MANAGING SWINE EFFLUENT APPLICATIONS UNDER IRRIGATED CONDITIONS IN NORTHEAST COLORADO

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INTRODUCTION

Waste water and manure produced by swine confinement operations can be a valuable source of nutrients for crop production. However, when these wastes are used under irrigated conditions, there is a significant potential for nutrient runoff or leaching to occur. In Colorado, nitrate (NO_3-N) contamination of groundwater is considered the greatest water quality hazard from confined animal feeding. Nitrate leaching depends on a number of site-specific factors, such as soil texture, soil moisture, waste application rate, source of waste, precipitation, and rate of N availability in the manure or waste water. The unique aspects of eastern Colorado agriculture and the recent influx of new swine operations has prompted a need for unbiased research data on managing swine effluent applications to cropland.

Soil application of manure is the most sensible way to recycle these materials because it helps to build and maintain soil fertility, improves soil tilth, and increases soil water-holding capacity. Environmental issues, consumer preference, and the concern for sustainable agriculture have also stimulated interest in organic production. However, transportation of animal wastes much beyond production locations is costly. As a consequence, fields located near feeding operations tend to receive high rates of manure and effluent, resulting in a buildup of residual soil NO_3-N. Figure 1 explains the process of the N cycle that swine effluent or any other manure goes through from time of application on the ground.

Objectives

A 3-year study was conducted by Colorado State University to evaluate the potential impact of swine effluent application on irrigated cropland in eastern Colorado. The goal of the study was to determine if swine effluent presented any additional management difficulties as compared to commercial N fertilizer, and to determine which Best Management Practices (BMPs) are most appropriate for our conditions.

The specific objectives of this study were to:

1. Evaluate the use of swine effluent as a nutrient source for irrigated corn production,
2. Evaluate N leaching from swine effluent vs. commercial-N fertilizer under irrigated conditions,
3. Develop BMPs for using swine effluent as a fertilizer.

PROCEDURES

The study began in March of 1995 on a farmer's field in Yuma County, and continued through the 1997 crop season. A 36-acre, center-pivot irrigated field (loamy sand to sandy soil texture) was divided into three areas, each representing one replication. The treatments consisted of 3 rates of swine effluent, 3 rates of commercial-N fertilizer, and a control treatment. Effluent from a two-stage lagoon containing approximately 75 lb N/acre-inch was used to fertilize for a 180 bu/acre corn yield goal. Treatments included:

a. Control (25 lb N/Acre)
b. Low Rate (130 lb N/Acre)
c. Agronomic Rate (185 lb N/Acre)
d. High Rate (235 lb N/Acre)

Swine effluent was applied through the center pivot sprinkler system at the above-mentioned rates during the growing season up to tasseling. Plots that did not receive any effluent during the application received an equivalent amount of irrigation water. Commercial-N fertilizer was applied similarly.

An irrigation scheduling program was followed by using evapotranspiration (ET) and soil moisture data of 0-5-ft. depths. For this site, irrigation was scheduled to replenish the soil profile when 50% depletion occurred.

