IMPACT OF NITROGEN APPLICATION TIMING ON CORN YIELD AND FARM PROFITABILITY IN DIFFERENT WHEAT COVER CROPPING SYSTEMS

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ABSTRACT

The continuous increase in the concentrations of nitrogen (N) and phosphorus (P) in the Upper Mississippi River Basin (UMRB), has led to the introduction of mitigation strategies with the use of winter cereal cover crop such as winter wheat (*Triticum aestivum*). The understanding of the use of these winter cereal cover crops in relation to soil N and its impact on corn yield is imperative. The study investigates the impact of cover crop and N application timing on corn production over two years. The experimental design was a Randomized Complete Block Design with four treatments and four replicates in Agronomy Research Center, Carbondale, IL between two growing seasons. The Main plots were cover crop treatments and subplots were the subplots five N fertilizer application timings (ranging from all N fertilizer upfront to all N applied at sidedress timing). Corn yield was higher in 2018 than 2019 reflecting more timely precipitation in that year. In 2018, grain yield declined by 12.6% following the wheat cover crop compared to no cover crop control, indicating a yield penalty when corn was preceded with a wheat cover crop. In 2018, a year with timely and sufficient rainfall, there were no yield differences among N treatments and N balances were near zero. In 2019, delaying the N addition to sidedress timing resulted in high yields. Split application of N (50-100 lbs/acre or 50-150 lbs/acre) was consistently most productive in both years suggesting that there is an advantage to sidedressing than upfront N application in cover crop systems.

INTRODUCTION

Illinois is evaluating management practices to reduce N losses to the Upper Mississippi River Basin (UMRB) (Lacey et al., 2020). Based on Illinois Nutrient Loss Reduction Strategy (INLRS, 2017), winter cereal cover crops are the best on-farm practices to reduce N loss in corn–corn or corn–soybean (*Glycine max* L.) cropping systems. Therefore, planting winter cereal cover crops has been encouraged to effectively reduce nitrate-N in the tile drainage. Planting a winter cereal cover crop before corn could decrease corn yield as a result of reduced N availability in spring due to N immobilization caused by high C:N ratio of cover crop residue or soil moisture depletion by the winter cereal early in the spring (Singh et al., 2020). There have been studies on cover crop N release potentially happening simultaneously with cash crop N demand, but results have shown a decrease in cash crop N uptake (Ruffatti et al., 2018). The literature suggests corn N need increases or corn yield potential decreases when rye (*Secale cereal* L.) is planted prior to corn (Pantoja et al., 2015). Unlike cereal rye, studies on wheat as a cover crop prior to corn are scant in Illinois. Wheat is a low-cost and versatile cover crop and growers are often familiar with wheat management. Our objective was to evaluate whether split N application to corn changes corn N need and NUE in no-cover crop compared to following an early terminated wheat cover crop.

MATERIALS AND METHODS

Experimental Site and Weather Conditions

A field trial was conducted at the Agronomy Research Center in Carbondale, IL (37.75° N, 89.06° W) during 2017–2018 and 2018–2019 growing seasons. From this point forward, to simplify presenting our results, 2017–2018 is referred to 2018 and 2018–2019 is referred to 2019. In 2018, soil was classified as Weir silt loam (fine, smectitic, mesic Typic Endoaqualfs) and in 2019, the soil was classified as Stoy silt loam (fine-silty, mixed, superactive, mesic Fragiaquic Hapludalfs).

Mean air temperature during the growing season (May–November) was close to the 30-year average in Carbondale, IL (data not shown). The cumulative growing season precipitation (May–November) was 844.80 mm (33.2 inches) in 2018 and 852.42 mm (33.5 inches) in 2019, while the 30-year average precipitation during May–November amounted to 718.82 mm (28.3 inches). These data indicate that both 2018 and 2019 were wetter than the 30-year average and that differences from year-to-year were mainly due to temporal distribution rather than total precipitation. Precipitation in May 2018 was close to 30-year average but lower than 2019, indicating more suitable growing conditions for timely corn planting and corn establishment in 2018 than 2019.

