Effect of Time of Manure Application and a Cover Crop on Nitrogen Availability and Corn Yield

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Abstract

Cover crops are being considered by some producers to minimize nitrate losses from the soil, enhance N availability, and increase corn (Zea mays L.) yield from fall-applied manure. A two-year study was conducted on clay loam mollisols at the University of Minnesota Southern Research and Outreach Center to determine the role of time of manure application and an oat (Avena sativa) cover crop on nitrate concentration in the soil profile, corn yield, and N uptake. Target dates for swine (Sus scrofa domesticus) manure application were 1 Aug., 1 Sept., 1 Oct., 1 Nov., and 15 April. Oats was established immediately after the 1 Aug. and 1 Sept. manure applications and on a set of zero-N control plots. Across the 2-yr period, oat growth and N uptake were 2.6 and 2.1 times greater, respectively, for Aug. establishment. Oat growth and N uptake were 1.4 times greater when manure was applied. Corn yields, ranging from 13.1 to 14.0 Mg ha^{-1}, were not different among the five application dates when the cover crop was absent. Corn yields and N uptake were reduced 3.3 Mg ha^{-1} and 56 kg ha^{-1}, respectively, when oats were established 1 Aug. and 1.0 Mg ha^{-1} and 26 kg ha^{-1} with 1 Sept. establishment. These data plus the soil nitrate data indicate that substantial N was sequestered by the oat cover crop, which substantially reduced corn yield and N uptake. Foregoing an oat cover crop and applying manure later in the fall or early spring appears to be a better management practice for corn producers in Southern Minnesota.

Introduction

Due to manure storage limitations and/or time management of both the producer and the custom applicator, some swine producers desire to apply manure in the late summer after harvest of small grains. Cover crops such as oats are being considered by some producers to stabilize N from the manure by taking up some of the nitrate and transpiring water, minimizing nitrate loss from the soil profile.

Objective

To determine: 1) corn yield, N uptake and nitrate distribution in the soil profile as affected by late summer and fall application of swine manure with and without an oat cover crop and 2) oat yield and N uptake as affected by time of planting and manure application.

Experimental Procedures

A field experiment was conducted at the Univ. of Minnesota's Southern Research and Outreach Center on a Clarion-Nicollet clay loam complex in 2007-08 and on a Webster clay loam in 2008-09. Spring wheat (*Triticum aestivum*) was the previous crop both years. Treatments were replicated four times in a randomized complete-block design. Other pertinent procedures are shown in Table 1.

Table 1. Listing of pertinent experimental methods used.

Experimental Methods	2007-08	2008-09
Tillage	Disk, 25 July	Disk, 8 Aug.
Plant "Forage Plus" oats	2 Aug.	11 Aug.
	31 Aug.	4 Sept.
Apply Glyphosate to non-oat plots	17 Aug.	5 Sept.
Harvest oats (removed forage)	25 Oct.	20 Oct.
Spring tillage	Disk & f. cult., 30 Apr.	Disk & f. cult., 22 Apr.
Plant corn	1 May	23 Apr.
Measure surface residue	19 May	6 May
Combine harvest corn	9 Oct.	27 Oct.

Experimental Procedures (continued)

Liquid swine manure was obtained each year from an under-barn pit of a local hog producer. Manure management decisions by the producer caused substantial variability in manure-N content in 2008. The manure was thoroughly agitated and sweep-injected about 10 to 15 cm deep on 75-cm centers using a research plot applicator. Manure samples were collected, frozen, and sent to the Univ. of Wisconsin Soil and Forage Analysis Lab. Application dates and available N rates applied are shown in Table 1.

Table 2. Manure application dates and available N rates.

Target Application date	2007/08 Actual Date	2007/08 Available[1/] N rate (kg N ha^{-1})	2008/09 Actual Date	2008/09 Available[1/] N rate (kg N ha^{-1})
1 Aug.	2 Aug.	166	8 Aug.	133
1 Sept.	31 Aug.	165	2 Sept.	99
1 Oct.	12 Oct.	142	1 Oct.	161
1 Nov.	31 Oct.	143	31 Oct.	88
15 Apr.	17 Apr.	161	14 Apr.	134
Target Application Rate		168		134

[1/] Assuming 80% of total N in manure is available.

Fig. 1 Applying manure treatments in Aug., 2007.

Fig. 2 Post-application of manure in Aug.

Substantially different climate regimes for the two manure application seasons are shown in Table 3.

Table 3. Monthly air temperature and precipitation departures from normal during the study period.

Month	Temperature 30-Yr[1/] Normal	Temperature Departure 2007/8	Temperature Departure 2008/9	Precipitation 30-Yr[1/] Normal	Precipitation Departure 2007/08	Precipitation Departure 2008/09
	- - - - - - - - - - - °C - - - - - - - - - - -			- - - - mm - - - -		
Aug.	20.5	0.6	-0.4	116	157	-61
Sept.	15.6	1.5	1.3	81	38	-44
Oct.	8.7	3.1	0.1	65	79	-16
Nov.	-0.3	0.9	1.2	59	-53	-2
Apr.	7.2	-1.5	0.4	82	-39	-21
May	14.6	-1.6	-0.2	101	23	-52
June	19.8	-0.5	-1.0	107	2	-37
July	21.6	0.4	-2.7	114	1	-75
Aug.	20.5	-0.4	-1.4	116	20	-32
Sept.	15.6	1.3	2.2	81	-61	-43

[1/] 30-yr normal = 1971-2000.

