EVALUATING EFFICACY OF 590 FALL MANURE MANAGEMENT PRACTICES TO IMPROVE CORN N UTILIZATION?[1]

Anna O. Teeter, Todd W. Andraski, and C.A.M Laboski[2]

Abstract

Fall applications of manure have the potential for high nitrogen (N) losses. Cereal/grass cover crops have been shown to take up fall applied N. Similarly, using nitrapyrin (Instinct®) has been shown to prevent loss of fall applied N. No studies have been conducted to evaluate combining these tools to prevent N loss. This experiment was performed in 2016 and 2017 on a well-drained and somewhat poorly drained silt loam soils. This study was conducted to determine if using Instinct® and spring wheat (*Triticum aestivum)* with fall applied manure could improve nitrogen availability to corn (*Zea mays*) due to a synergistic effect. Dairy slurry was broadcast and incorporated in the fall either with or without Instinct® and with or without cover crop. Fertilizer N treatments were split (40 lbs/a at plant and sidedressed at growth stage V6) applied in 40 lb N/a increments up to 240 lb N/a. The amount of soil nitrate in the upper 12 inches of soil was reduced up to 41% in the first four weeks after application. Eight weeks after manure application the cover crop reduced soil nitrate concentration up to 68%. Instinct® did not have any significant effect on soil nitrate concentration. At the V6 corn growth stage cover crop increased soil nitrate concentration 31% compared to manure only plots. Cover crop significantly reduced grain yield by as much as 38 bu/a. At one site year in 2017, cover crop with Instinct® significantly decreased grain yield compared to manure only, manure with cover, and manure with Instinct®. In the fall Instinct® does not perform in long warm periods before the soil cools and may also be affected by manure organic matter cover crop effectively takes up soil N.

Introduction

There is rising concern for the high rates of N loss in agricultural crop production. These N losses transport through the soil via leaching and contaminate local drinking water and run off the soil surface where it eventually flows to the Mississippi river, and collects in the Gulf of Mexico (Kladivko et al., 2014). Losses of nitrate can denitrify in anerobic, wet, conditions contributing to greenhouse gas emissions and reducing air quality. Even with this concern there is still some preference for growers to apply their fertilizer or manure in the fall. In the Midwest soils in the fall are drier and provide a better surface for application equipment compared to spring soils that can be very wet. Emptying manure pits in the fall also gives growers a chance to lower their manure levels before winter ensuring they prevent overflow. In addition, there is more time in the fall to apply fertilizer as there is no competition from planting crops.

Because of this need for fall application, mitigation techniques must be employed to prevent as much N loss as possible. Cover crops are a tool which recently have been shown to be an effective means of N uptake in fall applied manure and are labeled as catch crops. Catch

[1] Research funded by DuPont Pioneer.

[2] Former Graduate Research Assistant, Researcher, and Professor, Dept. of Soil Science, Univ. of Wisconsin-Madison, 1525 Observatory Dr. Madison WI, 53706.

crops are typically grasses; rye or winter wheat are the most popular, as their growth before frost will take up N (Dabney et al., 2001; Strock et al., 2004; Snapp et al., 2005a; b; Lacey and Armstrong, 2015). There is strong evidence that these practices reduce nitrate losses during winter months with fall manure applications, but there are mixed results on the impact on yield (Thilakarathna et al., 2015). After the winter season the cover crop is intended to mineralize N during the cash crop growing season, although results are inconsistent (Ketterings et al., 2015). Overall cover crops are a potentially useful tool for preventing N losses.

Nitrification inhibitors are another tool used to mitigate N losses. After the hydrolysis of urea to ammonium from manure fertilizers, the ammonium is relatively quickly converted to nitrate where it is easily lost because it has a weak negative charge (Beeckman et al., 2018). Nitrification inhibitors are designed to prevent the first step of nitrification, the conversion of ammonium to nitrite by *Nitrosomonas spp.* Instinct® (nitrapyrin) is a commonly used nitrification inhibitor in the USA. Instinct® is a bacteriostatic compound as it inhibits enzymatic activity, and is not a broad spectrum bactericide (McCarty, 1999; Beeckman et al., 2018). In studies with high soil organic matter Instinct®'s efficacy decreased, compared to soils with low organic matter (McCarty and Bremner, 1989). High temperatures also tend to reduce longevity of Instinct® (Touchton et al., 1979). Vetsch et al. (2017), has demonstrated the use of Instinct® to successfully increase N availability of fall applied swine manure to corn and increased yields.

