APPLYING SWINE EFFLUENT WITH SDI AND LEPA SPRINKLER IRRIGATION

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ABSTRACT

A two-year study was initiated in the spring of 2000 at the Northwest Research-Extension Center, Colby, Kansas (USA) to compare the application of swine effluent through subsurface drip irrigation (SDI) and simulated low energy precision application (LEPA) sprinkler irrigation. Results suggest both methods can be successfully used, obtaining crop yields of approximately 250 bu/acre with good nutrient uptake. Averaged over the two years of the study, SDI produced 10-20 bu/acre greater than LEPA sprinklers for equivalent effluent applications. Plant uptake and residual soil nitrogen were also greater with SDI, suggesting that appreciable N-losses were occurring with volatilization or leaching with LEPA.

INTRODUCTION

The use of livestock effluent through agricultural irrigation systems can have positive or negative impacts on the environment, depending on the method and intensity of use. The effluent can also be an inexpensive fertilizer resource for crop producers, providing nutrients in a timely fashion to the crop in a readily plant-available form. Subsurface drip irrigation (SDI) has been shown to be technically feasible with beef feedlot runoff effluent in K-State research performed in western Kansas (Trooien et al., 2000; Lamm et al., 2002). The use of SDI with effluent brings many potential advantages but a scientific comparison of SDI to sprinkler (such as low-energy precision application, abbreviated LEPA) application of effluent has not been performed previously. Use of swine effluent through SDI may or may not bring real environmental advantages in the form of reduced nutrient accumulation at the soil surface or in or below the root zone. Sprinkler irrigation is currently the common practice for effluent application in the Great Plains.

The overall objective of this project was to compare the environmental, cropping, and irrigation system impacts of swine effluent applied with SDI or simulated LEPA sprinkler irrigation. The specific questions to be answered were: 1) What are the environmental impacts of swine effluent when applied with SDI or LEPA irrigation, specifically in terms of nutrient utilization and redistribution in the soil profile? 2) What are the crop impacts of swine effluent application through SDI compared to LEPA irrigation? 3) Is swine effluent use through SDI technically feasible?

METHODS

Research plots were established at the Northwest Research-Extension Center at Colby, Kansas in the spring of 2000. The study was conducted for crop years 2000 and 2001. The deep silt loam soil can supply about 17.5 inches of available soil water for an 8-foot soil profile. The climate can be described as semi-arid with a summer precipitation pattern with an annual rainfall of approximately 19 inches. Average precipitation is approximately 12 inches during the 120-day corn growing season.

Swine effluent was hauled to the site from Premier Pork, Scott City, Kansas. The logistics of hauling sizable quantities of effluent necessitated relatively small research plots. The plots were 15 ft wide accommodating 6 corn rows and 54 ft long. Buffer areas of irrigated corn (50 ft wide) surround the plot area to minimize the effect of wind and heat on the plot area. Each treatment was replicated 3 times in a complete randomized block design. Since livestock effluent can rapidly experience volatilization losses and other transformations when transferred from larger lagoons into smaller tanks, the application methodology was restricted to two 2-day application periods during mid to late June and early July. The water was hauled to the site and immediately applied during a two-day period.

The treatments were as follows:

1. SDI control treatment (No application of effluent, but SDI fertigation of commercial fertilizer, 200 lbs N/acre inseason through dripline.)
2. Application of 1 inches of effluent per year with SDI, 0.5 inch per application.
3. Application of 2 inches of effluent per year with SDI, 0.5 inch per application.
4. Application of 0.6 inches of effluent per year with simulated LEPA.
5. Application of 1 inches of effluent per year with simulated LEPA, 1 inch per application.
6. Application of 2 inches of effluent per year with simulated LEPA, 1 inch per application.

The effluent/fertigation for treatments 3 and 6 were applied in two separate periods approximately 2 weeks apart (Table 1). An application period for SDI was two consecutive daily events of 0.5 inches (1 inch in 2 days). The application period for LEPA was initiated at the same time but just consisted of a single 1 inch application. Additional freshwater irrigation was scheduled as needed using a calculated water budget approach. Weather data were collected with an automated weather station approximately 0.5 mile from the research site to schedule irrigation. SDI and LEPA irrigation capacity was limited to 0.25 inches/day that approximates full irrigation in the majority of years in Northwest Kansas. Irrigations were scheduled when the calculated soil water depletion exceeded 1 inch for a given treatment. The SDI treatments received as-needed irrigations of 0.5 inches every two days while the LEPA had 1-inch applications on a 4-day schedule. Soil water measurements were made in one ft increments to a depth of 8 ft with the neutron attenuation method on a weekly basis to determine crop water use but were not used to adjust irrigation schedules.

The plot area had 5 ft spaced raised beds with two corn rows centered on the shoulders of the bed. This is the traditional "K-State bed system for SDI" (Lamm, 2001). The driplines with a 12-inch emitter spacing were spaced 60 inches apart with an installation depth of 17 inches. Each dripline was centered between two corn rows spaced 30 inches apart on the 60 inch crop bed (Figure 1). The nominal flow rate was 1 gal/min for each 100 ft of dripline. This is a higher than typical dripline flowrate for the region, but was selected so that the application period could be minimized, thus helping to avoid further effluent losses and transformations. There were three driplines in each plot and each whole plot was 54 ft long. Each plot was instrumented with a municipal-type flowmeter (nutating disk) to record total accumulated flow. The LEPA plots also had driplines because the study area was developed in the spring of 2000. The installation period required some freshwater application, so the addition of driplines to the LEPA plots allowed equal soil water conditions at the beginning of the actual study.