• Aug.–Oct. was warm and wet in 2007-08 and dry with normal temperatures in 2008-09.

• Growing season temperatures were cooler than normal each year, but 2008-09 was considerably drier than 2007-08.

Results: Cover Crop

Oats were planted within 3 days after the liquid manure was injected (Fig. 3). Growth had occurred by early Sept. in 2007 (Fig. 4). Substantial growth differences between the early-Aug. and early Sept. plantings are evident at harvest in 2007 (Fig. 5).

Fig. 3. Planting oats in Aug. 2007.

Fig. 4. Oat growth in Sept. 2007.

Fig 5. Oat harvest in Oct. 2007 (established 2 Aug. on left and 31 Aug. on right).

Oat growth and N uptake were significantly greater in 2007 than in 2008 (Tables 4 and 5).

Table 4. Oat dry matter yield, N concentration, and forage N uptake in October 2007.

Oat planting date	Manure application date	DM Yield (Mg ha^{-1})	[N] (mg kg^{-1})	N Uptake (kg N ha^{-1})
2 Aug.	None	3.6	31.9	108
"	2 Aug.	4.4	32.5	144
31 Aug.	None	1.3	38.6	50
"	31 Aug.	2.1	41.3	85
ANOVA-factorial design				
Planting Date (PD)				
2 Aug.		4.0	32.2	126
31 Aug.		1.7	39.9	67
P > F:		0.003	0.082	0.010
Manure Application (MA)				
No		2.5	35.3	79
Yes		3.3	36.9	115
P > F		0.210	0.699	0.080
Interaction				
PD x MA (P >F):		0.985	0.801	0.980

Table 5. Oat dry matter yield, N concentration, and forage N uptake in October 2008.

Oat planting date	Manure application date	DM Yield (Mg ha^{-1})	[N] (mg kg^{-1})	N Uptake (kg N ha^{-1})
11 Aug.	None	1.5	26.6	40
"	8 Aug.	1.7	36.5	64
4 Sept.	None	0.5	38.0	18
"	2 Sept.	0.5	32.0	16
ANOVA-factorial design				
Planting Date (PD)				
11 Aug.		1.6	31.6	52
4 Sept.		0.5	36.7	18
P > F:		0.001	0.064	0.001
Manure Application (MA)				
No		1.0	32.3	30
Yes		1.1	35.9	41
P > F		0.275	0.171	0.012
Interaction				
PD x MA (P >F):		0.388	0.028	0.012

• Dry matter and N uptake yield were considerably greater for early Aug. planting compared to early Sept.

• Manure application increased total N uptake but did not significantly affect DM yield or N concentration.

• The planting date × manure application interaction for N uptake in 2008 indicated manure increased uptake when oats were planted in Aug., but not when planted in early Sept.

• Surface residue coverage after planting corn averaged 30% for the oat treatments and 18% for the non-oat treatments (data not shown). This small difference in residue coverage was considered to not be a factor affecting corn yields.

Results: Mineral Soil N

Soil nitrate determined in 30-cm increments to 120 cm in Nov., 2007 (wet fall) and to 90 cm in June, 2008 was markedly affected by manure application time and the oat cover crop (Fig 6 and 7).

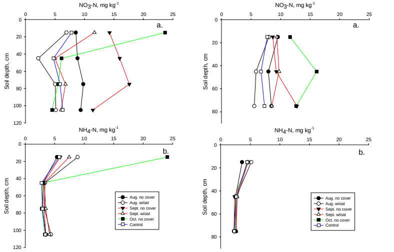

Fig. 6. Nitrate-N (a) and ammonium-N (b) in the 0 - 120 cm soil profile on 9 Nov., 2007 as influenced by time of hog manure application and presence of an oat cover crop.

Fig. 7. Nitrate-N (a) and ammonium-N (b) in the 0 - 90 cm soil profile on 16 June, 2008 as influenced by time of hog manure application and presence of an oat cover crop.

• Nitrate-N concentrations in the top 120 cm in Nov. were reduced to the same levels as the zero-N control treatment when an oat cover crop was planted following manure application (Fig. 6a).

• Nitrate was leached to 120 cm by Nov. when manure was applied in early Aug. and Sept., but not below 30 cm when applied in Oct. (most remained as ammonium-N) (Fig. 6a and 6b).

• By June, 2008, nitrate concentration in the 90-cm profile was greatest when manure was applied in Oct. and lowest when oats was planted in Aug. (Fig. 7a).

Soil nitrate determined to 90 cm in Nov., 2008 and June, 2009 was markedly influenced by manure application time and the oat cover crop (Fig. 8 and 9).