Experimental Design and Treatments

The experiment was conducted as a randomized complete block design with split plot arrangement and four replicates. The main plots were two cover crop treatments: no cover crop (control) and a cover crop (wheat) terminated four weeks (at stem elongation stage) prior to corn planting and the subplots were five N timing applied to the subsequent corn. All N treatments received a total amount of 150 lbs N/acre at a various combination of preplant and post-plant sidedress as: (1) 150 lbs N/acre applied at planting; (2) 50 lbs N/acre applied at planting plus 100 lbs N/acre applied at sidedress; (3) 100 lbs N/acre applied at planting plus 50 lbs N/acre applied at sidedress timing; and (4) 150 lbs N/acre applied at sidedress timing. A zero-N control treatment was also included in the study forming 10 treatments in total.

Cultural Management Practices

Wheat Establishment

Wheat (cv. “Agrimaxx 446”) was planted with a grain drill on 26 October 2017 and 15 November 2018 at a rate of 1.5 million seeds/acre.

Corn Planting and Management

Plots were 33 ft long and 10 ft wide. A no-till drill was used to plant corn (Dekalb “DKC64-35RIB”) at 30,000 seeds/acre on 25 May 2018 and 24 May 2019. Preplant N was applied at planting in the form of liquid urea ammonium nitrate (UAN; 28%). The sidedress N was applied at corn V5 stage (18 June 2018 and 1 July 2019) using

UAN (28%). Later sidedress timing in 2019 reflects the challenging year with excessive rainfall in 2019.

Data Collection

Wheat Sampling

Tissue samples were collected four weeks before corn planting date on 20 April 2018 and 23 April 2019 when wheat plants were at the stem elongation stage (Feekes 7). Samples were then dried at 60 °C until constant dry weight. The oven-dried samples were then ground to 0.6 mm particle size and analyzed for N and C content using dry combustion (Flash 2000 Elemental Analyzer, Thermo Scientific, Cambridge, UK).

Corn Sampling

The corn was machine-harvested on 13 November 2018 and 10 October 2019. A grain subsample was taken from each plot for measuring N concentration using wet chemistry. Nitrogen removal by stalks and leaves was estimated at 45% of the grain N removal (Otte et al., 2019). Sum of N content in grain and N content in stalks was used for NUE calculation.

Nitrogen Balance and N Use Efficiency

Nitrogen balance for each treatment was calculated by subtracting N removed by grain harvesting (lbs grain yield/acre × % N in the grain) from N applied for each fertilizer treatment in each year (Sadeghpour et al., 2017). Since corn stover remained in the field, N content of corn stover was not included in N removal calculation.

The NUE (lbs DM lbs N) was determined as (lbs DM at Nx - lbs DM at N0)/lbs of applied N where Nx = N rate > 0, and N0 = no N application (Ketterings et al., 2007).

Statistical Analysis

Data were analyzed using Proc Mixed of SAS. The fixed effect in the model was year, cover crops, and N treatments and block was a random effect. When treatment effects were significant, mean separation was performed using least significant difference (LSD).

RESULTS AND DISCUSSION

Wheat Biomass and N Uptake

Wheat produced 0.71 tons/acre biomass (dry matter basis) by the time of termination in 2018 which was four-fold higher than in 2019 reflecting: (i) earlier planting in 2018; and (ii) less favorable growing conditions in 2019. Nitrogen uptake by wheat cover crop in 2018 was 21 lbs N/acre, which was more than three-fold higher than 2019. This indicates the importance of timely planting of wheat to establish and perform well in spring.

Corn Grain Yield, N removal, Balances, and NUE

Grain yield was influenced by year, cover crop, N application, and year × N application. Mean grain yield was notably greater in 2018 (9813.9 lbs/acre) than in 2019 (5263.9 lbs/acre), reflecting the effect of precipitation on year-to-year yield variation (Table 1). While 2018 received even and timely precipitation, 2019 was a very wet year in Carbondale, IL contributing to substantial N loss and thus lower grain yields. Maximum corn grain yield in cover crop treatment was 14% lower compared to the maximum yield in no cover crop control confirming that N immobilization could most likely have caused yield reduction (Weidhuner et al., 2019). In 2018, a year with timely precipitation, there were no corn yield differences among N application treatments (Table 1). In 2019, an extremely wet year, corn grain yield increased by delaying N application from planting to sidedress timing indicating that later application of N possibly decreased N losses (leaching or nitrous oxide emissions) in heavy soils of southern Illinois (Table 1). This highlights the importance of timely application of N fertilizer to meet corn N demands after the V4 stage.