Measurements and Data Collection

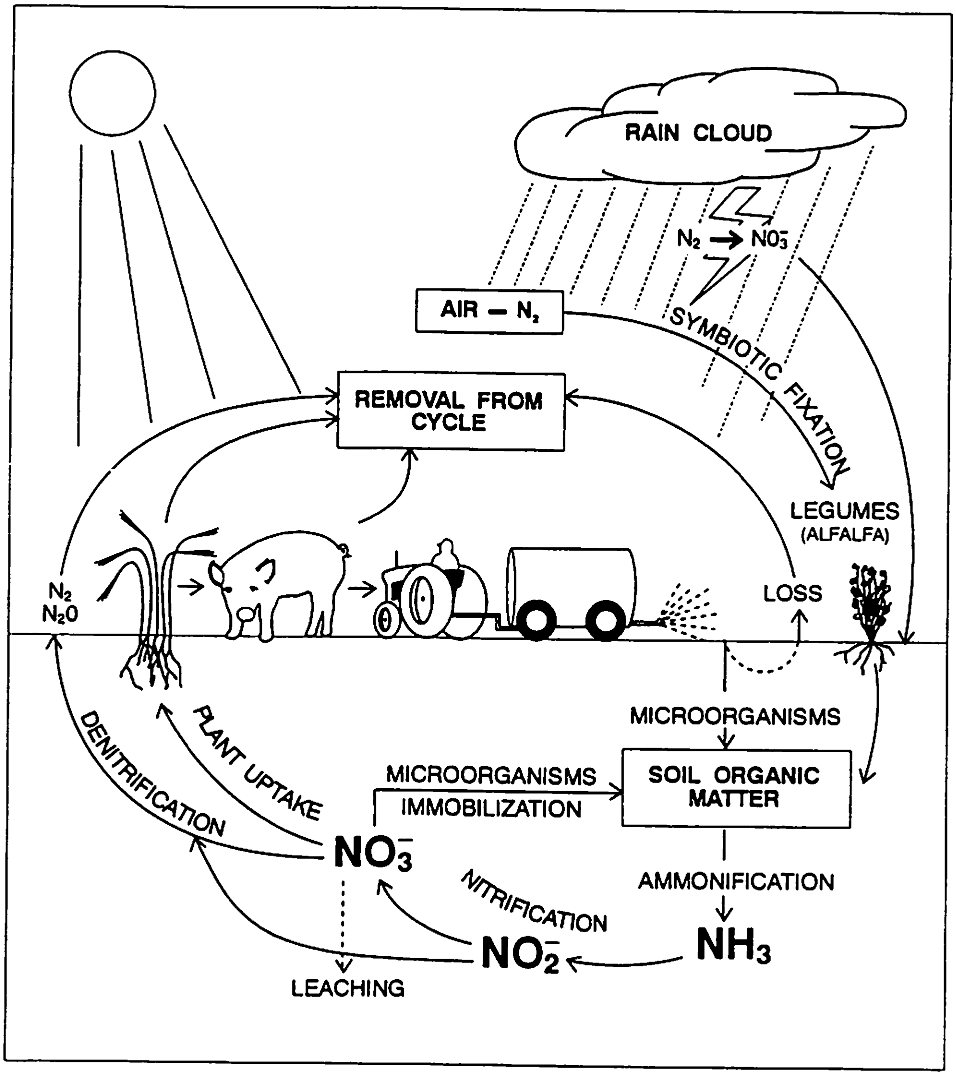
Data collected over the 3-year experiment included:

1. Swine waste composition analyses.
2. Initial soil chemical analyses for the depths 0-10 feet in 6" increments for the top foot and one foot increments to ten feet.
3. Soil moisture measurements once a week using a neutron probe for depths 0-5 feet.
4. Mid-season plant analyses that included leaf and stalk for total N and total P content.
5. Mid-season soil sampling for NO_3-N and NH_4-N for the above-mentioned depths.
6. At harvest, grain, leaf, and stalk analyses for total N and P.

7. Total N & P uptake, rate and amount of mineralized N (N release) from the effluent source.
8. Final yield for grain and dry matter.

These data were used to compare the 3 rates of swine effluent to commercial-N fertilizer for N buildup, NO_3-N leaching, and crop response.

Figure 1. The Nitrogen Cycle



Source: Saskatchewan Pork Industry "Manure Management Recommendations" B. Garth Larson, P.Ag., Quadra Management Services Ltd., June 1991

RESULTS AND DISCUSSION

Residual Soil-N Build-up Under Different Rates of Swine Effluent and Commercial-N Fertilizer:

Soil-N in the soil profile of 0-10 feet under different rates of swine effluent and commercial-N fertilizer treatments during the 1995, 1996, and 1997 growing seasons are summarized in Figures 2a, 2b, and 2c. Figure 2a shows accumulated soil-N for 0-10 feet under agronomic and high rates of effluent and control treatments. In 1995, there was greater soil-N build-up under both agronomic and high rates, as compared to the control treatment. The difference between residual soil-N under both rates (agronomic and high) was not significant (at alpha = 0.1)(alpha = 0.1 means we are 90% confident that the effluent or commercial-N fertilizer treatments caused the differences we observed), as shown in Fig 2c, and indicated by the same letter on bars in Fig 2c. Results of 1996 and 1997 show lower residual soil-N than in 1995. The reason is due to several factors: 1) N content of swine effluent was different every year; 2) yield was greater in 1996 and 1997 than in 1995, which contributes to higher plant N-uptake, and consequently, more N extraction from the soil profile, especially at the top 4 feet (Tables 1, 2, & 3).

Residual soil-N under commercial-N fertilizer agronomic and high rates shows a similar trend to swine effluent rates. However, the high rate of commercial-N fertilizer shows high residual soil-N as compared to the control and agronomic rates in 1995 and 1997. The comparison of commercial-N fertilizer rates shows significant residual soil-N, as compared to the effluent at similar application rates (at alpha = 0.1)(Fig. 2c). After 3 years of commercial-N fertilizer application, residual soil-N was significantly higher under the high rates (high rate). In contrast, residual soil-N under the different effluent application rates was not substantial (Fig. 2c). Therefore, after 3 years of swine effluent application, residual soil-N is highly related to the N content of swine effluent content at the time of application, the amount of N applied from the effluent, and the crop uptake patterns.

Residual Soil-N in Top 10 Feet of the Soil Profile:

Soil-N distribution in the soil profile under different swine effluent and commercial-N fertilizer application rates from 1995 to 1997 are summarized in Figure 3(a and b). Figure 3a shows soil-N (total of NH_4-N+NO_3-N) at different soil depths down to ten feet deep under the agronomic rate of both swine effluent and commercial-N fertilizer, as compared to the control treatment for 1995 to 1997. The results show no significant difference in residual soil-N buildup at the top 3 feet under the agronomic commercial-N fertilizer and effluent rates, as compared to control treatment (at alpha = 0.1). In contrast, there was a