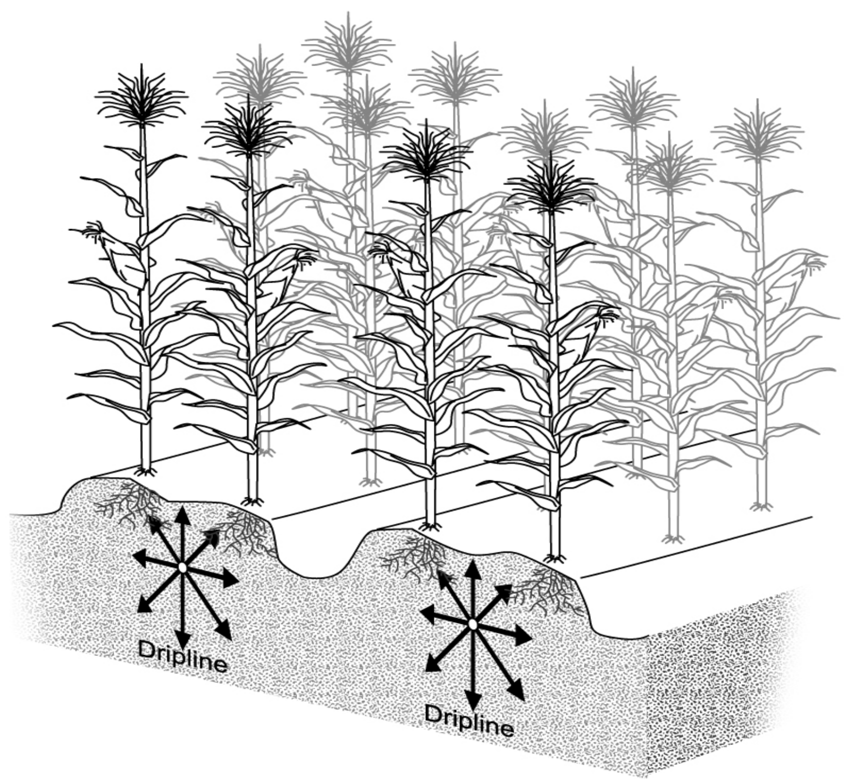

Figure 1. Physical arrangement of the subsurface dripline in relation to the corn rows.

The simulated LEPA was accomplished by applying equal amounts of water to furrow basins between adjacent pairs of corn rows. Equal amounts of water are accomplished by delivering water to each furrow basin through a small-diameter irrigation tube connected to a flow divider (Figure 2). This differs from surface drip irrigation in that the application time is much less. The application time for the 1-inch application is approximately 45 minutes, similar to LEPA irrigation, rather than as much as 20 hours for surface drip irrigation. The geometry of the irrigation delivery points for the SDI and LEPA systems allows that the edge rows in the LEPA plot do not receive an adequate irrigation amount. Periodic surface irrigation amounts were supplied to these LEPA edge rows to alleviate this problem, yet not influence the center two plot rows being utilized for sampling.

Table 1. Amounts of seasonal irrigation, applied nitrogen and the source for corn in a biological effluent study, Colby, Kansas, 2000-2001.

Irrigation System & Effluent Amount	Irrigation	------------- Nitrogen fertilizer, lbs/acre, in the indicated source -----				
	inches	Starter	Effluent 1st App	Effluent 2nd App	Irrigation	Total
Year 2000						
SDI, Control	19.5	30	0	200*****	14.6	245
SDI, 1.0 inch effluent	19.5	30	184	0	14.6	229
SDI, 2.0 inches effluent	19.5	30	184	159	14.6	388
LEPA, 0.6 inches effluent	20.0	30	110	0	15	155
LEPA, 1.0 inches effluent	20.0	30	184	0	15	229
LEPA, 2.0 inches effluent	20.0	30	184	159	15	388
** Control commercial fertilizer applied June 26, 2000*						
SDI effluent applied June 15-16, and June 29-30, 2000, 0.5 in/day						
LEPA effluent applied June 15 and June 29, 2000, 1.0 in/day						
Year 2001						
SDI, Control	18.0	30	0	200*****	13.5	244
SDI, 1.0 inch effluent	18.0	30	165	0	13.5	209
SDI, 2.0 inches effluent	18.0	30	165	147	13.5	356
LEPA, 0.6 inches effluent	18.0	30	99	0	13.5	143
LEPA, 1.0 inches effluent	18.0	30	165	0	13.5	209
LEPA, 2.0 inches effluent	18.0	30	165	147	13.5	356
** Control commercial fertilizer applied June 22, 2001*						
SDI effluent applied June 22-23, and July 5-6, 2001, 0.5 in/day						
LEPA effluent applied June 22 and July 5, 2001, 1.0 in/day						
Sum of both years 2000 - 2001						
SDI, Control		60	0	400	28	488
SDI, 1.0 inch effluent		60	349	0	28	437
SDI, 2.0 inches effluent		60	349	306	28	743
LEPA, 0.6 inches effluent		60	209	0	29	298
LEPA, 1.0 inches effluent		60	349	0	29	438
LEPA, 2.0 inches effluent		60	349	327	29	744

Pioneer[1] corn hybrid 3162 was planted at approximate seeding rates of 29,000 and 34,000 plants/acre on April 27, 2000 and April 30, 2001, respectively. This hybrid is a full season hybrid for the region with an approximately 118 day comparative relative maturity requirement. Pest (weeds and insects) control was accomplished with standard practices for the region. The corn rows were planted parallel with the dripline with each corn row approximately 15 inches from the nearest dripline. A raised bed was used in corn production. This allows for centering the corn rows on the dripline and limits wheel traffic to the furrow. This controlled traffic can allow for some shallow cultivation procedures.

