Soybean, Wheat, and Forage Subsurface Drip Irrigation using Treated Swine Effluent

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Abstract

Two experimental subsurface drip irrigation (SDI) systems have been initiated to evaluate the use of treated swine effluent on a continuous soybean/wheat crop rotation and on a forage crop. The SDI systems were installed in Duplin County, North Carolina at the location of an innovative swine wastewater treatment system. The effluent from the treatment facility will be applied to both the soybean/wheat and forage crops at agronomic nutrient rates. Treated wastewater application below the soil surface reduces the nutrient loss potential through volatilization and places nutrients in the rooting zone. Preliminary results from the first year of the soybean/wheat rotation and forage operation will be discussed.

Introduction

Animal production has expanded rapidly during the early 1990's in the eastern US. In North Carolina, the number of swine has increased from approximately 2.8 million in 1990 to more than 9 million by 1996 (USDA-NASS, 2004). This rapid expansion of animal production has resulted in greater amounts of concentrated animal waste to be utilized or disposed of in an efficient and environmentally friendly manner. It has exceeded the pace at which new innovative treatment systems have been developed, and it has resulted in the animal production industry aggressively investigating and adapting new alternative wastewater treatment technologies. Additionally, the expansion of animal production has led to fewer, more concentrated operations that are challenged to treat, utilize, and/or dispose of the waste in an environmentally friendly manner. Additional challenges and concerns from these operations are odors, ammonia emissions, and pathogens. Many new and innovative systems still rely on the final land application of treated wastewater which typically use high volume sprinkler irrigation systems.

Subsurface drip irrigation (SDI) systems can help to address some concerns about land application of treated animal effluent. The SDI systems apply effluent below the soil surface and can eliminate spray and drift from land application thereby reducing odors and ammonia volatilization. The SDI systems may also be used during periods of high wind or low temperatures when sprinkler application would not be acceptable.

Subsurface drip irrigation systems have been used in Kansas to apply beef lagoon effluent with successful results (Lamm et al., 2002). In the southeastern Coastal Plains, little research has been conducted using SDI systems for application of wastewater. The objective of this work is to determine the feasibility of and management guidelines for SDI systems applying treated wastewater in the eastern Coastal Plains.

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Methods

Site Description

The study was conducted on a 4-ha site of Autryville loamy sand (Loamy, siliceous, subactive, thermic Arenic Paleudults) in Duplin County, North Carolina. Two subsurface drip irrigation (SDI) systems (forage SDI and soybean/wheat SDI) were installed in the summer of 2003.

Forage SDI: The forage SDI system was approximately 0.53 ha. The system consisted of 36 total plots (9.6 x 9.6 m) with 9 treatments. The treatments were irrigation application amount (75 or 100% of ET), nutrient source (commercial or treated effluent), SDI lateral spacing (0.6 and 1.2 m), and also a non-irrigated treatment.

Soybean/Wheat SDI: The soybean/wheat SDI system was approximately 0.7 ha. The system consisted of 20 total plots (12.8 x 12.8 m) with 5 treatments. The treatments were irrigation application amount (100% of ET or limited application ~1.25 mm/d), SDI lateral spacing (0.6 and 1.2 m), and a non irrigated treatment. The limited irrigation treatment was designed to apply a small daily application to utilize the excess wastewater generated by the treatment system. All nutrients for the soybean/wheat SDI system were supplied with treated effluent.

In both systems, SDI laterals were installed at 0.3 m below the soil surface using two poly-hose injection shanks mounted on a tool bar. The irrigation system for each plot consisted of individual PVC pipe manifolds for both the supply and discharge. Discharge manifolds were flushed back to the adjacent lagoon. Irrigation laterals had in-line, pressure compensating labyrinth emitters spaced 0.6 m apart with each delivering 1.9 L/h.

Control System: The SDI irrigation system was controlled by a 200 GHz Pentium PC running a custom Visual Basic (VB) program. The VB program operated a digital output PCI board, an A/D input board, and a counter/timer board. The digital output board operated supply pumps and solenoid valves. The A/D input board read supply line pressures. The counter/timer board recorded flows. Float switches controlled tank levels.

Each water source had a dedicated pump and supply tank. Selected treatments could receive treated effluent and all treatments could receive well water. Screen filters were used for both water types. A media filter with sand and gravel was used to filter the treated effluent before it reached the screen filter.

Flowmeters were used on each water source as well as each treatment. Supply pressures were monitored using pressure transducers. A pressure transducer was placed before and after the screen filter for each water source.

Weather Station: A tripod mounted weather station was installed at the irrigation site. The station used a CSI data logger to measure relative humidity, air temperature, solar radiation, wind speed, wind direction and rainfall. The data logger tabulated data at 5 minute intervals. The data was downloaded daily to the irrigation control PC via broad spectrum radio.

Irrigation Scheduling: Once the weather data was received from the data logger, potential ET was calculated using a SAS program. The potential ET was then multiplied by a crop coefficient to obtain the daily ET value for the crop. The ET and daily rainfall were accumulated for the previous seven days. When the cumulative ET for the previous days exceeded the accumulated rainfall by greater than 6 mm, an irrigation event was initiated.

