[Kansas Agricultural Experiment Station Research Reports](https://newprairiepress.org/kaesrr)

Volume 9
Issue 8 *Kansas Fertilizer Research*

Article 9

2023

Assessing Corn Response to Cover Crops and Nitrogen Fertilization in a No-Till, Three-Year Rotation in Northeast Kansas

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Recommended Citation

Grünberg, Jessica; Correira, Alexis; Roozeboom, Kraig L.; Presley, DeAnn R.; and Tomlinson, Peter J. (2023) "Assessing Corn Response to Cover Crops and Nitrogen Fertilization in a No-Till, Three-Year Rotation in Northeast Kansas," *Kansas Agricultural Experiment Station Research Reports*: Vol. 9: Iss. 8. https://doi.org/10.4148/2378-5977.8551

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Funding Source

U.S. Department of Agriculture National Institute of Food and Agriculture Sustainable Agricultural Systems (SAS) Coordinated Agricultural Projects (CAP) Title: Enhancing the Sustainability of US Cropping Systems through Cover Crops and an Innovative Information and Technology Network. Award No.: 2019-68012-29818. This work was also supported by USDA NIFA Hatch project KS23-0899-NC1195.

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Assessing Corn Response to Cover Crops and Nitrogen Fertilization in a No-Till, Three-Year Rotation in Northeast Kansas

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Summary
A long-term cover crop experiment was established in 2007 at Ashland Bottoms near Manhattan, KS, to determine the effect of cover crops and nitrogen (N) rates on subsequent corn growth and yield in a wheat-corn-soybean rotation. Treatments included chemical fallow, double crop soybean, different cover crops (cereal rye, crimson clover, a mix of cereal rye and crimson clover, and a diverse mix of seven species) planted in late summer after wheat harvest, and five N rates (0, 40, 80, 160, and 240 lb/acre) applied to the subsequent corn crop. Yield responded differently to N rate depending on cover crop treatment and year. In both 2021 and 2022, corn after chemical fallow and double crop soybeans maximized yields at 80 lb N/acre, but corn following cereal rye and the cereal rye-crimson clover mix needed 160 to 240 lb N/acre to maximize yield. Nitrogen fertilizer replacement values (NFRV) were negative for most cover crop treatments, indicating immobilization of soil N. The double crop soybean NFRV had the least negative value. Overall, N availability for uptake by the subsequent corn crop was reduced by cover crop treatments compared to the check. However, soil water used by the cover crops likely also contributed to corn yield reductions and confounded with NFRV estimations.

Introduction
Cover crops have the potential to benefit sustainable, no-till agricultural systems in various ways. In addition to providing physical protection from erosion and geophysical forces, certain cover crop species with a high carbon (C) to N ratio can lead to increased organic matter, which eventually can release N via mineralization (Lu et al., 2000) but likely not to the "subsequent" cash crop. Because legume cover crops fix their own N, and grass cover crops can scavenge N from deeper in the soil profile, mixtures of legumes and grasses are planted to maximize the potential benefits of both species (Fageria et al., 2005). However, some studies have found that N is immobilized following initial decomposition of legume and grass cover crop species (Jensen, 1997). Weather and soil conditions, and the quality and quantity of the cover crops, significantly affect the decomposition rates and nutrient release of cover crops following termination (Thapa et al., 2021).

Additionally, sufficient soil moisture in the growing season is critical for corn growth and grain fill. Although 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 cash crop yields.

A long-term cover crop study near Manhattan, KS, has been continuously managed for more than 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 showed N immobilization during grain sorghum following cover crop treatments, with the largest reduction following a grass cover crop (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. Preza-Fontes et al. (2017) reported that 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 N fertilizer. In 2020, corn replaced grain sorghum in the rotation, and yield and NRFV for corn following different cover crop treatments will be discussed.

Procedures

The study was established in 2007 at the Kansas State University Department of Agronomy Research Farm located 8 miles south of Manhattan at Ashland Bottoms. The soil at this location was a moderately well-drained Wymore silty clay loam, with a 30-year normal (1991-2020) annual mean precipitation of 33.4 inches, and annual mean temperature of 54.3°F (*https://climate.k-state.edu/*).

The study consisted of all phases of a wheat-corn-soybean rotation, where each phase of the rotation was present every year. The experimental design was a randomized complete block design with four replications. Treatments were 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 planted on April 30, 2021, and May 11, 2022. Planting occurred approximately 10 days after cover crop termination. Corn plots were 8 rows wide; each plot was 20 by 225 ft, and each subplot was 20 by 45 ft. Cover crop 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/C), and a diverse mix of seven cover crop species (DM). The N fertilizer treatment included five rates (0, 40, 80, 160, and 240 lb/acre) applied as 28% UAN split with 40 lb at planting and the balance at V4-6. The UAN was applied with a straight flat-coulter liquid fertilizer applicator to inject N fertilizer below the residue layer. No P or K fertilizer was applied. Plots were sprayed with residual herbicides at planting and after planting to control weeds that emerged after planting in both years.