Figure 2. Flow divider with tubes used to deliver irrigation water to individual furrow basins.

A starter fertilizer was band-applied at planting to all plots in the amount of 30 lbs N/acre and 45 lbs P_2O_5/acre. Additionally the fresh irrigation water was sampled to determine its contribution of N. The swine effluent was monitored and analyzed as it came out of the lagoon and as it was actually applied to insure that it was physically, chemically and biologically representative of a typical effluent application. The nutrient conditions at the time of application were the values used to compare applied to recovered nutrients.

Initial soil sampling of each plot was used to determine baseline N, P, EC and pH conditions for the plot area. There was no reason to believe that there would be any stratification in any horizontal direction at the initiation of the study, so only one sampling hole for each plot was utilized. Samples were taken in 6-inch increments in the top 3 ft and 1 ft increments in the 3-8 ft depth range (18 plots x 11 depth increments = 198 samples).

Soil sampling after harvest (Fall 2000 and 2001) was as follows for N, P, EC and pH

- LEPA: 0 to 1 ft in 3-inch depth increments, 1-3 ft in 6-inch depth increments, 3 to 8 ft in 1 ft depth increments, with horizontal locations at the middle of bed, 7.5 inches from middle of bed, corn row, 7.5 inches from middle of furrow, and corn furrow (9 LEPA plots x 5 horizontal locations x 13 depths = 585 samples)
- SDI: 0 to 2 ft in 3-inch depth increments, 2-3 ft in 6-inch depth increments, 3 to 8 ft in 1 ft depth increments at distances from dripline of 0, 3, 6, 10, 15, 20 and 30 inches (9 SDI plots x 7 horizontal locations x 15 depths = 945 samples)

The soil samples were dried and finely ground to pass through a 2 mm sieve and then sent to the KSU Soils Laboratory for chemical determinations.

Whole corn plant sampling at physiological maturity was used to determine biomass, and the N-P-K uptake of above ground dry matter. Corn grain yield and yield components were determined from hand harvesting a 6 m long section of crop row at physiological maturity.

Analyses to be discussed here include corn grain yield and yield components, nutrient uptake by crop, water use and soil profile distribution, water use efficiency, residual N and distribution patterns in soil, and comparisons of applied nutrients to those recovered in crop and soil.

RESULTS AND DISCUSSION

Irrigation and water use

Cumulative precipitation and corn evapotranspiration for the 120-day corn growing period at Colby, Kansas from May 8, 2000 through September 4, 2000 was 6.18 inches and 25.85 inches, respectively. Similar extreme drought conditions existed in 2001 with cumulative precipitation of 6.95 inches and corn evapotranspiration of 26.04 inches for the period May 13 through September 9. The long term average (1972-99) precipitation and corn evapotranspiration for the more typical 120-day period running from May 15 through September 11 is 12.61 inches and 22.56 inches, respectively. Thus irrigation requirements were much higher than normal (19.5 inches for the SDI and 20.0 inches for the LEPA irrigation in 2000 and 18.0 inches for all treatments in 2001).

Water use was significantly higher (P=0.05) for the LEPA sprinkler irrigation plots as compared to the SDI plots in 2000 averaging approximately 3 additional inches of use (Table 2). Since irrigation was only 0.5 additional inches for the LEPA sprinkler irrigation plots, this extra water use came by decreasing soil water storage. This extra water use was visually evident near the end of the cropping season because there was increased early senescence for the LEPA sprinkler irrigation plots due to decreased soil water reserves. It is not clear why the LEPA sprinkler irrigation treatments had higher total water use in 2000, but a partial reason may be increased water losses from evaporation from the soil surface or deep drainage. Drier soil surfaces with SDI can reduce soil evaporation while smaller SDI applications can also decrease deep drainage. In 2001, there were no statistically significant differences in water use between irrigation systems but LEPA treatments tended to have slightly higher water use. When averaged over the two years, water use for LEPA treatments had approximately 2 inches greater water use than SDI which was statistically significant (P-0.05).

Table 2. Yield component and water use data for corn in a biological effluent study, Colby, Kansas, 2000-2001.