The objective of this study was to determine if there is a synergistic effect of cover crop and Instinct® on availability of N from fall applied dairy slurry.

Material and Methods

Site Conditions and Plot Setup

Research was conducted in 2016 and 2017 at two locations, Arlington Agricultural Research Station and Marshfield Agricultural Research Station. Arlington Agricultural Research Station is on a well drained Plano silt loam soil (fine-silty, mixed, mesic Typic Agriudolls). Marshfield Agricultural Research Station is on a somewhat poorly drained Withee silt loam soil (fine-loamy, mixed Aquic Glossoboralfs) (NRCS USDA, 2017).

Treatments

The experimental design was a randomized complete block with 11 treatments and 4 replications, totaling 44 plots. The plots were 10 feet wide (four rows of corn with 30 inch-spacing) and 40 ft long. There were four fall treatments that had 7,000 gal/a of dairy slurry broadcast and incorporated either with or without 78 oz/a Instinct® and either with or without a fall cover crop. There were seven synthetic split fertilizer treatments (40 lbs N/a at plant plus sidedress at growth stage V6) applied in 40 lb N/a increments up to 240 lb N/a. The previous crop was corn silate. Hard-red spring wheat was planted in the fall after manure application at a population of 2.5 bu/a in 7.5-inch rows. The reason for using spring wheat as the cover crop are several fold: 1) Instinct® is only registered for use on corn or wheat in Wisconsin; 2) spring wheat has greater fall biomass production than winter wheat; 3) spring wheat winter kills so it is unnecessary to terminate in the spring and can speed up spring field operations; and 4) the fall growth can be used as a forage if needed. Corn was planted in May at a population of 35,000 seeds/a. Each plot had an initial starter fertilizer of 110 lb/a of 9-23-30 placed 2x2. Corn was managed using the University of Wisconsin recommendations, including preplant and post emergence herbicide application.

Soil, Plant and Manure Sampling

Manure samples collected during application were analyzed for dry matter, total C, total N, NH_4^+-N, total P, total K, pH, and ash (Peters et al., 2003). Manure total N for Arlington 2016 was 126 lb/a and 49.6% was NH_4^+, for 2017 total N was 116 lb/a and 50.9% was NH_4^+. For Marshfield 2016 total N was 58 lb/a and 44.8% was NH_4^+, and for 2017 total N was 69 lb/a and 44.9% was NH_4^+.

In the fall, a soil sample from the control treatment was collected in each replicate and comprised of 6 cores collected to a depth of 6 inches and was analyzed for Bray 1 P and K (Bray and Kurtz, 1945). Weight loss on ignition (Schulte and Hopkins, 1996) was used to analyze organic matter, and 1:1 soil to water was used to analyze pH. In treatments where manure was applied, as well as the control treatment, soil samples were collected to 12 inches in the fall at 4 and 8 weeks after manure application as well as in the spring at the V6 corn growth stage. Samples were oven dried then ground and passed through a 2 mm sieve before analysis. All samples analyzed for nitrate and ammonium were extracted with 2*N* KCL with a 1:10 soil to solution mixture and shaken for one hour (Bundy and Meisinger, 1994) and then analyzed with Flow Injection Analysis (Růžička and Hansen, 1984).

Just prior to winter kill spring wheat biomass samples were collected from 15 inch sections from 5 rows and then analyzed for total N concentration. Grain was harvested from each replicate and analyzed for total N concentration. All grain and plant samples were oven dried then ground and passed through a 1 mm sieve before analysis. Total N concentrations were measured using a Kjeldahl digestion for all plant and grain samples (Nelson and Sommers, 1973).