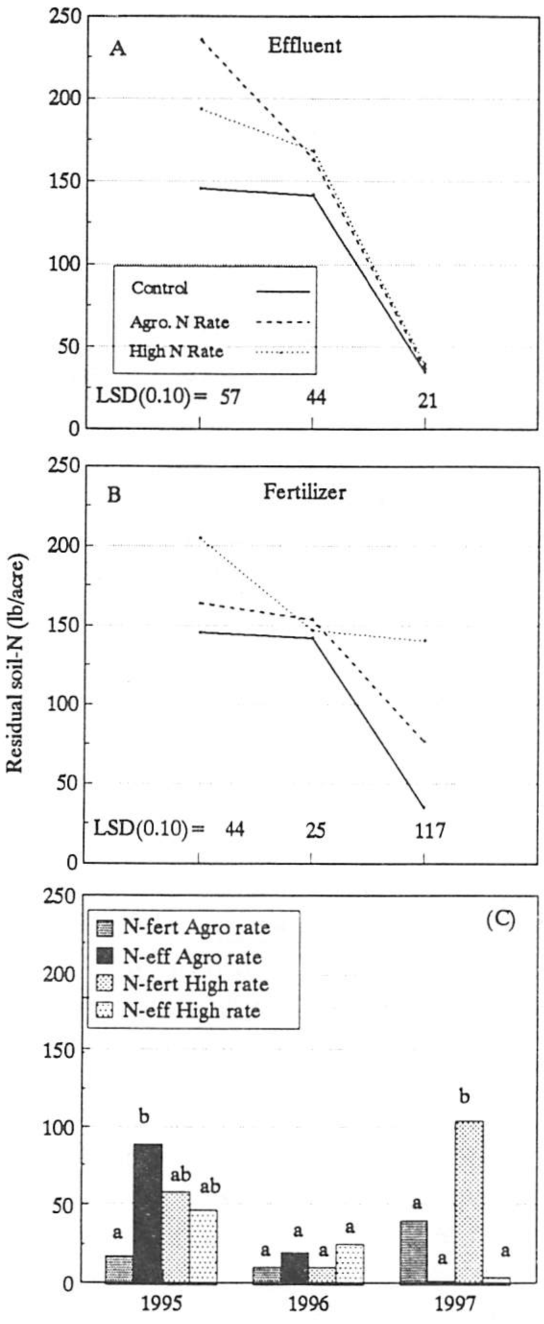


Fig. 2. Residual soil-N as (NH_4-N+NO_3-N) in the 0-10 ft profile under different application rates of (a) Effluent, (b) Commercial fertilizer, and (c) Residual soil-N of different application rates, as compared to the control. Treatments with same letters are not significantly different (at alpha = 0.1).

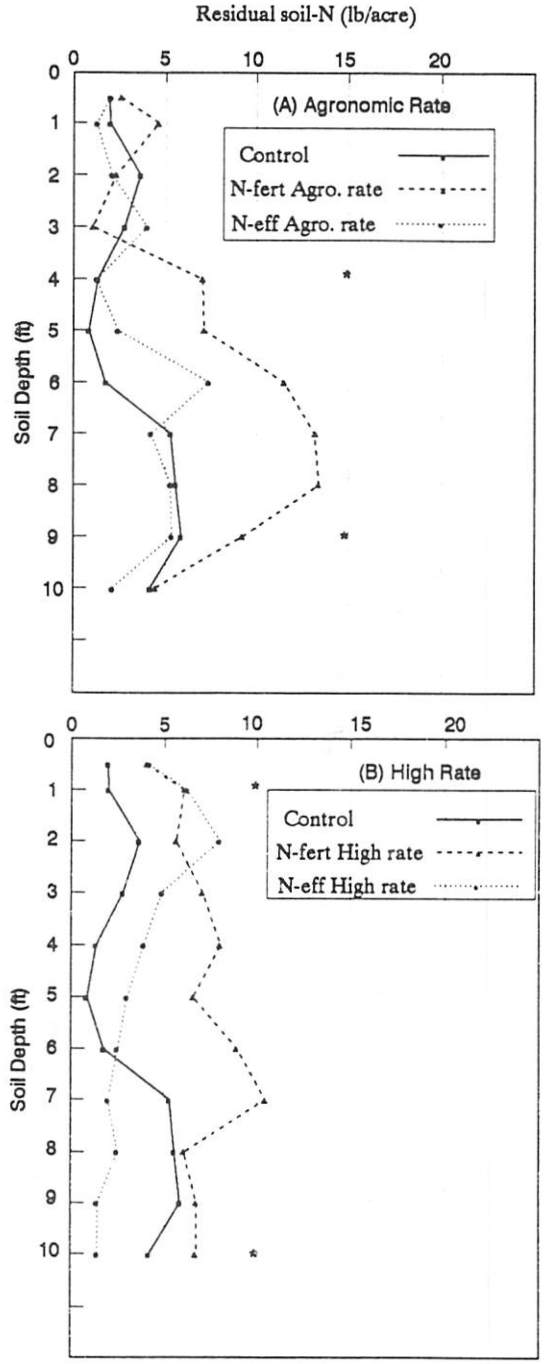


Figure 3. Residual soil-N profile after 3 years of swine effluent and commercial-N fertilizer applications of (a) Agronomic and (b) High rates. *Soil-N of different treatments at different depths between two asterisks are significantly different (at alpha = 0.1).

significant difference in residual soil-N buildup under commercial-N fertilizer agronomic rate, as compared to the effluent and control treatments for depths 4-8 feet (at alpha = 0.1). Results show no significant difference in soil-N between effluent, commercial-N fertilizer, and control treatments below eight feet.

