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Coupling Manure Injection with Cover Crops to Enhance Nutrient Cycling

Jeremy W. Singer
U.S.D.A., jeremy.singer@ars.usda.gov

Cynthia A. Cambardella
U.S.D.A.

Thomas B. Moorman
U.S.D.A.

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Jeremy W. Singer, Research Agronomist, USDA-ARS National Soil Tilth Lab.

Cynthia A. Cambardella, Research Soil Scientist, USDA-ARS National Soil Tilth Lab.

Thomas B. Moorman, Supervisory Research Microbiologist, USDA-ARS National Soil Tilth Lab.

Introduction

Large-scale hog (*Sus scrofa*) production is a major agricultural enterprise in the Midwest. Large numbers of confined hogs produce about 50 million tons per year of swine manure in Iowa alone. Rapid expansion of concentrated animal feeding operations (CAFOs) has resulted in increased concentrations of manure nutrients in surface waters which contribute about 15% of the total nitrate load in the Mississippi River Basin. Producers are being encouraged to develop manure management practices that fulfill crop production requirements, while minimizing the potential for environmental pollution.

The most commonly used manure management practice in the Midwest involves fall application to land where corn (*Zea mays* L.) will be grown in the subsequent growing season. Fall planted annual cover crops can capture manure nutrients and immobilize them in plant biomass, subsequently reducing the potential for nutrient loss through run-off or leaching. Decomposition of cover crop residue the following spring may help synchronize manure N availability and corn N uptake, improving nutrient-use efficiency within the crop rotation.

Description of experiment

We conducted experiments to evaluate the effects of integrating a cereal rye (*Secale cereale* L.)/ oat (*Avena sativa* L.) cover crop with liquid swine manure application on retention of manure N in a corn-soybean [*Glycine max* (L.) Merr.] cropping system. Our objectives were to compare soil N changes after manure application with and without a cover crop and to evaluate cover crop and soil N response for three manure-N rates. Target N rates for manure application were 0, 100, 200, or 300 lb N/acre. Liquid swine manure was injected about six to eight weeks after a 70% rye/30% oat cover crop mixture was drop-seeded in soybean (Table 1). Manure was injected to a depth of 8 inches using a narrow-profile knife. We measured cover crop shoot biomass and N and P uptake in mid-November and mid-April following manure injection. Surface soil (0-8 in) inorganic N in the manure injection band was quantified every week for up to 6 weeks after manure application and in the following spring before and up to 6 weeks after killing the cover crop prior to corn planting. Soil profile (to 48 inches in 8 inch increments) inorganic N was also quantified before manure application in the fall and before the cover crop was killed the following spring. Late-spring soil nitrate analyses were used to determine the sidedress N rate in corn. Corn grain yield data were measured each fall.

Table 1. Field operations conducted from 2005-2007 in two fields at the Iowa State University Agronomy and Agricultural Engineering Research Farm near Ames, IA.

Field Activities	Dates
Cover crop seeded	8/31/05 and 9/8/06
Deep soil cores-fall	10/5/05 and 10/13/06
Manure applied	10/11/05 and 10/25/06
Surface soil cores-fall	10/11-11/22/06 and 10/25-11/16/06
Deep soil cores-spring	4/14/06 and 4/18/07
Cover crop killed	4/18/06 and 4/20/07
Surface soil cores-spring	4/27/06 and 5/1-6/7/07

Results and Discussion

Soil inorganic nitrogen

Surface soil nitrate-N concentrations were more than 30 times higher in the fall of 2005 than in 2006. Nitrate-N was significantly lower under the rye/oat cover crop at 22 days after manure application in the fall of 2006 (0.8 ppm with cover crop; 3.2 ppm without cover crop), but in 2005, the difference was not apparent until 42 days after manure application (56.0 ppm with cover crop; 89.0 ppm without cover crop). September and October were significantly warmer and drier in 2005 than in 2006. Soil nitrate-N production increases with increasing temperature and nitrate-N leaching potential increases with increasing rainfall. Therefore, significant amounts of soil nitrate- N were probably lost from the top 8 inches of soil in 2006 compared to 2005. The rye/oat cover crop reduced nitrate-N in the surface soil and nitrate-N leaching beneath the manure band measured in April of 2006 (Fig. 1). Total soil profile inorganic N content was positively related to manure N application rate and was significantly lower under the rye/oat cover crop (Table 2).

Table 2. Total soil profile inorganic N to 4 ft. in the spring of 2006 following liquid swine manure injection the previous fall with and without a rye/oat cover crop (CC).

Treatment	Inorganic N
	—lb N ac^{-1}—
No CC, No Manure	92 bc†
CC, No Manure	47 c
Manure @ 200 lb N/ac	358 a
CC+manure @100 lb N/ac	159 bc
CC+manure @200 lb N/ac	202 b
CC+manure @300 lb N/ac	219 b
LSD (0.05)	137

† Means followed by the same letter are not different at 95%.

