Forage Subsurface Drip Irrigation using Treated Swine Effluent

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Abstract

An experimental subsurface drip irrigation (SDI) system was initiated to evaluate the use of treated swine effluent on a bermuda grass forage crop. The SDI system was installed in Duplin County, North Carolina at the location of an innovative swine wastewater treatment system. The effluent from the treatment facility was applied to Bermuda grass forage crop at agronomic nutrient rates. Treated wastewater application below the soil surface reduces nutrient loss potential through volatilization and places nutrients in the rooting zone. Results from the forage SDI system indicated that treatments receiving treated waste as their nutrient source had higher biomass yields.

Introduction

In the eastern US during the early 1990's, animal production has expanded rapidly. 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 uses high volume sprinkler irrigation systems.

Subsurface drip irrigation (SDI) systems can help 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.

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. A subsurface drip irrigation (SDI) system was installed in the summer 2003.

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 a non-irrigated control.

The SDI laterals were installed 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 well water and wastewater . A media filter with sand and gravel was used to filter the treated effluent before it reached the screen filter.

Flow meters were used on each water source as well as each treatment. Supply pressures were monitored using pressure transducers which were 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 modems.

Irrigation Scheduling: Once the weather data was received from the data logger, potential ET was calculated using a SAS program. Potential ET was then multiplied by a crop coefficient to obtain 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. Effluent grab samples were taken before each wastewater irrigation. These wastewater samples were analyzed to determine nutrients applied and to adjust subsequent wastewater applications.

Table 1. Typical 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

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, August 10, and September 21, 2004. In 2004, the Bermuda grass was over sown with wheat in December and harvested in June 2005. Bermudagrass hay was harvested on July 12, and August 15, 2005.

Results and Discussion

There were three Bermuda grass hay cuttings in 2004 and two cuttings in 2005 (Table 2). For this experiment, there were two water application rates, 100% and 75% calculated ET. The first cutting in 2004 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 spacing and for both application rates. This was partially explained by residual nutrients in the plots that were irrigated with treated wastewater during the winter wheat season.

Table 2. Bermudagrass hay yields for 2004 and 2005

			Harvest										Mean	
			1		2		3		4		5			
			Yield (kg/ha)		Yield (kg/ha)		Yield (kg/ha)		Yield (kg/ha)		Yield (kg/ha)		Yield (kg/ha)	
			Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Spacing (m)	Nutrient Source	% ET												
0	C	0	2640	583	2713	289	2786	506	6113	2071	3655	630	3582	1636
0.6	C	75	1903	460	3227	266	2372	216	5759	861	4221	195	3496	1476
		100	1738	379	2885	305	2084	484	5432	655	3809	424	3189	1425
	W	75	2825	441	2793	182	2364	416	6162	790	3872	386	3603	1472
		100	2806	1174	3081	541	2106	562	4957	1259	3910	1064	3372	1325
1.2	C	75	1907	527	3080	696	2218	771	4910	1847	3804	1326	3184	1510
		100	1878	594	2187	673	1586	527	5044	1426	3206	962	2780	1517
	W	75	3761	239	3149	650	3410	615	5354	521	4230	467	3981	920
		100	3124	695	2952	638	2515	588	5607	1708	3816	1215	3603	1460
$LSD_{0.05}$			897		740		783		1953		1211		892	

For the second and subsequent 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 irrigation treatments with wastewater typically had higher yields than those with irrigated conventional fertilizer. This may be attributed to additional small nutrient applications with the wastewater, whereas the conventional fertilizer was applied immediately after harvest. Leaching of nutrients out of the root zone for the conventional fertilizer plots may have also occurred. 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.

In addition to the yield results, the total water quantities and total nutrients applied to each treatment will be tabulated. The nutrient concentrations in the soil profile and in the pore water from suction lysimeters are being analyzed to determine the overall water and nutrient budgets for the crop.

References

Lamm, F. R., T. P. Trooien, G. A. Clark, L. R. Stone, M. Alam, D. H. Rogers, and A. J . Schlegel. 2002. Using beef lagoon wastewater with SDI. In Proc. Irrigation Assn. Int'l. Irrigation Technical Conf., Oct. 24-26, 2002, New Orleans, LA. Available from Irrigation Assn., Falls Church, VA.

USDA-NASS. 2004. Agricultural statistics database (http://www.nass.usda.gov:81/ipedb/). U.S. Department of Agriculture, National Agricultural Statistics Service, Washington, DC.

Vanotti, M.B., A.A. Szogi, P.G. Hunt. 2001. Wastewater treatment system. Patent Application Serial 09/903,620, allowed Apr. 21, 2004. US Patent & Trademark Office, Washington, DC.

Vanotti, M.B. 2004. Evaluation of Environmentally Superior Technology. Final Report for Technology Determination per Agreements Between the Attorney General of North Carolina and Smithfield Foods, Premium Standard Farms and Frontline Farmers. http://www.cals.ncsu.edu:8050/waste_mgt/smithfield_projects/phase1report04/A.9Super%20Soil%20final.pdf