Figure 3b shows the comparison of swine effluent and commercial-N fertilizer high rates to the control treatment for the 1995 to 1997 application period. Commercial-N fertilizer high application rate shows no significant increase in residual soil-N at the top 2-ft., as compared to effluent and control treatments (at alpha=0.1). Depth 2-3 feet show no difference in soil-N under both effluent and commercial-N fertilizer. In contrast, depths 4-10 feet show a significant difference in residual soil-N under the high rate of commercial-N fertilizer, as compared to a similar effluent application rate and control treatment.

The soil-N profile shows the potential of N buildup within the root zone and below. The results show greater residual soil-N under commercial-N fertilizer application rates, as compared to the effluent. Yield production and plant-N uptake under the commercial-N fertilizer treatment were significantly lower than those under swine effluent application rates (Tables 2 and 3), possibly explaining the difference in the soil-N accumulation.

Crop Yield Response and N & P Uptake:

Irrigated corn yield and N and P uptake, along with the rate of N applied as swine effluent and commercial fertilizer, are summarized in Tables 2 and 3. Yield performance during 1995, 1996, and 1997 under four different N application rates of both commercial and swine effluent shows greater yield response under swine effluent, as compared to commercial-N fertilizer for all years.

However, mean comparison of yield for effluent vs. commercial-N fertilizer treatments shows that the differences are not significant (alpha = 0.1). On the other hand, comparison of yields of different effluent or commercial-N fertilizer is significant for all rates, as compared to control treatment. Also, mean comparison for yields shows no statistical difference between agronomic and high rates (at alpha = 0.1). The differences in yield response were 24 - 32 bu/acre over 3 years for effluent over commercial-N fertilizer treatments.

Plant-N uptake was significantly greater under high effluent rate, as compared to the control and agronomic rate of swine effluent treatments for 1995 to 1997 (at alpha = 0.1). On the other hand, plant-N uptake under commercial-N fertilizer treatments shows significant differences between all application rates (at alpha = 0.1) during the 1995-1997 growing seasons (Table 2). Plant-N uptake under effluent treatments shows a significant increase (at alpha = 0.1), as compared to the commercial-N fertilizer treatments' N-uptake during the 1995-1997 growing seasons. Also, P-uptake shows a similar trend for swine effluent treatments over commercial-N fertilizer (Table 2).

There was also a significant difference in yields between different application rates of both effluent and commercial-N fertilizer. The results show that yield response was much greater under similar or the lesser-applied N rate under effluent, as compared to commercial-N fertilizer. This could be attributed to the additional macro- and micronutrients existing in swine effluent as shown in Table 1. The failure to achieve yield goals in 1995 and 1996 under the agronomic rate and the low yield response under the control treatment was due to early wet weather and late planting, in addition to the highly permeable sandy soil under irrigated conditions.

Table 1. Applied effluent analysis from a two-stage lagoon from finishing units in 1995-1996 and breeding units in 1997.

Constituents	Units	Values		
		1995	1996	1997
NH_4-N	mg/l	356.0	314.7	257.0
NO_3-N	mg/l	1.9	0.3	0.1
TKN	mg/l	470.0	321.3	262.9
Total N	mg/l	471.9	321.6	263.0
Total P	mg/l	100.0	64.9	45.9
Total K	mg/l	270.0	247.3	241.0
pH	---	7.1	7.7	7.6
E.C.	mmhos/cm	5.4	3.9	4.8
Dry Matter	%	0.2	0.1	0.1
Total S	mg/l	1.0	0.1	0.1
Total Ca	mg/l	130.0	91.6	72.5
Total Mg	mg/l	60.0	50.8	42.5
Total Na	mg/l	70.0	73.5	52.0
Total Fe	mg/l	1.0	2.0	0.9
Total Mn	mg/l	1.0	0.5	0.4
Total Cu	mg/l	1.0	0.3	0.2
Total Zn	mg/l	1.0	0.3	0.1
Total Al, Ni, Mo, Cd, Cr, B, Ba, Si, V-Sr, Pb*	mg/l	0.001-2.5	0.1-0.8	0.01-1.6

* Individual metal value did not exceed the range for that year.

Table 2. Total N & P uptake as affected by source of nitrogen and rate of application.