Irrigation System & Effluent Amount	Irrigation inches	Applied N[1] lb/a	Grain yield bu/a	Plant Pop. plants/a	Ears /plant	Kernels /ear	Kernel Wt. g/100 krnl.	Biomass ton/a	Water use[2] inches	WUE[3] lb/acre-in
Year 2000										
SDI, Control	19.5	245	253	26136	1.04	570	41.4	10.6	30.1	472
SDI, 1.0 inch effluent	19.5	229	252	27297	0.97	595	40.6	11.4	30.4	464
SDI, 2.0 inches effluent	19.5	388	260	26717	1.04	573	41.4	10.9	29.5	492
LEPA, 0.6 inches effluent	20.0	155	237	26717	0.98	595	38.6	10.9	33.2	399
LEPA, 1.0 inches effluent	20.0	229	250	26717	0.99	603	40.0	11.1	32.8	427
LEPA, 2.0 inches effluent	20.0	388	246	27007	0.98	600	39.4	10.7	33.2	415
LSD P=0.05			NS	NS	NS	NS	1.6	NS	1.5	51
Year 2001										
SDI, Control	18.0	244	262	32960	0.97	561	37.1	11.5	28.5	517
SDI, 1.0 inch effluent	18.0	209	270	32525	0.94	598	37.4	12.4	27.4	553
SDI, 2.0 inches effluent	18.0	356	267	32525	0.94	597	37.2	11.5	28.1	531
LEPA, 0.6 inches effluent	18.0	143	214	33251	0.95	525	32.9	8.9	28.2	427
LEPA, 1.0 inches effluent	18.0	209	251	32815	0.95	557	36.9	10.2	28.7	493
LEPA, 2.0 inches effluent	18.0	356	237	33225	0.97	494	37.9	10.0	30.3	439
LSD P=0.05			22	NS	NS	63	2.6	NS	NS	53
Mean of both years 2000 - 2001										
SDI, Control			258	29548	1.01	565	39.3	11.1	29.3	495
SDI, 1.0 inch effluent			261	29911	0.96	596	39.0	11.9	28.9	509
SDI, 2.0 inches effluent			263	29621	1.00	585	39.3	11.2	28.8	512
LEPA, 0.6 inches effluent			225	29984	0.96	559	35.7	9.9	30.7	413
LEPA, 1.0 inches effluent			251	29766	0.97	580	38.4	10.6	30.8	460
LEPA, 2.0 inches effluent			241	30116	0.97	547	38.7	10.4	31.7	427
LSD P=0.05			20	NS	NS	NS	1.4	NS	1.0	35

1 Total applied N-P-K from the three sources: starter treatment at planting (30 lbs N/acre + 45 lbs/a P205), wastewater application, and the amount naturally occurring in the irrigation water (0.75 lbs/acre-inch).
2 Total of seasonal change of soil water storage in the 8 ft profile plus irrigation and precipitation.
3 Water use efficiency (WUE) is defined as grain yield in lb/acre divided by total water use in inches.

Corn yields and yield components

There were no significant differences in corn yields due to irrigation method or effluent application in 2000, though SDI yields tended to have slightly higher yields (Table 2). Grain yields were similar with commercial fertilizer or effluent for the SDI treatments at approximately 255 bu/acre. The smaller 0.6 inch effluent amount applied with LEPA had an appreciably lower grain yield (237 bu/acre), perhaps indicating some crop nutrient stress. There were no significant differences in kernels/ear, but LEPA treatments tended to have greater numbers than SDI treatments in 2000. This may be related to the extreme drought conditions which have reduced kernels/ear for SDI in some years (Lamm, 2004). Kernel weight at harvest was significantly affected (P=0.05) with the LEPA plots generally having lower kernel weight. This reduction in kernel weight may be reflecting the previously mentioned crop water stress that was apparent on the LEPA plots near physiological maturity. Final kernel weight for corn is usually set just prior to physiological maturity in mid to late September in this region (Northwest Kansas).

In 2001, grain yield, kernels/ear and kernel weight tended to be higher with SDI than with LEPA (Table 2). Grain yield averaged approximately 268 bu/acre for the two SDI effluent treatments (1 and 2 inch effluent applications) and approximately 244 bu/acre for similar LEPA treatments. Although extreme drought conditions continued in 2001, the number of kernels/ear tended greater with SDI than with LEPA. The LEPA treatment with the smaller 0.6 inch effluent application had significantly lower yields, which was further indication of the apparent combination of increased nutrient and water stress for the LEPA treatments compared to SDI.

There were no statistically significant differences in biomass at physiological maturity as affected by irrigation method or effluent application in either year although SDI tended to have greater biomass in 2001. Dry above-ground biomass was approximately 11 tons/acre at physiological maturity (Table 2).

Water use efficiency

Water use efficiency is defined as the crop yield per unit of total water use and thus can combine treatment effects related to grain yield and water use. As discussed earlier SDI yields tended higher and LEPA water use tended higher, so it was not surprising that water use efficiency was higher with SDI in both years (Table 2). Averaged over the two years of the study, SDI produced approximately 65 lbs more grain for each inch of total water use for similar effluent treatments. This is probably a combination of better nutrient utilization and less crop water stress for the SDI treatments.

Nutrient utilization and soil residual N

There were no significant differences in above-ground biomass nitrogen uptake in 2000 related to irrigation method or applied effluent but there was a slight trend for higher uptake with SDI and for increasing effluent rates with the LEPA treatments (Table 3). In 2001, there was a stronger trend towards higher crop N uptake with SDI and the lower 0.6 inch effluent application had significantly lower crop N uptake. There were no differences in plant uptake for the SDI treatments probably a good indicator of N sufficiency in the soil profile, but plant uptake increased with higher rates of effluent for the LEPA treatments, probably indicating some N losses due to volatilization or possibly leaching. The principal source of nitrogen in the swine effluent at application time is ammonium nitrogen which is subject to rapid volatilization losses when applied to the soil surface under hot weather conditions. The application of the effluent subsurface with the SDI system may have reduced or eliminated such losses.

Table 3. Applied nitrogen, plant uptake and change in residual soil nitrogen in a biological effluent study, Colby, Kansas, 2000-2001.