Statistical Analysis

Corn grain response to N was analyzed using SAS 9.4 (SAS Institute, 2004), PROC REG was used to analyze linear and quadratic regressions. PROC NLIN was used to analyze linear plateau regression and quadratic plateau regression. All four sites used the quadratic plateau regression except for Arlington 2016 because there was no response to N fertilization.

PROC MIXED was used to analyze means of data for plant and soil samples, and a p-value of 0.10 was used to establish significant differences between means.

Results and Discussion

At both Arlington and Marshfield 2016 soil samples collected 4 and 8 weeks after manure application in the fall had significantly lower soil nitrate concentrations when the cover crop was planted compared to manure without cover crop (Table 1). Cover crop reduced soil nitrate at Arlington 29 and 60% after 4 and 8 weeks, respectively. At Marshfield cover crop reduced soil nitrate 41 and 68% after 4 and 8 weeks, respectively. In 2016, V6 soil nitrate concentrations were 31% greater with cover crop compared to no cover crop at Arlington suggesting the cover crop helped retain N. In contrast, cover crop had significantly lower soil nitrate than without cover at Marshfield (Table 1). Wildlife grazed the cover crop approximately 7 weeks after manure application (Table 2) and removed N from the system which likely explains the reduced soil nitrate concentrations at V6. Due to excellent growing conditions and high soil N mineralization, there was no yield response to spring applied N fertilizer (Table 3); the control treatment yielded 265 bu/a. No yield differences were found between fall manure treatments (Table 4). At Marshfield the cover crop significantly reduced corn grain yield compared to no cover crop (Table 3). This is likely due to the wildlife grazing mentioned previously. The data demonstrate that if a fall cover is used for late fall forage or grazing, N taken up by the cover crop would be removed from the system and would be unavailable for the following crop.

At Marshfield 2017, 4 weeks after manure application there was no significant differences in soil nitrate concentrations. Eight weeks after manure application, soil nitrate concentrations were significantly lower with cover compared to without (Table 2), a 21% reduction. Differences in soil nitrate concentrations occurring later in the fall coupled with generally lower cover crop N uptake are evidence of the slow growth of the cover crop. Use of Instinct® did not affect cover crop biomass yield (Table 2) or biomass N uptake. In the spring, V6 soil nitrate concentrations were not significantly different from each other. In April, May, and June the precipitation was 3.2, 2.0, and 2.4 inches, respectively, above the 30 year average (Figure 1) providing conditions conducive to N loss. Grain yield from the various manure treatments were not significantly different from each other and yields from manure treatments (Table 1) were equivalent to the 0 lb N/a treatment (Table 3). This indicates all N from manure application was lost.

At Arlington in 2017, 4 weeks after manure application there was not a significant difference in soil nitrate concentration between treatments. Eight weeks after manure application cover crop significantly reduced soil nitrate concentrations compared to no cover crop (Table 1). Due to lower cover crop yields in 2017 compared to 2016, less soil N was taken up by the cover crop until later in the fall (Table 2). There was no significant difference between cover crop biomass with Instinct® and cover crop without Instinct®; however cover crop N uptake with Instinct® was significantly greater than cover crop without Instinct® (Table 2). Spring V6 soil nitrate concentrations for any fall manure treatment was not significantly different than the control. Cover crop with Instinct® grain yield was significantly lower than manure only, manure with cover crop or manure with Instinct® (Table 3). It is unknown as to why cover crop with Instinct® is 32 bu/a lower than manure only, but it may be due to higher N uptake by cover crop with Instinct® (Table 2).

Use of Instinct® with manure did not change soil nitrate concentrations whether used in conjunction with cover crop or not for all four site years. It is likely that with warmer than average November temperatures (Figure 1) and above average precipitation following manure application, Instinct® degraded quickly in the soil and could not preserve ammonium for the following crop.