Source	1995 *Total Amount Available lb/acre	1995 Total Uptake lb/acre	1996 Total Amount Available lb/acre	1996 Total Uptake lb/acre	1997 Total Amount Available lb/acre	1997 Total Uptake lb/acre
Nitrogen:						
Effluent::						
Control	25	33.2	25	38.1	25	46.1
Low	130	76.0	130	68.0	130	108.1
Agronomic	185	110.0	185	125.1	185	141.5
High	235	136.7	235	153.5	235	198.1
Commercial-N Fertilizer:						
Control	25	33.2	25	38.1	25	46.1
Low	130	50.5	130	85.3	130	52.3
Agronomic	185	56.6	185	118.5	185	127.4
High	235	100.4	235	139.7	235	163.4
LSD (0.1)		33		27		58
Phosphorous:						
Effluent:						
Control	26.5	13.4	25.7	13.9	42.9	11.8
Low	34.4	24.0	45.2	20.0	47.2	31.2
Agronomic	45.2	26.4	78.2	33.1	71.9	31.9
High	58.0	26.6	72.1	32.4	92.2	41.0
Commercial-N Fertilizer:						
Control	26.5	13.4	32.5	13.9	49.0	11.8
Low	27.7	17.4	38.4	20.6	23.8	13.1
Agronomic	27.7	18.1	47.7	20.4	24.7	19.7
High	27.7	20.5	32.5	19.1	28.6	21.1
LSD (0.1)		7		5		10

* Total available N and P includes applied and soil available N and P.

** Differences between uptake averages greater than LSD values are significant at alpha = 0.1.

Table 3. Grain yield of irrigated corn under swine effluent and commercial-N fertilizer application rates.

Source	N Rate*	1995 Yield	1996 Yield	1997 Yield
Effluent Rates:	lb N/acre	-------- bu/acre --------		
Control	25	35	42	44
Low	130	91	68	131
Agronomic	185	115	118	180
High	235	123	136	195
Commercial Rates:				
Control	25	35	42	44
Low	130	79	85	76
Agronomic	185	94	116	131
High	235	109	112	138
LSD (0.1)**		31	26	60

* N rate as effluent or commercial-N fertilizer includes credits from soil N, O.M., starter-N, and irrigation water.

** Differences between means greater than LSD values are significant at alpha = 0.10.

CONCLUSIONS AND RECOMMENDATIONS

Several important aspects of managing swine effluents became apparent from this study. First, we found the N in swine effluent from a 2-stage lagoon was almost entirely (98%) in the ammoniacal form (NH_3 or NH_4). This is significant because ammonium-nitrogen is completely available to the crop, the same as most commercial-N fertilizers. Therefore, managing effluent-N becomes very similar to managing commercial fertilizer-N; the challenge is to apply the correct amount for the crop and to manage the irrigation water inputs to minimize leaching. Managing effluents containing predominately ammonium-nitrogen is different than managing most solid manures, where the N is largely bound up in organic forms and slowly becomes available to crops. The most challenging aspect of managing effluent may be to determine how much volatilization loss is likely to occur. Our preliminary data indicated that up to 60% of the N applied in swine effluent through center-pivot irrigation was lost to volatilization.

We also found that applying swine effluent in the fall results in greater ammonium-nitrogen (NH_4-N) loss from the root zone. Therefore, swine effluent should be applied during the growing season at rates that closely approximate crop requirements. Leaching from the root zone to the aquifer may result from over-application, but can be mitigated by controlling timing of application rates. In general, the N in swine effluent behaved similarly to commercial-N fertilizer in our studies. We found a crop yield increase of 24-32-bu/acre on the effluent treatments over the commercial-N fertilizer, but this was most likely due to the additions of other macro- and micronutrients in the swine effluent. The higher yields achieved under effluent application resulted in increased N and P uptake and reduced soil-N accumulations. As with all irrigated crop production situations in Colorado, proper irrigation water management is the key to sustaining crop yields while minimizing water quality problems.

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