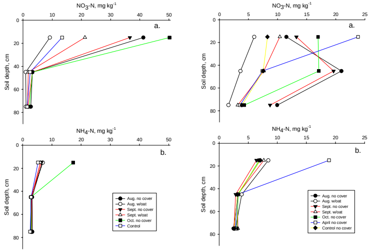

Fig. 8. Nitrate-N (a) and ammonium-N (b) in the 0 - 90 cm soil profile on 3 Nov., 2008 as influenced by time of hog manure application and presence of an oat cover crop.

Fig. 9. Nitrate (a) and ammonium (b) in the 0 - 90 cm soil profile on 15 June, 2009 as influenced by time of hog manure application and presence of an oat cover crop.

• Nitrate remained in the top 30 cm in early Nov. for all manure treatments. Nitrate-N concentrations were greatest for the three manure treatments without oats and lowest for the Aug. manure application with an oat cover crop (Fig. 8a).

• By June, 2009, nitrate from the Aug. and Sept. manure applications had leached to the 60–90 cm depth. Nitrate from the Oct. and April applications was greatest in the 30–60 cm and 0–30 cm depths, respectively. Nitrate concentrations throughout the profile were lowest for the oat cover crop treatments (Fig. 9a).

• Ammonium-N concentrations in the 0–30 cm layer were significantly greater in Nov. and June for the Oct. and April applications, respectively (Fig 8b and 9b).

Results: Corn Yield and N Uptake

Corn yields and total N uptake shown in Table 6 were significantly influenced by manure application date and presence of the oat cover crop in both years.

Table 6. Corn grain yield and total N uptake in 2008 and 2009 as influenced by time of manure application and an oat cover crop.

Manure treatment: Target appl. date	Avail. N rate 2007-08 (kg N ha^{-1})	Avail. N rate 2008-09 (kg N ha^{-1})	Oat cover crop	Grain yield 2008 (Mg ha^{-1})	Grain yield 2009 (Mg ha^{-1})	Total N uptake 2008 (kg N ha^{-1})	Total N uptake 2009 (kg N ha^{-1})
1 Aug.	166	133	None	13.0	13.2	161	165
1 Aug.	166	133	Yes	10.8	8.8	123	91
1 Sept.	165	99	None	13.4	13.3	168	160
1 Sept.	165	99	Yes	12.7	11.4	151	125
1 Oct.	142	161	None	14.0	14.0	182	187
1 Nov.	143	88	None	13.0	12.7	183	139
15 Apr.	161	134	None	14.0	13.7	191	180
None	0	0	Yes, 1 Aug.	9.1	5.5	98	52
None	0	0	Yes, 1 Sept.	10.3	6.5	113	63
None	0	0	No	11.2	9.9	136	99
ANOVA – RCB design all treatments							
P > F:				0.001	0.001	0.001	0.001
LSD (0.10):				1.4	0.9	20	17
CV (%):				9.4	6.7	10.5	10.2
Orthogonal comparisons							
Target appl. date (TAD)							
1 Aug.				11.9	11.0	142	128
1 Sept.				13.1	12.4	159	142
P > F:				0.044	0.011	0.021	0.130
Cover crop (CC)							
No				13.2	13.2	164	162
Yes				11.9	10.1	137	108
P > F:				0.033	0.001	0.002	0.001
TAD x CC interaction							
P > F:				0.149	0.014	0.140	0.051

• Grain yield and total N uptake were significantly greater when manure was applied in Sept., due to greater leaching losses for manure applied in August and greater uptake by oats when planted in August.

• Planting an oat cover crop near 1 Aug. and 1 Sept. significantly reduced corn yield and total N uptake on both the manured plots and the zero-N control plots.

• Grain yields and total N uptake were reduced similar amounts (2.2 Mg ha^{-1} and 38 kg N ha^{-1}) in 2008 for the manured and zero-N plots when oats were planted 1 Aug. Yield and uptake reductions were less similar when oats were planted 1 Sept.

• Grain yields in 2009 were reduced similar amounts (4.4 Mg ha^{-1}) for the manured and zero-N plots when oats were planted 1 Aug. When planted 1 Sept., grain yields were reduced less on the manured plots (1.9 Mg ha^{-1}) than on the zero-N plots (3.4 Mg ha^{-1}), indicating manure-N offsetting soil N removal by the oats.

• The interaction between manure application date and cover crop in 2009 indicated grain yield and total N uptake were not different between 1 Aug. and 1 Sept. manure application dates when an oat cover crop was not planted but both were significantly reduced when oats was planted in August (greater oat growth) compared to September.

Conclusions

• Oat growth and N uptake can be substantial when planted in early Aug.

• Oats can sequester large amounts of N. How much is in the root mass?

• Substantial leaching of nitrate below 90 cm can occur (2007-08) when liquid hog manure is applied in Aug. or early Sept.

• Corn yields can be reduced considerably when an oat cover crop is established in Aug. or early Sept. even when an adequate rate of hog manure was applied.

Recommendations

• If an oat cover crop is desired, do not plant earlier than 25 Aug. Supplemental fertilizer N must be spring applied when an oat cover crop is grown even if "adequate" manure N was fall applied.

• Late fall and early spring manure applications are preferable to Aug. and Sept. applications with or without a cover crop.

Acknowledgement

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