RESEARCHREPORT

ENVIRONMENT

Title: Swine manure applications for soybean production – environmental and pathological implications – NPB #06-118

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Industry Summary

Environmental concerns regarding the application of nitrogen containing manure to soybean fields have been raised recently across the Corn Belt. The concern is that because soybeans are leguminous plant species (able to fix atmospheric nitrogen) application of supplemental nitrogen may result in an increase in the amount of nitrate-nitrogen that may be lost to the environment and negatively impact water quality. Additionally, some research has shown that application of organic amendments may have beneficial impacts on soil-borne pathogens. The purpose of this research was to determine the potential threat of swine manure application to water quality by monitoring soil nitrate levels throughout the growing season and to determine if some benefit may be derived from the application of swine manure to soybeans in the form of soybean cyst nematode (SCN) suppression. Findings from one year suggest that applications of manure that do not supply more than 120 pounds of nitrogen per acre should represent a minimal risk of nitrate-nitrogen loss. There is a greater risk of nitrate-nitrogen loss early, but mid- and late-season losses appear unlikely at nitrogen rates at or less than 120 pounds per acre. Soybean yields were increased when swine manure was supplied most likely as a result of supplementation of both phosphorus and potassium since the site was nearing deficient levels. Finally, the application of swine manure did decrease nematode infection level when manure was surface applied and incorporated with tillage especially at the early stages of soybean growth. The injected manure treatments on 30" centers did not show the same response suggesting that soil contact may play an important role in determining suppression.

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ABSTRACT

Recent environmental pressure has been placed on the practice of applying animal manures to fields going into soybean production because of the perceived over-application of nitrogen to a legume crop that does not require nitrogen fertilization. The objective of this study was to evaluate the impact of manure application to soybean fields on soil nitrate accumulation and soybean crop productivity. Additionally, this work was conducted to determine the impact of manure application on soil-borne pathogens specifically soybean cyst nematode. A single field experiment was established at the Western Research Station near South Charleston, OH in the spring of 2007. Liquid swine manure was applied at 3 different nitrogen (N) rates (based upon manure analysis and estimated availability) using two application methods (surface application or injection). The surface application treatments were either incorporated by tillage or left on the soil surface. Commercial fertilizer treatments (3 same N rates) were also included as positive controls. After soybean planting, soil samples were collected to measure soil nitrate to a depth of 2 feet at three different times during the growing season and after crop harvest. At two different growth stages (V4 and R1) soybean roots were collected and analyzed to determine soybean cyst nematode infection levels. Even though N application did result in higher soil nitrate levels for some treatments, applications rates that were lower (less than or equal to 120 lb N/acre) represent a lower risk of possible nitrate loss. This is especially true later in the growing season. Early in the growing season application of N supplying fertilizers did result in higher nitrate levels. This is expected when plant growth is progressing slowly and nutrient demand from the soil is low. Nitrogen supplied via manure and commercial fertilizer resulted in larger N uptake than the controls at the later stages of growth. This reveals that despite the fact that soybeans can fix their own N, in the presence of soil inorganic-N soybeans will take advantage of the nitrogen rich environment by taking up nitrogen. This work also reveals that fertilization may decrease soybean cyst nematode infection although at this point the mechanism is not fully understood.

INTRODUCTION

Soybeans are leguminous plant species capable of fixing nitrogen (N) from the atmosphere to support their growth and development. Despite the fact that soybeans can fix their own N, in a soil environment rich in inorganic N they will scavenge for available N decreasing the level of root nodulation (Schmidt et al., 2000; Hesterman and Isleib, 1991). Studies conducted to measure the impact of N fertilization of soybeans reveals that crop response to commercial N fertilizer does not result in increased crop production unless soil conditions inhibit rhizobium infection (low soil pH, cool, wet soils, etc.) (Reese Jr., and Buss, 1992; Schmidt et al., 2000; Osborne and Riedell, 2006). Because soybeans are unlikely to benefit from N fertilization most Land Grant Universities do not recommend application of N containing fertilizers to soybeans because it is not economical to do so unless extraneous soil conditions exist. Manure application for soybean production can provide needed phosphorus, potassium, and additional nutrients, but because of the environmental risks associated with excessive application of N state and federal agencies have considered encouraging producers not too apply manure on soybean production ground. This could place more pressure on swine operations to identify available land for recycling manure nutrients.

