mixtures can be planted to maximize the potential benefits of both species (Fageria, N. K. et al 2005). However, some studies have found that N is immobilized following initial decomposition of legume and grass cover crop species (Jensen, E.S. 1997). Decomposition rates of cover crops significantly depend on weather conditions as well as cover crop quantity and quality (R. Thapa et al 2021). Additionally, sufficient soil moisture in the growing season is critical for corn grain fill. While cover crop mulch can preserve incoming soil moisture, it is possible for covers to take too much moisture from the soil if they are not terminated early enough in a dry spring (Kelley, 2021). Therefore, it is important to continue studying nutrient dynamics and subsequent cash crop yields following cover crops to understand the site-specific relationship between cover crop species, nutrient return to the cash crop, and subsequent yields.

A long-term cover crop study near Manhattan, Kansas has been continuously managed for over 15 years in a sorghum - soybean – wheat/cover crop rotation, with corn replacing sorghum starting in 2020. A 9-year summary of results from this site observed nitrogen immobilization during grain sorghum following cover crop treatments, with the largest reduction following a grass cover crop (G. Preza-Fontes et al 2017). These results were expressed as the N-fertilizer replacement value (NRFV), indicating how much N was added (or lost) to the system following each cover crop. At that time, most cover crop species resulted in negative NRFV values because sorghum grain yields following the cover crops were less than after chemical fallow with no nitrogen fertilizer (G. Preza-Fontes et al 2017). We now have 2 full years of yield and NRFV data for corn following different cover crop species and mixes and can determine if the effects on corn are similar to what was observed in grain sorghum.

MATERIALS AND METHODS

The study was established in 2007 at the Kansas State University Department of Agronomy Research Farm located 8 m south of Manhattan at Ashland Bottoms. The soil at this location was a moderately well drained Wymore silty clay loam, the average annual precipitation is 36 inches, and the annual mean temperature is 54.9 ºF (https://climate.k-state.edu/).

The study consisted of all phases of a wheat (*Triticum aestivum L.*) – corn (*Zea mays*) – soybean [*Glycine max (L.) Merr*] rotation, where each phase of the rotation was present every year. The experimental design was a randomized complete block design with four replications with treatments arranged in a split-plot structure with cover crops as whole plots and N rates applied to corn as subplots. Field measurements were recorded for the corn crop, which was planted immediately after cover crop termination on April 30 and May 11 in 2021 and 2022, respectively. Corn plots were 8 rows wide, and each whole plot was 20 by 225 ft, and each subplot was 20 by 45 ft. Cover crops treatments consisted of two control treatments, chemical fallow (CF) and double crop soybean (DSB), plus four cover crop treatments, crimson clover (CC), cereal rye (CR), crimson clover and cereal rye mix (R/CC), and a diverse seven species cover-crop mix (FTM). The N fertilizer treatment included five rates (0, 40, 80, 160, and 240 lb ac^{-1}) applied as 28% UAN split with 40 lb at planting and the balance at V4-6. UAN was applied with a straight flat-coulter liquid fertilizer applicator to inject N fertilizer below the residue layer. No phosphorous or potassium fertilizer were applied. Plots were sprayed with residual herbicides at and after planting to control weeds both years.

After corn reached physiological maturity, yield was determined by combine harvesting plants from the center two rows of each subplot. Grain moisture and test weight were measured with a moisture meter (Model GAC 2000, DICKEY-John Corp., Springfield, IL), and yields were corrected to 15.5% moisture content. A quadratic regression was used to describe the relationship between corn yield and N fertilizer rate after each cover-crop treatment in each year. Nitrogen fertilizer replacement value for cover crops and double crop soybean were obtained by solving the CF quadratic equation for the amount of N required to produce the grain yield obtained for the 0-N plot of each cover crop (G. Preza-Fontes et al 2017).

Mixed-effects models were fitted with using PROC GLIMMIX of the SAS® software (SAS Institute, 2011). The effects of CCs, N rates, Year, and their interactions were evaluated by ANOVA, and Least Square Means method was used to assess the difference between the means of the treatments.

RESULTS

Weather information from 2021 and 2022 growing seasons was summarized and compared to normal values (30-year average) for this location (Table 1). For both years, precipitation indicated significantly drier conditions than normal, particularly at corn 2022 planting date (April-May). Cover crops biomass following 2022 was higher than the one from 2021 (6 lb/ac vs 11 lb/ac, respectively). The three-way interaction of cover crop × N rate × year was significant for corn yield ($P = <0.0001$); therefore, years were analyzed separately (Table 2).

Table 1. Weather information for 2021 and 2022 corn growing season, and 30-years average.