After corn reached physiological maturity, yield was determined by harvesting plants from the center two rows of each subplot with a plot combine. 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 (Preza-Fontes et al., 2017).

Mixed-effects models were fitted with using PROC GLIMMIX of the SAS software (SAS Institute, 2011). The effects of cover crops, N rates, year, and their interactions were evaluated by ANOVA, and means were separated at $\alpha = 0.05$.

Results

Weather information from the 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 drier conditions than normal, particularly at corn planting in 2022 (April-May). Cover crop biomass was higher for most treatments in 2022 than 2021 (Table 2). Dry conditions during cover crop growth before corn planting and during early corn growth likely resulted in reduced soil moisture reserves available for corn growth during critical stages of corn yield component formation.

The three-way interaction of cover crop × N rate × year was significant for corn yield (P = <0.0001), therefore years were analyzed separately (Table 3). In both years, corn yield response to N varied depending on cover crop treatment (Table 3, Figure 1). In 2021, corn after CC and CR obtained the highest yield at the maximum N rate (240 lb N/acre), but corn after the DM and R/C reached maximum yield at 160 lb N/acre. Corn after DSB and CF obtained the highest yield at 80 lb N/acre. 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 CF, CR and R/C treatments. In both years, when no fertilizer was applied, the highest corn yields were achieved after DSB and CF treatments, and lowest yields were after CR and the R/C.

The NFRV differed among cover crop treatments (Table 4). In both years, most cover crop treatments produced a negative NFRV, except for DSB, which had a slightly positive value in 2021 and slightly negative value in 2022, both being close to a 0 lb/acre credit. In general, the lowest values of NFRV corresponded to CR and R/C, with intermediate values from CC and DM.

As a summary, yield and NFRV presented similar results, where higher corn yields were achieved following CF and DSB. Negative NFRV values were observed for most of the cover crop treatments, except for the DSB check. 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 compared to Normal (Table 1). In 2022, corn after all of the cover crop treatments was not able to reach the same yield as after CF or DSB (Table 2, Figure 1), even with the highest N rate, indicating another factor (such as available water) may have limited the yield. Thus, the magnitude of N supplied from cover crops can vary because growth is sensitive to environmental conditions that influence biomass production. Greater biomass production in 2022 could also mean more water consumption by cover crops and less available water during corn vegetative stages. Finally, when looking at differences between cover crop species, CR has a higher C/N ratio and therefore immobilizes more N than the other cover crops. Legumes and brassicas have a higher capacity to accumulate and provide N, however, the short growing season of these cover crops could limit this potential. According to these results, DSB immobilized less N than the other cover crop treatments, with a potential for providing N available for corn uptake. Soil water extraction by DSB ceased several months earlier than for the other cover crop treatments, providing more time for soil moisture to recharge before corn planting. Management of N in corn following cover crops should account for the potential for N immobilization and soil water extraction depending on growth and residue quality of the preceding cover crop.

Acknowledgments

U.S. Department of Agriculture National Institute of Food and Agriculture Sustainable Agricultural Systems (SAS) Coordinated Agricultural Projects (CAP) Title: Enhancing the Sustainability of US Cropping Systems through Cover Crops and an Innovative Information and Technology Network. Award No.: 2019-68012-29818. This work was also supported by USDA NIFA Hatch project KS23-0899-NC1195.

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Table 1. Weather information for Normal, 2021, and 2022 cover crop and corn growing seasons

Period	Normal†	2020-2021	Departure	2021-2022	Departure
Precipitation			inches		
June 1- Aug 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- Aug 31	76.8	77.8	1.0	78.0	1.2
Sept 1 - Dec 31	50.1	50.6	0.5	55.3	5.2
Jan 1 - April 30	40.9	40.7	-0.2	40.1	-0.8
May 1 - June 30	69.5	69.3	-0.2	70.9	1.4
July 1 - Sept 30	75.0	76.7	1.7	76.1	1.1

† 30-year average, 1991 to 2020. *https://climate.k-state.edu/*

Table 2. Total cover crop biomass by treatment in 2021 and 2022

	Dry biomass[1]	
Treatment	**2021**	**2022**
	ton/acre	
Chemical fallow	0.58a[2]	0.39c
Cereal rye	0.43b	0.94a
Rye/clover mix	0.52a	1.01a
Diverse mix	0.30c	0.65b

[1]These values are for total dry biomass, including weeds.
[2]Biomass values followed by the same lower-case letter are not significantly different, $\alpha = 0.05$. These are compared within the respective years.