Previous work has shown that soybeans can take up soil inorganic nitrogen from both manure and commercial forms of nitrogen. The most extensive work was conducted in Minnesota, but this experiment relied on post-harvest soil profile nitrate analysis to determine residual nitrate to a depth of four feet (Schmidt et al., 2000). Ohio production fields are extensively tiled (drained) to an average depth of 30 to 36 inches, and thus a single post-harvest estimate of profile nitrate may be misleading. This is especially true if the growing season has been exceptionally wet.

Organic soil amendments can have positive impacts on soil borne pathogens and plant health (Hoitink and Boehm 1999, Lazarovits 2001). In soybeans, several researchers have conducted investigations into the effects of manure applications on crop health and found that results are dependent upon the timing and amount of organic amendment applied. For example, application of compost 3 to 6 months prior to soybean planting resulted in decreased *Phytophthora* damage and increased yield in moderately susceptible cultivars (Hoitink and Schmitthenner, 1988). Swine manure has also shown some suppressive ability on soybean cyst nematode egg hatch attributed to high salt content and high concentration of organic chemicals, though SCN egg counts were increased in the fall due to manure application (Reynolds et al., 1999). However, high rates of swine manure application have also been shown to aggravate other soilborne disease problems such as white mold (Schmidt et al 2001). Thus, it is important to systematically determine how timing and rate affect disease pressure so as to not negatively offset the nutrient benefits of such applications.

OBJECTIVES

The objective of this study was to evaluate the impact of manure application to soybean fields on soil nitrate accumulation and soybean crop productivity. Additionally, this work was conducted to determine the impact of manure application on soil-borne pathogens specifically soybean cyst nematode.

MATERIALS AND METHODS

A single field experiment was established in the spring of 2007 at the OARDC Western Research Station near South Charleston, OH. Swine manure was applied at three N rates 60, 120, and 180 lb/acre assuming that one third of the organic fraction was considered plant available and the ammonium-N manure fraction was considered 75% plant available. Manure samples were collected from the pit during and after application and used to represent the average manure analysis (Table 2). Historical manure analysis was used to determine manure application rates (Table 1). Liquid swine manure was applied either as a surface treatment or subsurface injected using Dietrich shanks to a depth of 4-5 inches. All plots that received subsurface injected liquid swine manure were tilled, and the surface application treatments were either no-tilled or tilled. Tillage comprised of a single tandem offset disk pass and a single pass of a finishing tool. Liquid swine manure was applied to the soil surface treatments on April 10. Due to rainfall on April 11, the subsurface treatments were applied on April 18, and tillage was done on April 20. A randomized complete block experimental design was used with four replications. Each plot was 10 ft by 30 ft. Phosphorus and potassium were supplied at rates equivalent to the amount of P and K supplied by the manure application. Urea, triple-superphosphate, and potash were supplied to the commercial treatments. Manure analysis information is presented in Tables 1 and 2.

Soil samples were collected at three dates – June 1, June 28, and July 18, and tissue samples were collected on June 28 and July 18 (that correspond with soybean vegetative stage V4 and R1, respectively). Soil samples were collected to a depth of 24” on the first two sampling dates and to a depth of 12” on the third sampling date due to dry soil conditions. Soil ammonium-N analysis was done using the steam distillation method, and nitrate-N analysis was done using an ion selective electrode (ISE). Tissue N concentration was determined using dry combustion. To ascertain the impact of soybean cyst nematode infection of plant roots, root samples were collected when soybean tissue was collected. Root samples were partitioned and tap root weight and total root weight were determined. Roots were visually inspected to determine SCN infection levels. Statistical analysis to determine differences between treatments was done using single degree of freedom contrasts in PROC GLM in SAS (SAS, 1998).

RESULTS AND DISCUSSION

Soybean Biomass

Soybean biomass measured at V4 was only increased above the corresponding control when swine manure was injected below the soil surface (Table 4). That application method also resulted in a linear increase in soybean biomass with increasing N application rate. Soybean biomass measured at R1 was increased above the corresponding control when manure or commercial fertilizer was surface applied and subsequently incorporated via tillage (Table 5). The only application method that did not result in a linear increase in soybean biomass was the swine manure surface application with tillage. These results may be explained by the positional availability of the applied nutrients do to tillage. Application methodologies that placed the nutrient closer to the root zone resulted in improved biomass accumulation. This response was unlikely due to the actual N application, but more likely attributable to the P and K added since soil test levels were at or below established critical levels (Table 3).