Irrigation System & Effluent Amount	Irrigation inches	Applied Nitrogen lbs N/a	Plant Uptake lbs N/a	Change in Residual Soil N (8 ft)			Nitrogen Balance[1] lbs N/a
				NH4-N lbs N/a	NO3-N lbs N/a	NH4-N plus NO3-N lbs N/a	
Year 2000				*Spring 2000 to Fall 2000*			
SDI, Control	19.5	245	234	21	-17	4	7
SDI, 1.0 inch effluent	19.5	229	246	23	21	2	-19
SDI, 2.0 inches effluent	19.5	388	236	5	74	79	73
LEPA, 0.6 inches effluent	20.0	155	206	13	-112	-100	49
LEPA, 1.0 inches effluent	20.0	229	225	1	-73	-72	76
LEPA, 2.0 inches effluent	20.0	388	231	4	-49	-45	202
LSD P=0.05			NS	NS	NS	NS	
Year 2001				*Fall 2000 to Fall 2001*			
SDI, Control	18.0	244	277	-39	-25	-64	31
SDI, 1.0 inch effluent	18.0	209	276	-33	-35	-68	1
SDI, 2.0 inches effluent	18.0	356	274	-8	91	83	-2
LEPA, 0.6 inches effluent	18.0	143	150	-37	-31	-67	60
LEPA, 1.0 inches effluent	18.0	209	218	-27	-46	-73	64
LEPA, 2.0 inches effluent	18.0	356	265	-32	64	31	60
LSD P=0.05			79	NS	NS	NS	
Sum of both years 2000 - 2001				*Spring 2000 to Fall 2001*			
SDI, Control		488	511	-18	-42	-60	37
SDI, 1.0 inch effluent		437	522	-10	-14	-66	-19
SDI, 2.0 inches effluent		743	510	-3	165	162	71
LEPA, 0.6 inches effluent		298	356	-24	-143	-167	109
LEPA, 1.0 inches effluent		438	443	-26	-119	-145	140
LEPA, 2.0 inches effluent		744	496	-28	15	-14	283

[1] Nitrogen balance as defined here is the total applied nitrogen minus the total of the quantity, above-ground biomass N uptake plus the soil residual nitrogen in the upper 8 ft soil profile. Positive values indicate losses primarily through volatilization or leaching, while negative values indicate increase in recovered nitrogen, probably due to mineralization that was not accounted for in the analysis.

There were no statistically significant differences in the change in residual soil N levels between any of the sampling periods, but there was a trend towards slightly lower losses of both ammonium nitrogen (NH4-N) and nitrate nitrogen (NO3-N) with SDI than with LEPA (Table 3). As effluent application increased to the highest level, soil residual N actually increased in storage for the SDI treatment (162 lbs N/a) and was only a small loss (14 lbs N/a) for the LEPA treatment when compared over the entire study period.

A comparison of the nitrogen balance of applied minus recovered nitrogen (Table 3) indicates that SDI recovered more nitrogen in plant uptake and the residual N than LEPA. When examining the total study period, the 1 inch effluent application with SDI resulted in 19 lbs additional N being recovered than was applied while the same effluent application on the LEPA treatment resulted in losses of 140 lbs N/acre. This further supports the statements about increased volatilization or leaching losses with LEPA.

At the end of the study (Fall 2001) after two years of treatments, the SDI treatments had more nitrate-N dispersed in the soil profile than the LEPA treatments and increasing levels of applied effluent also resulted in higher levels of nitrate-N (Figures 3-8.). The levels of nitrate-N for the 2-inch swine effluent with SDI (Figure 5) are tending to be excessive which indicates that effluent applications could be reduced with SDI and still maintain good corn yields (Table 2).

SUMMARY AND CONCLUSIONS

Each irrigation system produced excellent corn yields, but SDI gave significantly greater yields in 2001 and for the two-year average. Increased water and nitrogen stress may have played a combined role in reducing LEPA sprinkler yields. Plant nitrogen uptake for equivalent effluent treatments was numerically greater for SDI in both years and statistically significantly greater in 2001. Higher levels of nitrate-N existed in the soil when using the SDI method which suggests that effluent application amounts may need to be reduced when using this irrigation method. N losses for LEPA sprinkler were probably primarily ammonium-N volatilization losses due to the summer fertigation and possibly some leaching.

Environmentally, SDI has some advantages in that it can reduce odor and ammonium – N losses and still produce excellent corn yields. However, there are some logistical disadvantages that could important to the effluent generator. Some feedlots are more interested in effluent disposal than utilization. These results indicate more land resources would be needed for proper nutrient application with SDI. Additionally, the SDI system is permanently tied to the land source, whereas center pivot sprinklers can be moved to alternate disposal sites if nutrient loading of the original site becomes excessive.