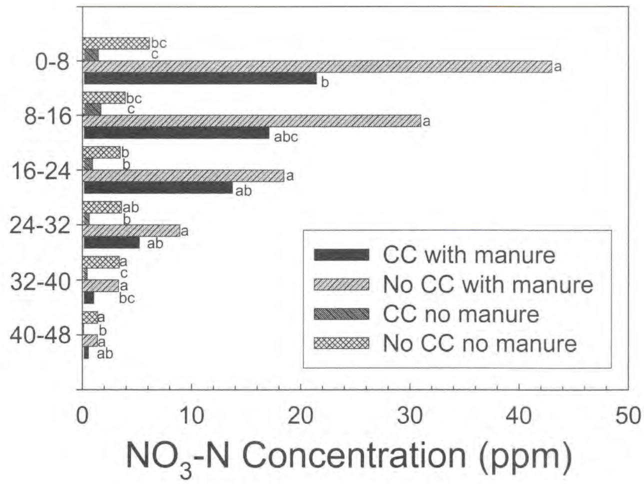

Figure 1. Soil profile nitrate-N concentrations under the manure injection band on April 14th 2006 following fall injection of liquid swine manure at a target manure N injection rate of 200 lb/ac in treatments with and without a rye/oat cover crop (CC). Horizontal bars followed by the same letter within a sampling depth are not different at 95%.

Cover crop biomass and nutrient uptake

Average cover crop shoot biomass was greater in the spring (1201 lb/ac) than the fall (268 lb/ac) both years (Table 3). Cover crop shoot biomass was greater in the no manure treatment in the fall of 2005 compared to the cover crop treatments with manure injection. In the fall of 2006, Cover crop shoot biomass was similar among the no manure, 200, and 300 lb manure N/ac treatments. Injecting at least 200 lb manure N/ac increased cover crop shoot biomass in the spring of 2006 compared to the no manure control and the 100 lb manure N/ac treatment, but no difference in shoot biomass among treatments was detected in the spring of 2007. Fall cover crop N and P uptake was not significant in the fall of 2005 and averaged 11 lb N and 1 lb P uptake/ac. In the fall of 2007, P uptake was less than 1 lb/ac. Nitrogen uptake was similar in the no manure cover crop treatment and the 200 lb manure N/ac treatment (6.4 lb N/ac). Nitrogen and P uptake after application of at least 200 lb manure N/ac was greater than the no manure cover crop control in the spring of 2006 (34.7 vs. 76.4 lb N/ac and 6.9 vs. 12.6 lb P/ac). In the spring of 2007, a similar response was observed for N (29.0 vs 43.4 lb N/ac in 2007), but P uptake was only greater than the no manure cover crop treatment after injection of 300 lb manure N/ac.

Conclusions

We have demonstrated that a rye/oat cover crop reduces soil inorganic N after liquid swine manure injection. Cover crop impacts on soil N are observed within a month after application and persist into the following spring. Cover crop N uptake was higher than the no manure cover crop control in the spring when at least 200 lb manure N/ac was applied. These results quantify the potential for cover crops to enhance plant nutrient uptake and reduce N leaching potential in farming systems utilizing manure. Future research will investigate the fate of manure N and cover crop nutrient availability for subsequent rotation crops.

Table 3. Cover crop (CC) shoot dry matter, N uptake, and P uptake in the fall and spring of two growing seasons following liquid swine manure injection at different target N rates near Ames, IA. A rye (70%)/oat (30%) cover crop was drop-seeded in soybean prior to soybean leaf drop in August of 2005 and 2006.

	Shoot dry matter	N uptake	P uptake
Fall 2005		lbs acre^{-1}	
CC only	479	11.7	1.3
CC+manure @100 lb N/acre	324	10.2	0.9
CC+manure @200 lb N/acre	308	9.9	0.9
CC+manure @300 lb N/acre	360	12.5	1.1
P > F	0.01	0.38	0.15
LSD (0.05)	66	NS†	NS
Spring 2006			
CC only	1326	34.7	6.9
CC+manure @100 lb N/acre	1402	51.0	8.5
CC+manure @200 lb N/acre	1885	77.3	13.2
CC+manure @300 lb N/acre	1738	75.4	11.9
P > F	0.01	< 0.01	< 0.01
LSD (0.05)	244	6.4	1.5
Fall 2006			
CC only	186	6.5	0.24
CC+manure @100 lb N/acre	133	4.7	0.29
CC+manure @200 lb N/acre	186	6.2	0.25
CC+manure @300 lb N/acre	164	5.5	0.22
P > F	0.02	0.02	0.01
LSD (0.05)	24	0.8	0.03
Spring 2007			
CC only	805	29.0	4.9
CC+manure @100 lb N/acre	685	31.3	4.2
CC+manure @200 lb N/acre	799	38.5	5.2
CC+manure @300 lb N/acre	969	48.3	6.5
P > F	0.13	0.01	0.03
LSD (0.05)	NS	8.3	1.0

†NS = not significant at P < 0.05.