Soybean Tissue Nitrogen Concentration

Soybean tissue N concentration measured at V4 increased linearly as N application rate increased for both the injected manure treatments and the commercial fertilizer treatments (Table 4). The lack of a significant difference between the control and the treatments means and a corresponding linear increase in tissue N concentration reveals that only at the high application rates were differences noted. Soybean tissue N concentration measured at R1 was increased above the corresponding control when manure was injected and when manure was surface applied and no tillage was done (Table 5). Subsequently, those same two application methods resulted in a linear increase in soybean tissue nitrogen concentration. This observation is slightly different that what was seen at the V4 stage measurements when the commercial fertilization treatments resulted in an increase in tissue N concentration.

Soybean Nitrogen Uptake

Soybean N uptake measured at V4 was increased above the control when manure was injected below the soil surface (Table 4). A linear increase in N uptake was noted when manure was injected or commercial fertilizer was surface applied and incorporated. Again, the lack of increased N uptake above the control and subsequent linear increase with increase N rate indicates that N uptake was only affected at the higher N application rates. The lack of response at this earlier growth stage is not surprising considering the small of biomass and nutrient accumulated at such early growth stages. Soybean N uptake measured at R1 was increased above the control for all application methods except when manure was surface applied and incorporated with tillage (Table 5). This may be due to positional availability of nutrients applied or the lack of when tillage was not done. All application methods resulted in a linear increase in soybean N uptake with increasing N application rate. This indicates that application of inorganic-N (or organic-N that can readily be converted to inorganic-N) results in greater N uptake by the soybean crop, reinforcing that application of inorganic-N to a leguminous crop species will be readily be taken up in lieu of N fixation.

Soybean Yield

Soybean yield was increased above the control for all treatments (Table 6). A linear increase in yield with increasing N application rate was only noted for the injected manure treatment. In all likelihood, the N application itself was not the factor that resulted in increased yield. A more plausible explanation is that the manure and commercial treatments provided P and K to a soil that was near current established critical levels (especially K). This is supported by visual assessments of treatments on July 18 when it was noted that control treatments were showing visual symptoms of K deficiency (in some plots quite severe). Dry conditions during the summer months contributed to this condition as well, but supplementation either with swine manure or commercial fertilizer decreased or removed any signs of K stress.

Soybean Cyst Nematode Root Counts

Tap root weight and total root weight were only increased above the control in a linear fashion with the application of commercial fertilizer for the first sampling date (Table 7). Nematodes infection was decreased below the control in a linear fashion when manure was surface applied and incorporated with tillage (Table 7). At the second sampling period, tap root weight and total root weight were not affected by treatment. Nematode infection level was decreased below the control treatments when manure was surface applied and incorporated with tillage or when commercial fertilizer was supplied (Table 8).

Soil Nitrate

Soil nitrate levels increased linearly at the 0-12” depth as N application rate increased across all application methodologies for the first soil sampling time (Table 9). With the exception of the injected manure treatment, all applications of nitrogen increased soil nitrate levels above that of the control. Soil nitrate levels were increased above the control for the 12-24” sampling depth when manure was surface applied and not incorporated with tillage and when commercial fertilizer was surface applied (Table 9). Those two treatments also showed a linear trend with increasing application rate.

At the second sampling date, soil nitrate levels in the 0-12” were increased above the control when manure was injected and when commercial fertilizer was surface applied and incorporated with tillage (Table

10). A linear increase in nitrate levels was observed with increasing N application rate for all treatments except when manure was applied to the surface and incorporated. At the 12-24" depth a linear increase in soil nitrate was noted when manure was injected below the soil surface (Table 10).

Soil nitrate levels at the 0-12" depth measured in late July were increased above the control when manure was injected below the soil surface and when commercial fertilizer was supplied (Table 11). A linear increase in soil nitrate level was also noted with increasing N application rate for the same two treatments.

Post-harvest soil nitrate-nitrogen measurements reveal that application of N whether manure-based or from a commercial fertilizer source did not significantly increase soil nitrate-nitrogen levels above that of the controls at either depth measured (Table 12). It should be noted, however, that when manure was injected below the soil surface and when commercial fertilizer was applied a linear increase in nitrate-nitrogen was observed. Numerically speaking, nitrogen application rates that do not exceed 120 lb N per acre apparently do not represent much risk of increasing nitrate-nitrogen loss based on post-harvest soil nitrate-nitrogen measurement.