Summary

Although there are positive impacts of both grass cover crop and Instinct® on N uptake from fall applied manure, there was no strong evidence that they worked synergistically to improve N availability to the corn crop. The use of spring wheat as a cover crop did reduce soil nitrate 4 and 8 weeks after fall dairy slurry application, but this was not converted into available

N during the growing season. It may be more practical to recover the growing cover crop as a forage and eliminate the possibility of N escaping during the growing season, and fertilize the cash crop accordingly. In this study Instinct®'s efficacy was challenged with at least two months of warm weather before the soil froze and slowed biological activity. In addition, Instinct® was applied with manure, which contains high levels of organic matter which may bind compound lowering it's efficacy.

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Table 1. Soil nitrate concentrations at 4 and 8 weeks after fall manure application and in the spring at V6 at Arlington and Marshfield in 2016 and 2017.

	2016			2017		
	Post fall manure			Post fall manure		
Treatments	4 weeks	8 weeks	V6	4 weeks	8 weeks	V6
	-------------------------------lb N/a------------------------------					
Arlington						
Control	61 c †	24 b	70 b	43	35 a	51
Slurry	128 a	58 a	74 b	39	33 a	49
Slurry + Instinct®	124 a	57 a	79 b	38	38 a	55
Slurry + Cover crop	91 b	23 b	97 a	35	20 b	51
Slurry + Cover crop + Instinct®	87 b	22 b	95 a	38	17 b	46
p-value	<0.01	<0.01	<0.01	0.95	<0.01	0.70
Marshfield						
Control	42 bc	33 b	66 ab	17	19 a	14
Slurry	59 a	45 a	82 a	15	19 a	17
Slurry + Instinct	51 ab	51 a	85 a	15	19 a	13
Slurry + CC	35 c	17 c	60 b	16	15 b	13
Slurry + CC + Instinct®	37 c	15 c	56 b	15	15 b	15
p-value	0.03	<0.01	0.09	0.68	<0.01	0.27

† For a given location, values within each column followed by the same letter are not significantly different (p<0.1).

Table 2. Fall sampled spring wheat biomass yield and biomass N uptake at Arlington and Marshfield in 2016 and 2017, 8 weeks after manure application.

	2016		2017	
Treatment	Arlington	Marshfield	Arlington	Marshfield
	-----------------------lb/a-----------------------			
Biomass yield				
No Instinct®	1664	307†	498	350
Instinct®	1407	221	528	320
p-value	0.08	0.03	0.14	0.52
Biomass N uptake				
No Instinct®	70	13	18	10
Instinct®	64	9	20	9
p-value	0.03	0.06	0.07	0.24

† Grazed by wildlife between 4 and 8 weeks after manure application, 1 to 5 inches in height.

Table 3. Corn grain response to split N applications at Arlington and Marshfield in 2016 and 2017.

Treatment	2016 Arlington	2016 Marshfield	2017 Arlington	2017 Marshfield
		--------------------------------bu/a----------------------		
0	265	160 c †	186 d	74 e
40	266	201 b	199 cd	90 d
80	274	220 a	216 bc	134 c
120	272	231 a	219 b	155 b
160	268	234 a	228 ab	170 a
200	273	222 a	237 a	175 a
240	276	230 a	233 ab	181 a

† Values within each column followed by the same letter are not significantly different (p<0.1).

Table 4. Corn grain response to various dairy slurry treatments at Arlington and Marshfield in 2016 and 2017.

Treatment	2016 Arlington	2016 Marshfield	2017 Arlington	2017 Marshfield
		----------------------bu/a---------------------		
Slurry	259	192	185 a†	78
Slurry + Instinct®	267	184	191 a	77
Slurry + Cover Crop	261	154	180 a	75
Slurry + Instinct® + Cover Crop	260	164	153 b	72
p-value				
Instinct®	0.46	0.95	0.07	0.35
Cover crop	0.61	0.02	<0.01	0.56
Instinct® x Cover crop	0.36	0.41	<0.01	0.74

† Values within each column followed by the same letter are not significantly different (p<0.01).