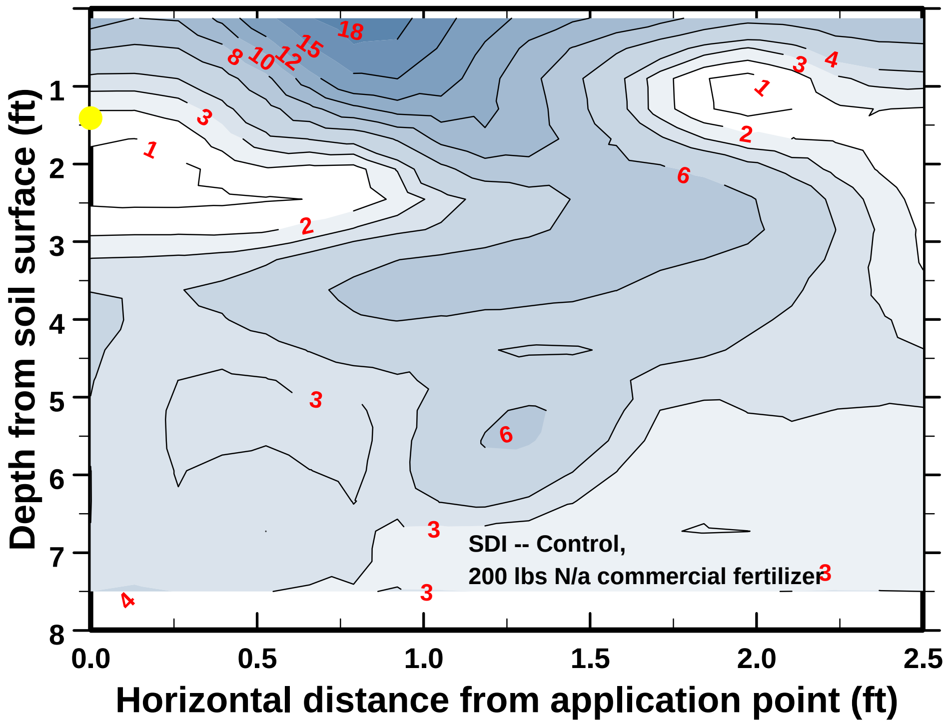

Figure 3. Nitrate-N concentrations, ppm, in the soil profile at specific depths and distances from the subsurface dripline (yellow dot) for the commercial fertilizer treatment in the fall of 2001, KSU Northwest Research Extension Center, Colby Kansas.

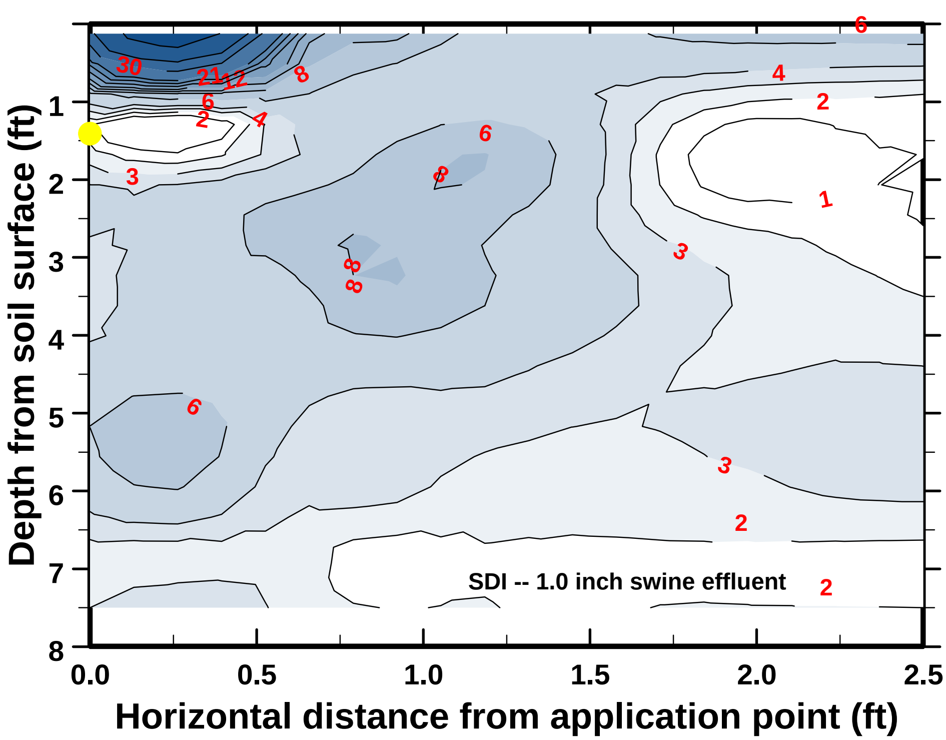

Figure 4. Nitrate-N concentrations, ppm, in the soil profile at specific depths and distances from the subsurface dripline (yellow dot) for the 1-inch swine effluent treatment in the fall of 2001, KSU Northwest Research Extension Center, Colby Kansas.