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Table 1. Initial manure test values, sampled winter 2005.

Moisture (%)	Total N	Ammonia-N	Organic-N	P_2O_5	K_2O
	---------------------------------lbs/1000 gal----------------------------------				
95.9	42.1	29.9	12.2	21.3	25.1

Table 2. Manure analysis as applied.

Moisture (%)	Total N	Ammonia-N	Organic-N	P_2O_5	K_2O
	---------------------------------lbs/1000 gal----------------------------------				
96.7	26.1	22.7	3.3	15.9	19.4

Table 3. Initial soil test information collected in the fall of 2006.

Soil pH[a]	Available P[b] (mg/kg)	Exchangeable K[c] (mg/kg)	Organic matter[d] (%)
5.9	17	87	2.5

a-1:1 soil:water; b-Bray-Kurtz P-1; c-ammonium acetate; d-loss on ignition

Table 4. Simple effects of manure and commercial fertilizer applied on soybean dry weight, tissue N concentration, and N uptake measured at growth stage V4 on June 28, 2007.

Application method	N source	N rate (lb/acre)	Dry weight (lb/acre)	Tissue N (%)	N uptake (lb/acre)
Surface (tilled)	None	0	2940	3.5	103
Surface (no-tilled)	None	0	4029	3.5	139
Injection (tilled)	None	0	2505	3.5	87
Injection (tilled)	Manure	60	3702	3.5	128
		120	3812	3.7	140
		180	4356	3.8	168
Surface (tilled)	Manure	60	3158	3.5	109
		120	3812	3.8	135
		180	3158	3.5	113
Surface (no-tilled)	Manure	60	3376	3.7	126
		120	3158	3.6	113
		180	3812	3.4	130
Surface (tilled)	Commercial	60	3703	3.4	125
		120	2614	3.6	91
		180	4356	3.8	167
Contrasts					
Manure injected versus control			**	NS	**
Manure injected linear			**	**	***
Manure surface tilled versus control			NS	NS	NS
Manure surface tilled linear			NS	NS	NS
Manure surface no-till versus control			NS	NS	NS
Manure surface no-till linear			NS	NS	NS
Commercial surface till versus control			NS	NS	NS
Commercial surface till linear			NS	**	*

***, **, * - significant at the 0.01, 0.05, 0.1 probability levels, respectively; NS – non-significant;

Table 5. Simple effects of manure and commercial fertilizer applied on soybean dry weight, tissue N concentration, and N uptake measured at growth stage R1 on July 18, 2007.

Application method	N source	N rate (lb/acre)	Dry weight (lb/acre)	Tissue N (%)	N uptake (lb/acre)
Surface (tilled)	None	0	7296	4.3	313
Surface (no-tilled)	None	0	10890	3.9	421
Injection (tilled)	None	0	10237	4.0	411
Injection (tilled)	Manure	60	9909	4.1	411
		120	12033	4.4	528
		180	12142	4.7	565
Surface (tilled)	Manure	60	12197	4.3	530
		120	11652	4.3	505
		180	12632	4.5	564
Surface (no-tilled)	Manure	60	10237	4.1	420
		120	12088	4.3	522
		180	12088	4.5	539
Surface (tilled)	Commercial	60	11326	4.3	482
		120	16444	4.5	739
		180	16771	4.3	712
Contrasts					
Manure injected versus control			NS	**	***
Manure injected linear			*	***	***
Manure surface tilled versus control			***	NS	***
Manure surface tilled linear			***	NS	***
Manure surface no-till versus control			NS	**	NS
Manure surface no-till linear			NS	***	**
Commercial surface till versus control			***	NS	***
Commercial surface till linear			***	NS	***

***, **, * - significant at the 0.01, 0.05, 0.1 probability levels, respectively; NS – non-significant;

Table 6. Effect of manure and commercial fertilizer applied on soybean yield.