Table 3. Corn yield means for main effects and interaction of cover crops treatments and nitrogen rates (N-rate) in 2021 and 2022

	Chemical fallow		Double crop soybean		Crimson clover		Cereal rye		Rye/ clover mix		Diverse mix		Average	
	bu/acre													
2021														
0	112	kj[1]	114	ij	74	l	45	n	57	mn	67	lm	78	E[2]
40	129	ghi	131	gh	97	k	66	lm	78	l	77	l	96	D
80	174	abc	163	b-e	129	ghi	102	kj	113	jk	118	hij	133	C
160	186	a	171	a-d	142	fg	155	def	150	ef	160	cde	161	B
240	177	ab	169	bcd	159	cde	175	abc	160	cde	174	abc	169	A
Average	156	A	150	A	120	B	109	C	111	BC	119	B		
2022														
0	113	ijk	108	jkl	89	mn	30	r	45	qr	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	c-g	94	ml	101	klm	125	hij	130	B
160	166	ab	158	abc	152	b-e	135	e-h	128	ghi	138	d-h	146	A
240	170	a	163	ab	151	b-f	134	fgh	128	ghi	153	bcd	150	A
Average	149	A	146	A	132	B	91	D	95	D	112	C		

[1]Cover crop by N-rate interaction values followed by the same lower-case letter are not significantly different, $\alpha = 0.05$.
[2]Cover crop or N-rate average values followed by the same upper-case letter are not significantly different, $\alpha = 0.05$.

Table 4. Corn yield at 0 lb N/acre-rate and nitrogen fertilizer replacement value (NFRV) for cover crop treatments in 2021 and 2022

	2021			2022		
Treatment	Yield 0-N	NFRV		Yield 0-N	NFRV	
	bu/acre	lb/acre		bu/acre	lb/acre	
Chemical fallow	112	---		113	---	
Double crop soybean	114	8	a[1]	108	-10	a
Crimson clover	74	-33	b	89	-36	b
Cereal rye	45	-58	c	30	-107	d
Rye/clover mix	57	-49	bc	45	-91	cd
Diverse mix	67	-40	b	55	-79	c

[1]Values followed by the same lower-case letter are not significantly different, $\alpha = 0.05$.

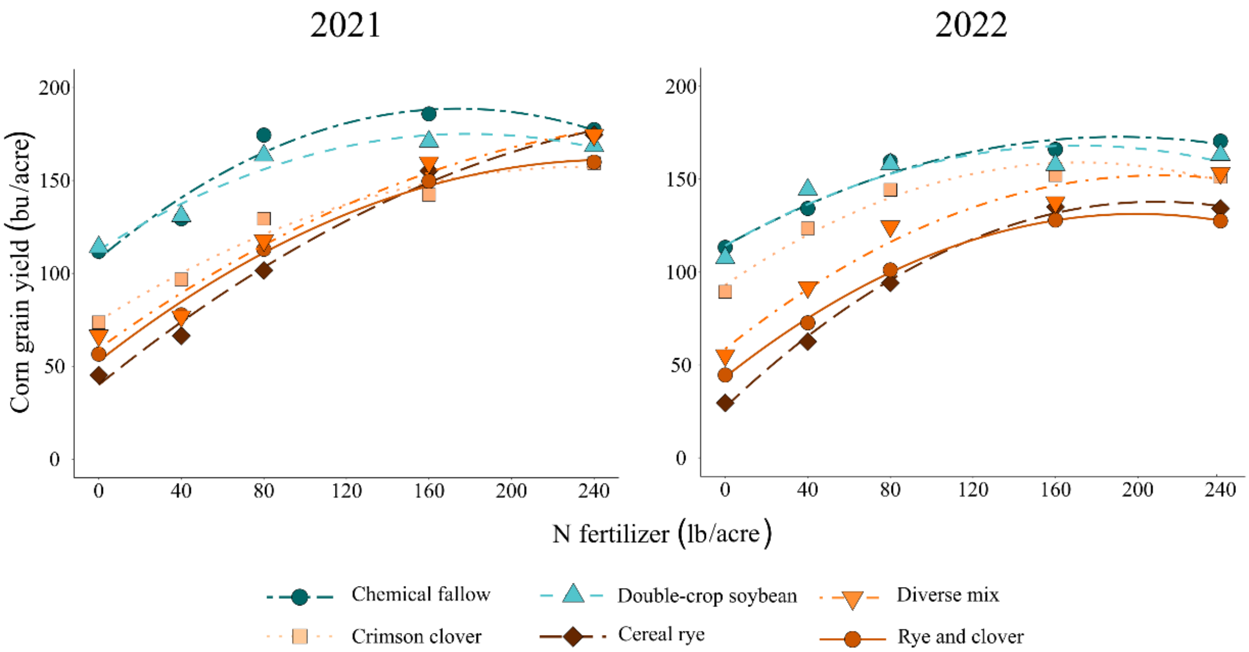

Figure 1. Corn yield response to N fertilizer application rates following different cover crop treatments in 2021 and 2022.