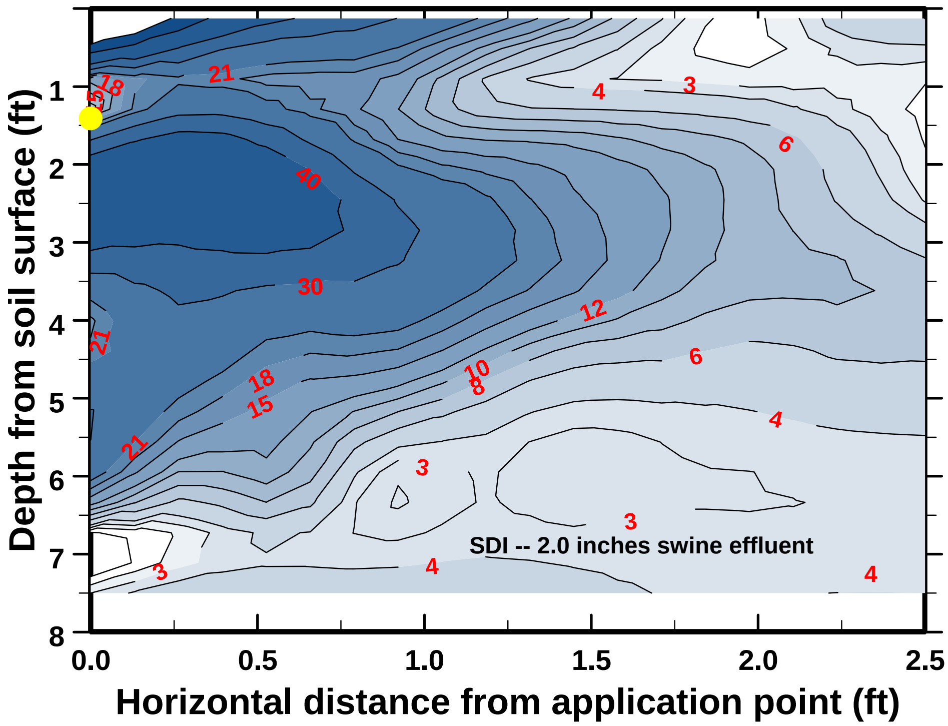

Figure 5. Nitrate-N concentrations, ppm, in the soil profile at specific depths and distances from the subsurface dripline (yellow dot) for the 2-inch swine effluent treatment in the fall of 2001, KSU Northwest Research Extension Center, Colby Kansas.

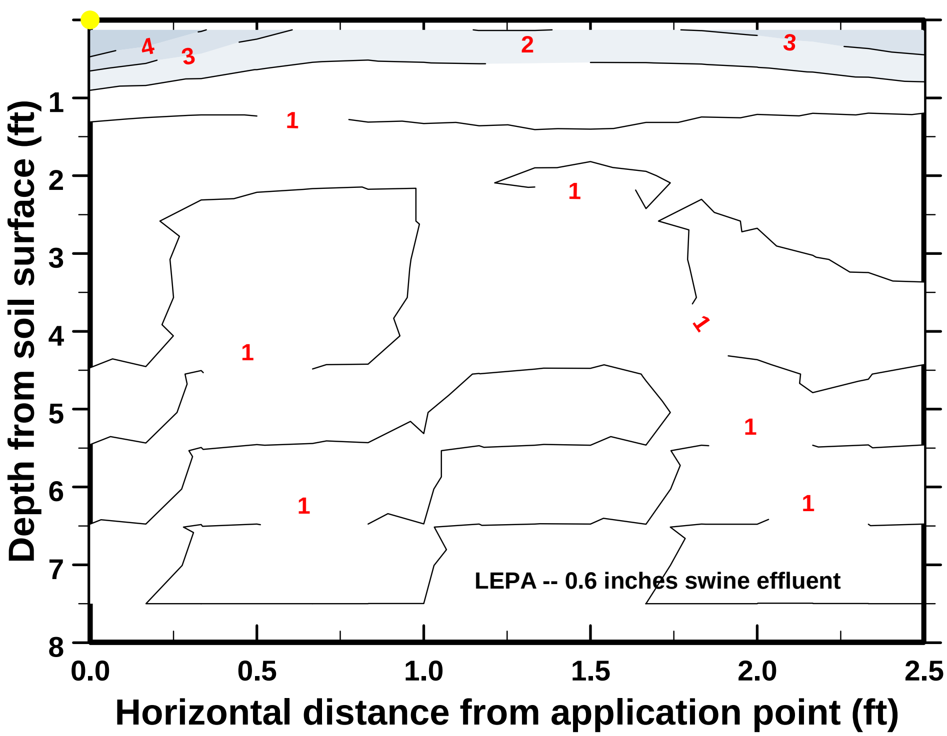

Figure 6. Nitrate-N concentrations, ppm, in the soil profile at specific depths and distances from the LEPA sprinkler (yellow dot) for the 0.6-inch swine effluent treatment in the fall of 2001, KSU Northwest Research Extension Center, Colby Kansas.