Application method	N source	N rate (lb/acre)	Soybean yield (bu/acre)
Surface (tilled)	None	0	69
Surface (no-tilled)	None	0	66
Injection (tilled)	None	0	56
Injection (tilled)	Manure	60	65
		120	75
		180	83
Surface (tilled)	Manure	60	77
		120	77
		180	77
Surface (no-tilled)	Manure	60	74
		120	80
		180	72
Surface (tilled)	Commercial	60	80
		120	79
		180	75
Contrasts			
Manure injected versus control			***
Manure injected linear			***
Manure surface tilled versus control			*
Manure surface tilled linear			NS
Manure surface no-till versus control			**
Manure surface no-till linear			NS
Commercial surface till versus control			**
Commercial surface till linear			NS

***, **, * - significant at the 0.01, 0.05, 0.1 probability levels, respectively; NS – non-significant;

Table 7. Effect of manure and commercial fertilizer applied on tap root weight, total root weight, and nematode counts at first sampling date – June 28.

Application method	N source	N rate (lb/acre)	Tap root weight (g)	Total root weight (g)	Nematode counts (/0.5g)
Surface (tilled)	None	0	1.1	2.0	15.8
Surface (no-tilled)	None	0	1.3	2.2	12.8
Injection (tilled)	None	0	1.3	2.5	12.8
Injection (tilled)	Manure	60	1.1	2.3	7.0
		120	1.1	2.8	4.3
		180	0.9	2.2	6.9
Surface (tilled)	Manure	60	1.9	3.6	3.3
		120	1.4	2.7	1.0
		180	1.1	2.2	3.5
Surface (no-tilled)	Manure	60	1.5	2.9	9.5
		120	1.0	2.1	7.5
		180	1.1	2.3	1.8
Surface (tilled)	Commercial	60	2.4	3.6	4.8
		120	2.4	4.1	12.5
		180	3.1	5.1	6.0
Contrasts					
Manure injected versus control			NS	NS	NS
Manure injected linear			NS	NS	NS
Manure surface tilled versus control			NS	NS	**
Manure surface tilled linear			NS	NS	*
Manure surface no-till versus control			NS	NS	NS
Manure surface no-till linear			NS	NS	NS
Commercial surface till versus control			**	***	NS
Commercial surface till linear			***	***	NS

***, **, * - significant at the 0.01, 0.05, 0.1 probability levels, respectively; NS – non-significant;

Table 8. Effect of manure and commercial fertilizer applied on tap root weight, total root weight, and nematode counts at first sampling date – July 31.

Application method	N source	N rate (lb/acre)	Tap root weight (g)	Total root weight (g)	Nematode counts (/0.5g)
Surface (tilled)	None	0	3.6	10.7	42.3
Surface (no-tilled)	None	0	3.1	10.2	16.3
Injection (tilled)	None	0	3.6	9.2	15.0
Injection (tilled)	Manure	60	2.7	8.4	6.6
		120	3.4	7.0	15.9
		180	2.9	8.4	14.5
Surface (tilled)	Manure	60	1.9	7.1	1.8
		120	2.7	9.0	4.0
		180	3.8	9.7	41.3
Surface (no-tilled)	Manure	60	3.5	7.2	13.8
		120	2.4	6.5	8.8
		180	3.6	7.6	7.5
Surface (tilled)	Commercial	60	2.3	7.5	4.8
		120	4.2	13.3	9.3
		180	4.7	12.2	9.8
Contrasts					
Manure injected versus control			NS	NS	NS
Manure injected linear			NS	NS	NS
Manure surface tilled versus control			NS	NS	***
Manure surface tilled linear			NS	NS	NS
Manure surface no-till versus control			NS	NS	NS
Manure surface no-till linear			NS	NS	NS
Commercial surface till versus control			NS	NS	***
Commercial surface till linear			NS	NS	***

***, **, * - significant at the 0.01, 0.05, 0.1 probability levels, respectively; NS – non-significant;

Table 9. Effects of manure and commercial fertilizer applied on soil nitrate concentrations at two depths (0-12" and 12-24") measured on June 1, 2007.

Application method	N source	N rate (lb/acre)	Nitrate-N concentration	
			0-12"	12-24"
			---------------mg/kg-------------	
Surface (tilled)	None	0	9.1	6.5
Surface (no-tilled)	None	0	10.9	6.3
Injection (tilled)	None	0	15.0	7.5
Injection (tilled)	Manure	60	13.1	8.3
		120	27.6	8.3
		180	22.8	8.0
Surface (tilled)	Manure	60	13.6	7.0
		120	20.1	7.7
		180	21.8	8.4
Surface (no-tilled)	Manure	60	16.1	7.1
		120	17.8	7.6
		180	23.0	10.4
Surface (tilled)	Commercial	60	16.0	7.1
		120	25.9	9.6
		180	29.1	9.2
Contrasts				
Manure injected versus control			NS	NS
Manure injected linear			***	NS
Manure surface tilled versus control			**	NS
Manure surface tilled linear			***	NS
Manure surface no-till versus control			**	**
Manure surface no-till linear			***	***
Commercial surface till versus control			***	**
Commercial surface till linear			***	***