Corn N removal was influenced by year, cover crop, year × cover crop, N application, and year × N application. Mean N removal (112 lbs/acre) was greater in 2018 than N removal (46 lbs/acre) in 2019 due to much lower grain produced in that year. Excluding the zero-N control, N removal was 124.9 lbs/acre in 2018 vs. 50.8 lbs/acre N removal in 2019. In 2018, N removal by corn after wheat cover crop was 20% lower compared to the control treatment without cover crop (data not shown). In 2019, N removal was similar between the two cover crop treatments (data not shown). This indicates that, in the year with a favorable condition (2018), corn had decent growth and required N. Thus, wheat presence, using some of the available N, in addition to N immobilization resulted in a significant difference between no cover crop and cover crop treatments. In 2019, a wet growing season impacted corn growth resulting in lower N removal.

Nitrogen balance was affected by year, cover crop, year × cover crop, N application, and year × N application. Excluding the zero-N control, N balance was 2.6 lbs/acre in no cover crop control and 26.5 lbs/acre in wheat cover crop, suggesting more N was needed when wheat was the preceding cover crop to corn compared to no cover crop control.

All N application treatments had slightly positive N balance (13.3 lbs/acre; average of N treatments) with no difference among the N treatments. In 2019, N balance was lower in all sidedress treatments followed by split application of 50 lbs N/acre at planting plus 100 lbs N/acre at sidedress timing, indicating lower yield, and possibly greater N loss with early N application timing in a very wet year.

Nitrogen use efficiency was affected by year, cover crop, year × cover crop, and year × N application. The NUE was higher in 2018 than 2019 in line with slight positive N balances, and overall greater yield in that year.

Table 1. Corn grain yield and nitrogen (N) concentration, N balance and removal, partial factor productivity (PFP), and N use efficiency (NUE) as affected by different N rates in 2018 and 2019 growing seasons.

		Grain Yield	Grain N Concentration	N Removal	N Balance	NUE
	N treatments †	(lbs/acre)	(%)	(lbs/acre)	(lbs/acre)	lbs yield/lbs N
2018	N0	6156 [b]	1.052 [b]	64.2 [b]	-64.7 [b]	
	N150U	10795 [a]	1.136 [a]	122.7 [a]	16.4 [a]	28.5 [a]
	N100U50S	11241 [a]	1.147 [a]	129.4 [a]	9.7 [a]	30.0 [a]
	N50U100S	10349 [a]	1.173 [a]	121.8 [a]	17.3 [a]	25.0 [a]
	N150S	10884 [a]	1.164 [a]	126.1 [a]	13.0 [a]	29.0 [a]
2019	N0	2854 [c]	1.010 [a]	29.0 [b]	-29.0 [c]	
	N150U	3390 [c]	0.950 [a]	31.2 [b]	107.9 [a]	3.6 [c]
	N100U50S	5085 [b]	0.949 [a]	41.6 [b]	97.6 [a]	15.8 [b]
	N50U100S	6066 [a,b]	1.060 [a]	64.5 [a]	76.6 [b]	24.2 [a]
	N150S	6423 [a]	1.026 [a]	66.1 [a]	73.1 [b]	25.5 [a]

Numbers within columns followed by different letters indicate significant difference at $p \leq 0.05$. † N0, zero-N control; N150U, 150 lbs N/acre applied at planting; N100U50S, 100 150 lbs N/acre applied at planting plus 50 150 lbs N/acre applied at sidedress timing; N50U100S, 50 150 lbs N/acre applied at planting plus 150 lbs N/acre applied at sidedress; N150S, 150 lbs N/acre applied at sidedress timing.

CONCLUSIONS

Our results indicate weather conditions, especially temporal distribution and amount of rainfall, impact the effectiveness of split N application. In 2018, a year with timely and sufficient rainfall, there were no differences among N treatments except for zero-N control. In a wet growing season, delaying N addition improved NUE and corn grain yield indicating N losses were substantial early in the season and that later N fertilization allows for better utilization of applied N. Wheat cover crop effect on corn N requirement was also weather dependent. In 2018, wheat decreased corn yield potential possibly due to N immobilization, which indicates a need for revisiting corn N rate recommendations and fine-tuning N application timing following wheat cover crop. In 2019, due to excessive rainfall, corn yields were lower than average and cover crop effects on corn yield were not detectable. Overall, inclusion of crediting system for cover crops could help current N management systems in Illinois.

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