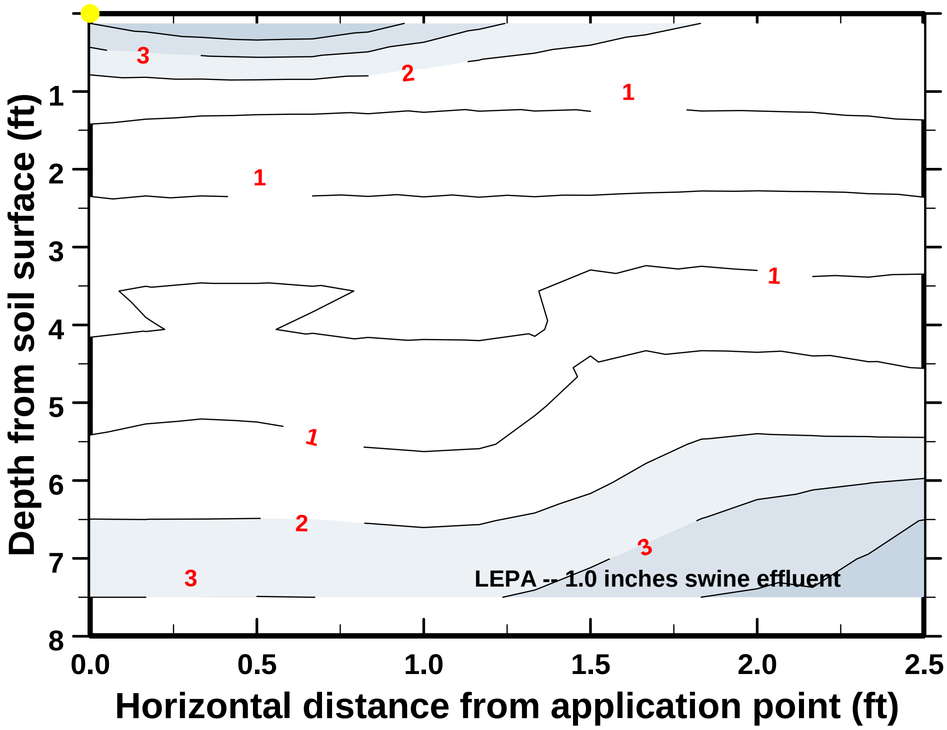

Figure 7. Nitrate-N concentrations, ppm, in the soil profile at specific depths and distances from the LEPA sprinkler (yellow dot) for the 1.0-inch swine effluent treatment in the fall of 2001, KSU Northwest Research Extension Center, Colby Kansas.

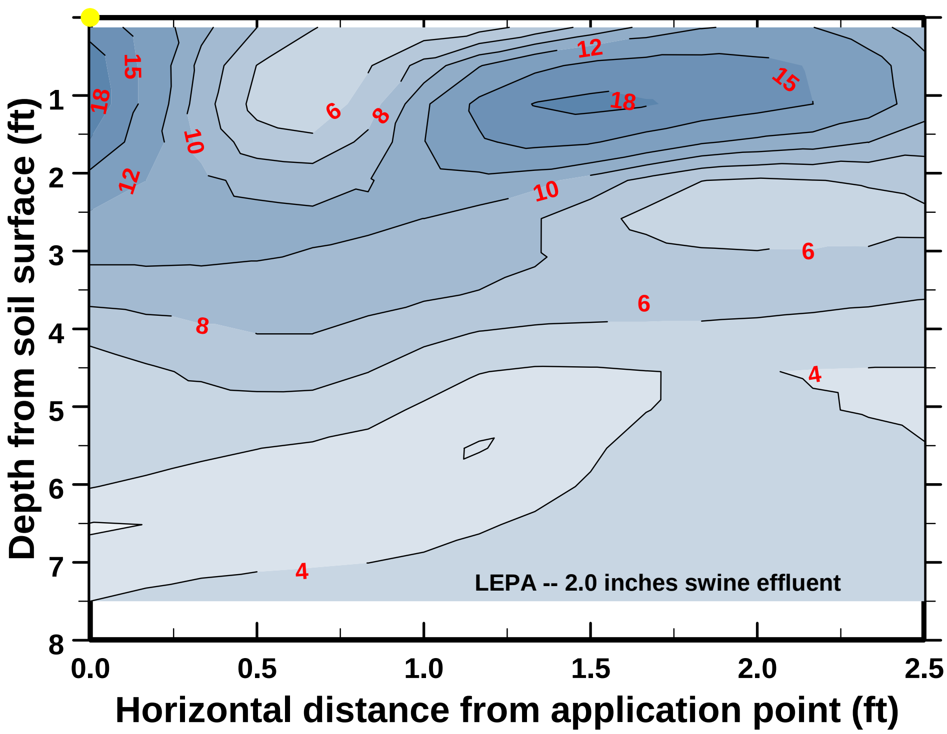

Figure 8. Nitrate-N concentrations, ppm, in the soil profile at specific depths and distances from the LEPA sprinkler (yellow dot) for the 2.0-inch swine effluent treatment in the fall of 2001, KSU Northwest Research Extension Center, Colby Kansas.

REFERENCES

Lamm, F. R. 2001. K-State's Permanent Bed System for SDI. Available at http://www.oznet.ksu.edu/sdi/Reports/2001/Kbed.pdf

Lamm, F. R. 2004. Comparison of SDI and Simulated LEPA Sprinkler Irrigation for Corn. In Proc. Irrigation Assn. Int'l. Irrigation Technical Conf., November 14-16, 2004, Tampa, FL. Available from Irrigation Assn., Falls Church VA. IA Paper No. IA04-1098. pp 475-485. Also available at http://www.oznet.ksu.edu/sdi/Reports/2004/LS100104.pdf

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 effluent with SDI. In Proc. Irrigation Assn. Int'l. Irrigation Technical Conf., October 24-26, 2002, New Orleans, LA.. Available from Irrigation Assn., Falls Church, Virginia. 8 pp. Also available at http://www.oznet.ksu.edu/sdi/Reports/2002/MWIAPaper.pdf

Trooien, T.P., F. R. Lamm, L. R. Stone, M. Alam, D. H. Rogers, G. A. Clark, A. J. Schlegel. 2000. Subsurface drip irrigation using livestock effluent: Dripline flow rates. App. Engr. in Agr. 16(5):505-508. Also available at http://www.oznet.ksu.edu/sdi/Reports/2000/SDILWaste.pdf

[1] *Mention of tradenames is for informational purposes and does not constitute endorsement of the product by the authors or Kansas State University.*

This paper was first presented at the 27th Annual International Irrigation Association Exposition and Technical Conference, San Antonio, Texas, November 5-7, 2008. Paper No. IA06-1517. Proceedings available on CD-Rom from Irrigation Association, Falls Church, Virginia

Contribution No. 07-56-A from the Kansas Agricultural Experiment Station.