Wastewater Treatment System: An innovative swine wastewater treatment system was designed and tested at full-scale on a 4,400-head finishing farm as part of the Agreement between the Attorney General of North Carolina and Smithfield Foods/Premium Standard Farms to replace current anaerobic lagoons with environmentally superior technology (Vanotti, 2004). The treatment system was developed with the objectives 1) to eliminate animal-waste discharge to surface and ground waters, 2) to eliminate contamination of soil and groundwater by nutrients and heavy metals, and 3) to eliminate or greatly reduce the release of ammonia, odor, and pathogens.

The effluent treatment system consisted of three modules. The first module separated solids and liquids. The second module removed nitrogen using a combination of nitrification and denitrification. The third module removed phosphorous in the Phosphorus Separation Module, developed by USDA-ARS (Vanotti et al., 2001), and it recovered the phosphorus as calcium phosphate. This process required only small additions of liquid lime. The alkaline pH with this process reduced ammonia volatilization losses and killed pathogens. Treated wastewater was recycled to clean swine houses and for the SDI systems. The system removed 97.6% of the suspended solids, 99.7% of BOD, 98.5% of TKN, 98.7% of ammonia, and 95% of total P. Average inflow concentrations and system outflow nutrient concentrations are shown in table 1.

Table 1. Treated Effluent Characteristics.

Water Quality Parameter	Raw Flushed Manure (mg/L)	Treated Effluent (mg/L)
pH	7.6	10.5
TSS	11,051	264
BOD_5	3,132	10
COD	16,138	445
Soluble P	135	8
TP	576	29
TKN	1,584	23
NH_4-N	872	11
NO_3-N+NO_2-N	1	224

Crop Management

Soybean/Wheat: Four soybean varieties were planted on June 25, 2003 using a no-till grain drill. The four varieties were Delta Pine 7220 RR, Northrup S73 Z5 RR, Pioneer 97B52 RR, and Southern States RT6202N RR. The soybeans were harvested on November 18, 2003, using an Almaco plot combine. The soybeans were followed by wheat, which was planted on December 2, 2003. There were four varieties of wheat: Vigor Tribute, Pioneer 26R61, USG 3209, and SS FFR566. The wheat was harvested on June 29, 2004.

Bermuda Grass Forage: Bermuda grass was over sown with SS FFR535 wheat variety using the no-till grain drill on December 2, 2003. The winter cover crop was mowed after heading and bailed on May 27, 2004. Bermuda grass hay was then harvested on July 1, 2004, and August 10, 2004.

Results and Discussion

Soybean: Soybean yields were greatly influenced by the varieties (Table 2). The SDI lateral spacing appeared to have little influence on the soybean yields for most varieties studied. Water application rate had the greatest influence on yield. The 100% ET application rate consistently had higher yields than the limited and non-irrigation treatments. The non-irrigation yields were very similar to the limited irrigation treatments. The limited irrigation treatment was designed to apply a small daily application to utilize the excess wastewater generated by the treatment system. This small application appeared inadequate to move the water laterally and provide water to the soybeans between the laterals.

Table 2. Soybean yields for 2003 season.

Spacing (m)	Application Rate	Delta Pine	Northrup	Pioneer	Southern States
		(kg/ha)			
1	100% ET	2475	1728	1702	1649
1	Limited	1990	1706	1576	1296
2	100% ET	2663	2099	1876	1982
2	Limited	1754	1584	1548	1290
	Non-Irrigated	1853	1738	1191	1809

Wheat: The wheat crop yields were also dependent on the varieties (Table 3). The variety yields ranged from 52 to 1400 kg/ha with the higher yields resulting from the 100% ET water application treatments. The lateral spacing for the wheat showed more difference than the soybean crop. The 1-m lateral spacing had higher yields for all varieties. The limited irrigation treatment had similar yields for the two lateral spacings and was generally lower than the non-irrigated yields.

Table 3. Wheat yields for 2003-2004 season.

Spacing (m)	Application Rate	Vigoro Tribute	Pioneer 26R61	USG 3209	SS FFR566
		(kg/ha)			
1	ET	233	1397	811	1362
1	Limited	224	852	301	679
2	ET	153	1038	502	752
2	Limited	52	748	366	653
	Non-Irrigated	280	970	665	843

Bermuda Grass Forage: There were two Bermuda grass hay cuttings (Table 4). For this experiment, there were two water application rates, 100% and 75% calculated ET. The first cutting produced yields that appeared to be counter intuitive. The treatments using commercial fertilizer had much lower yields than the treatments with treated wastewater for both lateral spacings and for both application rates. This was partially explained by residual nutrients in the plots that were irrigated with treated wastewater during the wheat season.

Table 4. Bermuda grass hay yields for first two cuttings in 2004.

Spacing (m)	Application Rate	Fertilizer Source	First Cutting kg/ha	Second Cutting kg/ha
0.6	ET	Commercial	3831	6360
0.6	75% ET	Commercial	4195	7114
0.6	ET	Treated	6186	6792
0.6	75% ET	Treated	6229	6158
1.2	ET	Commercial	4140	4820
1.2	75% ET	Commercial	4204	6790
1.2	ET	Treated	6887	6509
1.2	75% ET	Treated	8292	6942
	Non-Irrigated	Commercial	5820	5982

For the second cutting, results for both the commercial and treated waste water treatments were similar. For this cutting, there was little difference between lateral spacing, fertilizer source, and irrigation applications. Generally, irrigated treatment yields were higher than the non-irrigated treatment. The lack of differences between the yields for the different lateral spacing could assist future designs and lower the initial cost of SDI systems by using wider lateral spacings with little yield differences.

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