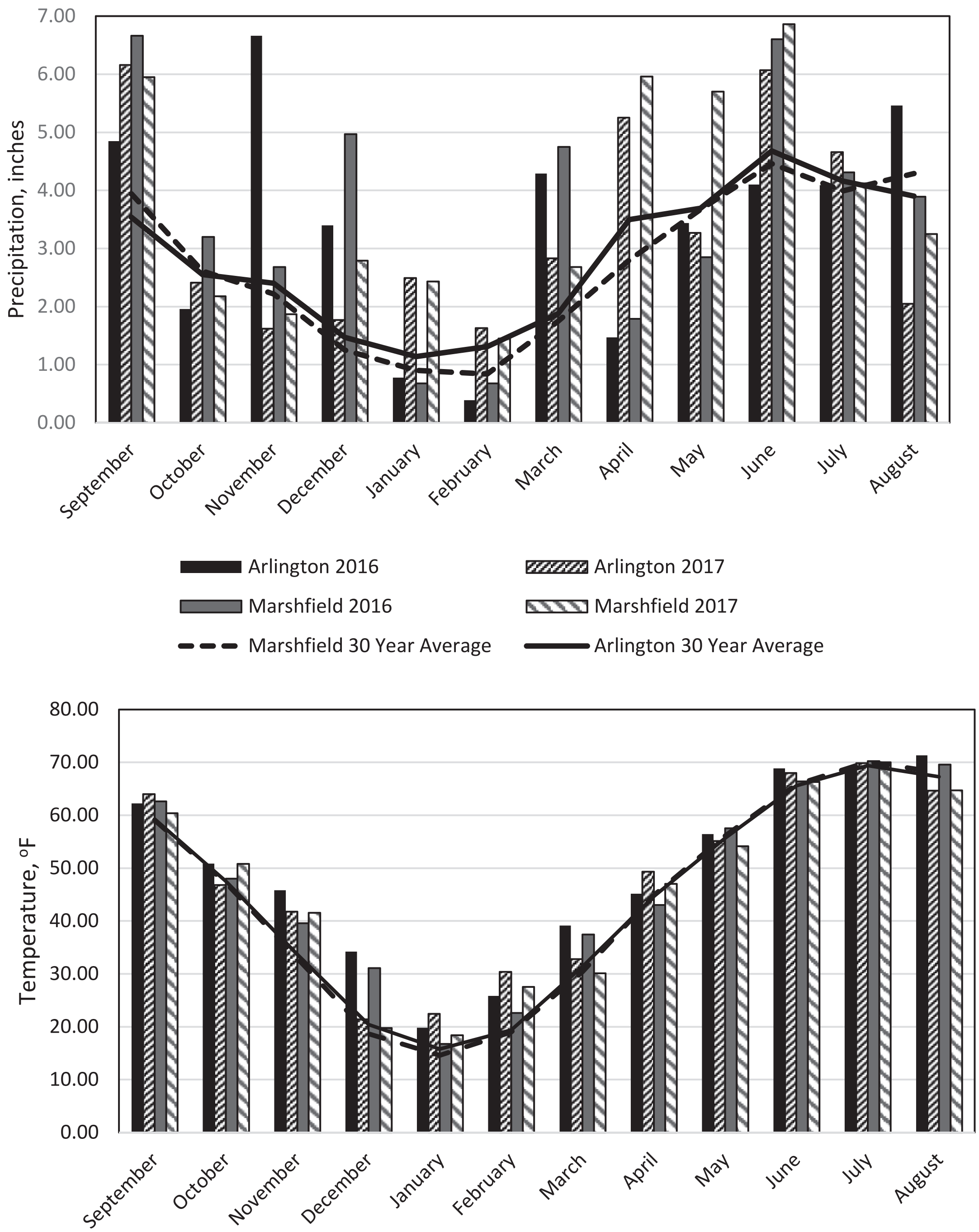

Figure 1. Mean monthly air temperature in ^{o}F of all four site years, and thirty year averages (upper graph). Monthly sum of precipitation in inches over all four site years and 30-year averages (lower graph).