	Period	30-y avg	2020 - 2021	Departure	2021-2022	Departure
Precipitation (in)	June 1- August 31	18.1	12.1	-6.0	3.2	-14.9
	Sept 1 - Dec 31	11.1	6.0	-5.1	8.2	-2.9
	Jan 1 - April 30	10.1	6.4	-3.7	4.0	-6.1
	May 1 - June 31	12.8	8.8	-3.9	14.7	1.9
	July 1 - Sept 30	15.2	5.7	-9.6	8.1	-7.1
Temperature (°F)	June 1- August 31	76.8	77.8	1.0	78.0	1.2
	Sept 1 - Dec 31	50.1	50.6	-24.4	55.3	-19.7
	Jan 1 - April 30	40.9	40.7	-26.7	40.1	-27.3
	May 1 - June 31	69.5	69.3	13.2	70.9	14.8
	July 1 - Sept 30	75.0	76.7	32.9	76.1	32.3

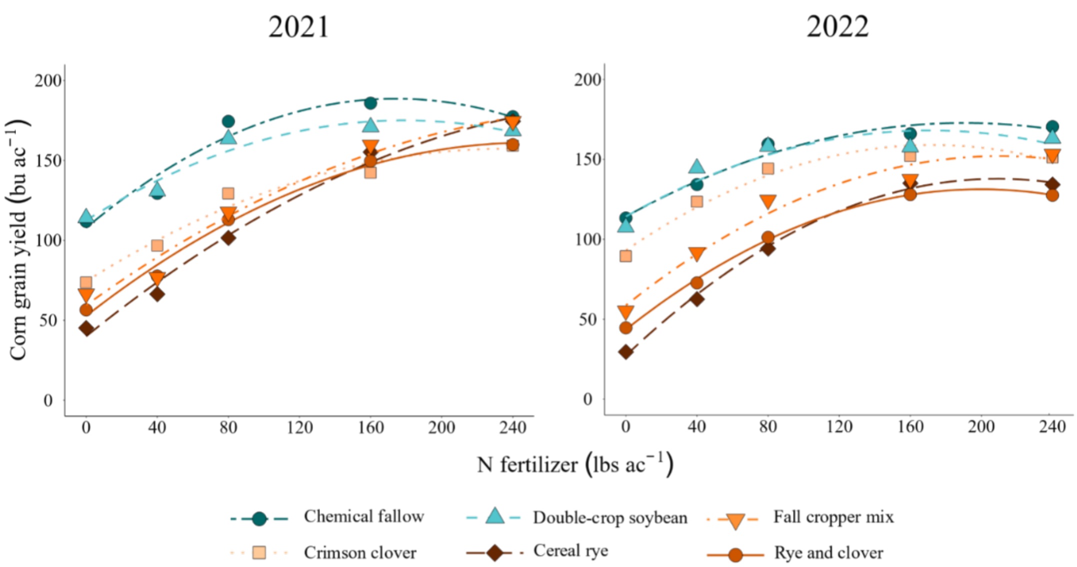
Table 2. Corn yield means for main effects and interaction of cover crops treatments (CCs) and Nitrogen rates (N-rate) in 2021 and 2022. Lower case letters indicate Least Square Means significant differences for interactions, while upper case letter indicate Least Square Means significant differences for main effects.

	CF	DBS	CC	CR	R/C	FTM	N-rate
				bushels per acre			
2021							
0	112 kj	114 ik	74 l	45 n	57 mn	67 lm	78 E
40	129 ghi	131 gh	97 k	66 m	78 l	77 l	96 D
80	174 abc	163 e	129 ghi	174 j	113 jk	118 hij	133 C
160	186 a	171 cde	142 fg	155 d-e	150 ef	160 cde	161 B
240	177 ab	169 bcd	159 cde	175 abc	160 cde	174 abc	169 A
CCs	156 A	150 A	120 B	109 C	111 BC	119 B	
2022							
0	113 ijk	108 jkl	89 mn	30 r	45 r	55 pq	73 D
40	134 fgh	144 c-g	124 hij	63 op	73 no	92 ml	105 C
80	160 abc	158 abc	144 g	94 ml	101 klm	125 hij	130 B
160	166 ab	158 abc	152 e	135 e-h	128 ghi	138 h	146 A
240	170 a	163 ab	151 f	134 fgh	128 ghi	153 bcd	150 A
CCs	149 A	146 A	132 B	91 D	95 D	112 C	

CF: Chemical fallow, DBS: Double crop soybean, CC: Crimson clover, CR: Cereal Rye, R/C: Rye and clover, FTM: Fall cropper mix.