***, **, * - significant at the 0.01, 0.05, 0.1 probability levels, respectively; NS – non-significant;

Table 10. Effects of manure and commercial fertilizer applied on soil ammonium and nitrate concentrations at two depths (0-12” and 12-24”) measured on June 28, 2007.

Application method	N source	N rate (lb/acre)	Nitrate-N concentration	
			0-12”	12-24”
			--------------mg/kg--------------	
Surface (tilled)	None	0	10.6	6.4
Surface (no-tilled)	None	0	6.4	5.2
Injection (tilled)	None	0	7.4	6.4
Injection (tilled)	Manure	60	7.9	6.3
		120	9.6	6.6
		180	23.4	9.8
Surface (tilled)	Manure	60	8.9	5.6
		120	15.4	10.1
		180	14.1	7.9
Surface (no-tilled)	Manure	60	10.8	6.2
		120	15.1	7.4
		180	19.0	8.0
Surface (tilled)	Commercial	60	10.7	6.1
		120	14.1	6.7
		180	17.5	8.3
Contrasts				
Manure injected versus control			**	NS
Manure injected linear			***	**
Manure surface tilled versus control			NS	NS
Manure surface tilled linear			NS	NS
Manure surface no-till versus control			***	NS
Manure surface no-till linear			***	NS
Commercial surface till versus control			NS	NS
Commercial surface till linear			**	NS

***, **, * - significant at the 0.01, 0.05, 0.1 probability levels, respectively; NS – non-significant;

Table 11. Effect of manure and commercial fertilizer applied on soil ammonium and nitrate concentrations at one depth (0-12”) measured on July 18, 2007.

Application method	N source	N rate (lb/acre)	Nitrate-N concentration (mg/kg)
Surface (tilled)	None	0	5.9
Surface (no-tilled)	None	0	5.7
Injection (tilled)	None	0	5.4
Injection (tilled)	Manure	60	7.6
		120	11.2
		180	23.3
Surface (tilled)	Manure	60	6.5
		120	7.9
		180	11.6
Surface (no-tilled)	Manure	60	6.2
		120	8.7
		180	9.1
Surface (tilled)	Commercial	60	9.0
		120	12.1
		180	19.3
Contrasts			
Manure injected versus control			***
Manure injected linear			***
Manure surface tilled versus control			NS
Manure surface tilled linear			NS
Manure surface no-till versus control			NS
Manure surface no-till linear			NS
Commercial surface till versus control			**
Commercial surface till linear			***

***, **, * - significant at the 0.01, 0.05, 0.1 probability levels, respectively; NS – non-significant;

Table 12. Effect of manure and commercial fertilizer applied on soil ammonium and nitrate concentrations at two depths (0-12” and 12-24”) measured after soybean harvest, September 2007.

Application method	N source	N rate (lb/acre)	Nitrate-N concentration	
			0-12”	12-24”
			--------------mg/kg--------------	
Surface (tilled)	None	0	7.4	4.2
Surface (no-tilled)	None	0	7.7	4.5
Injection (tilled)	None	0	6.7	4.1
Injection (tilled)	Manure	60	6.7	4.1
		120	7.4	5.4
		180	11.4	6.3
Surface (tilled)	Manure	60	8.2	4.6
		120	8.4	5.2
		180	6.9	5.0
Surface (no-tilled)	Manure	60	7.3	4.3
		120	7.1	5.0
		180	8.9	4.6
Surface (tilled)	Commercial	60	7.3	3.5
		120	11.1	4.2
		180	10.0	6.0
Contrasts				
Manure injected versus control			NS	NS
Manure injected linear			**	***
Manure surface tilled versus control			NS	NS
Manure surface tilled linear			NS	NS
Manure surface no-till versus control			NS	NS
Manure surface no-till linear			NS	NS
Commercial surface till versus control			NS	NS
Commercial surface till linear			*	*

***, **, * - significant at the 0.01, 0.05, 0.1 probability levels, respectively; NS – non-significant;