During 2021 growing season, greatest yield was achieved with different N rates depending on cover crops treatment (Fig. 1). Although corn after crimson clover and cereal rye obtained the highest yield at the maximum N rate (240 lb/ac), corn after the fall cropper mix and the rye and clover mix reached maximum yield at 160 lb N per acre. Corn after double-crop soybean and chemical fallow obtained their highest yield at 80 lb/ac. Corn yields after the different cover crop treatments followed a similar pattern in 2022, although corn maximized yield after most cover crops at lower N rates, except for the chemical fallow and rye and clover mix treatments. For both years, when no fertilizer was applied, the highest corn yields were achieved after double crop soybean and chemical fallow treatments, and lowest yields were after cereal rye and cereal rye and crimson clover mix.

Figure 1. Yield response to different N-fertilizer application rates following different cover crops in 2021 and 2022.



The nitrogen fertilizer replacement value differed among cover crop treatments (P = <0.0001). In both years, most cover crop treatments produced a negative NFRV, excepted for double crop soybean, which provided 8 lb/ac of N during 2021 growing season. In general, the lowest values of NFRV were obtained by double crop soybean, while highest values corresponded to cereal rye and cereal rye and crimson clover mix (Table 3).

Table 3: Corn yield at 0 N-rate and Nitrogen fertilizer replacement value (NFRV) for all CC treatments in 2021 and 2022.

Treatment	Yield 0-N	NFRV	Treatment	Yield 0-N	NFRV
	bu/ac	lb/ac		bu/ac	lb/ac
	2021			2022	
CF	112	-	CF	113	-
DSB	114	8 a	DSB	108	-10 a
CC	74	-33 b	CC	89	-36 b
CR	45	-58 c	CR	30	-107 d
R/C	57	-49 bc	R/C	45	-91 cd
FTM	67	-40 b	FTM	55	-79 c

Higher corn yields were achieved following chemical fallow and double crop soybeans, and negative NFRV values along with lower yields were observed for most of the cover crop treatments, except for the double-crop soybean. This suggested that N availability for a subsequent corn crop was reduced after cover crop treatments compared to the chemical fallow. However, weather implications should also be considered, as both years of this study had less precipitation comparing to normal values (Table 1). Indeed, during 2022 growing season, none of the cover crop treatments were able to reach same yield as chemical fallow (Figure 1), even with the highest N rate, indicating another factor (possible available water) may be limiting yield. Thus, the magnitude of N supplied from CC varies because cover crop growth is sensitive to environmental conditions that vary CC biomass production from site to site and from year to year. Total CC biomass production in 2021 and 2022 were approximately 6 lb/ac and 11 lb/ac respectively. More biomass production in 2022 could mean also more water consumption by cover crops and less water available during corn vegetative stages. Finally, looking at differences between cover crops species, cereal rye has a higher C/N ratio, therefore immobilizes more nitrogen than the rest of the cover crops. Legumes and brassicas have a higher capacity to accumulate and provide nitrogen, however, the short growing season that all these cover crops had could limit this potential. According to these results, double crop soybean immobilizes less N than the rest of the cover crops treatments, with a potential for providing N available for plant uptake, which could be lost if it wasn’t stored by the cover crop. Further studies should be done in other legumes and mix of species to characterize their growth and N supply capacity in the Northeast plains of Kansas.

REFERENCES

Fageria, N. K., Baligar, V. C. and Bailey, B. A. Role of Cover Crops in Improving Soil and Row Crop Productivity. Communications in Soil Science and Plant Analysis, 36: 19, 2733 — 2757

Fontes, G.P., Tomlinson, P.J., Roozeboom, K.L. and Ruiz Diaz, D.A. (2017), Grain Sorghum Response to Nitrogen Fertilizer following Cover Crops. Agronomy Journal, 109: 2723-2737. https://doi.org/10.2134/agronj2017.03.0180

Jensen, E.S., 1997. Nitrogen immobilization and mineralization during initial decomposition of 15 N-labelled pea and barley residues. Biology and Fertility of Soils. 24, 39-44.

Kelley, Lyndon. 2021, Cover crop termination timing to help manage soil moisture. Michigan State University Extension.

Nippert, J. 2023. AWE01 Meteorological data from the konza prairie headquarters weather station . Environmental Data Initiative.

SAS Institue. 2011. SAS release 9.3 for windows. SAS Inst. Raleigh, North Carolina

Shirley, C., Bowman, G., & Cramer, C. (1998). Managing cover crops profitably. Burlington, VT, 912.

Thapa, R., Tully, K. L., Reberg-Horton, C., Cabrera, M., Davis, B. W., Fleisher, D., Gaskin, J., Hitchcock, R., Poncet, A., Schomberg, H. H., Seehaver, S. A., Timlin, D., & Mirsky, S. B. (2022). Cover crop residue decomposition in no-till cropping systems: Insights from multi-state on-farm litter bag studies. Agriculture, Ecosystems & Environment, 326, 107823. https://doi.org/10.1016/j.agee.2021.107823