IRRIGATING WITH SWINE EFFLUENT

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INTRODUCTION

Nebraska swine annually produced manure containing 40 million pounds of nitrogen. The trend toward increased concentration of animals in large production units makes it difficult to find enough available land for economical manure distribution at agronomic application rates. In Nebraska, pigs per farm have increased from 250 in 1982 to 507 in 1997. As the number of pigs per enterprise has increased, there has not been a corresponding increase in the number of acres per enterprise available for land application and crop utilization of the stored swine manure.

The goal of our research was to evaluate alfalfa as a nitrogen sink for swine effluent. Data from our experiment has shown that alfalfa receiving 600 pounds of swine effluent nitrogen per acre removed about 100 pounds more nitrogen per acre than alfalfa receiving no swine effluent. Established, irrigated alfalfa can remove more than 700 pounds of nitrogen per acre in the harvested hay (Table 4). The implication is that producers can reduce the land base for effluent distribution by more than 50% when compared to the 200 pound removal rate for corn followed by winter rye (Table 4). This could be beneficial to producers who do not have sufficient land to apply effluent at agronomic rates to corn or other row crops.

Additional advantages to alfalfa are: it covers the ground all year round which reduces the erosion potential; the nitrogen use curve is more constant through the season than for annual crops; uptake of phosphorus and potassium are relatively high; effluent application can occur at times that are not possible in a corn system; and alfalfa is deep rooted and can scavenge nitrogen from deeper in the soil than most other crops grown in Nebraska.

METHODS

A line-source sprinkler system was used to distribute a range of effluent rates to both alfalfa and corn. Figure 1 shows the distribution of the effluent and of fresh water. The experiment was designed so that the distribution patterns of both the fresh and effluent waters produce an even amount of water application. Therefore, only effluent rates changed. Rates of effluent were chosen that provided from 0 to 140% of the predicted nitrogen harvest for the corn-winter rye and alfalfa treatments. Irrigation of each crop could be controlled and was applied based on soil moisture and crop nitrogen needs with the caveat of needing to apply up to 600 lb-N per acre near the centerline.

Laboratory analysis showed that the effluent contained about 90 lbs. total nitrogen, 100 lbs. K_2O, and 10 lbs. P_2O_5 per acre-inch of water (Table 1). The goal was to apply sufficient effluent so that at the end of the growing season both the corn and alfalfa would have plot areas with an excess of applied N. In 1994, soil samples, leachate and crop harvest took place at 6 equally spaced areas across each cropping system plot for a range of 0 to 140 percent of nitrogen application versus estimated harvest removal.

At each sampling site a porous cup extractor was installed 6.5 feet in the ground (Insert, Figure 1). The soil water solution passing the cup was sampled and analyzed for nitrate. Neutron readings were recorded to determine the rate of water flow past the 6.5 foot depth. This information was used to determine the amount of nitrate leaching at each sampling site (Table 3).

The original alfalfa stand was planted in the fall of 1992 and replanted in 1993. In 1996 the corn-rye and alfalfa areas were switched. However, the gradient of increasing levels of swine effluent remained the same. In 1996, a non-nodulating alfalfa variety (Saranac) was planted along with the conventional variety and the number of subplots was reduced from 6 to 5 (Figure 1). Unlike the conventional variety, the non-nodulating isoline could not use atmospheric nitrogen for crop growth needs.

In each year, alfalfa samples were collected from each subplot using a flail-type forage harvester. Sampling protocol was designed to mimic a range of harvest management schemes. Thus, each replicate contained subplots that were harvested 3x, 4x, or 5x times per year. The 3x treatment was harvested at full bloom and the 4x and 5x at tenth bloom. The 5x treatment had the 5th harvest after a killing frost. Plant dry matter was collected from a 30 square foot area and used to estimate total dry matter production for the treatment. Laboratory analysis provided the N content in each alfalfa sample.

RESULTS

In 1994, dry matter production ranged from 9 to 10 tons of alfalfa per acre. Thus, the addition of 560 lb-N resulted in an additional ton of dry matter production (Table 2) and a slight increase crude protein of about 1.5% (data not shown). Yields were highest when the alfalfa was harvested 4 times per season at approximately 10% bloom. Apparently, the harvest after a killing frost reduced yields for the 5x treatment.

Subsurface drainage was greater than would be typical of a field managed using irrigation scheduling techniques (Table 3). This was due in large part due to near normal precipitation and below normal temperatures so little irrigation was necessary. Drainage ranged from 6 inches in plots receiving no lagoon water to 4 inches in plots receiving 560 lb-N. This reduction in drainage is attributed to the additional production (1 ton/ac) resulting from the lagoon water application.

The N concentration of soil water at the 6.5 foot depth had flow-weighted average concentrations that ranged from 4.9 ppm in plots receiving no lagoon water to 37 ppm where 560 lb-N were applied (Table 3). The acceptable N concentration is up for discussion, however, if the maximum contaminant level for drinking water of 10 ppm NO_3-N is used, our data would suggest that approximately 340 lb-N could be safely applied to irrigated alfalfa. We were not in a position to estimate losses of N to the atmosphere during and after application, but published values are typically greater than 30%. Assuming 30% application loss, the actual removal in the alfalfa dry matter would be close to 235 lb-N. This level of utilization agrees with laboratory research from Minnesota that suggests that alfalfa will preferentially fix up to 2/3 of the N removed in the forage. This happened despite N applications that would have met crop needs. Thus, a high percentage of the N contained in the alfalfa forage will continue to be fixed from the atmosphere.

Nitrate leaching losses ranged from 7 to 33 lb-N per acre (Table 3). Though a zero tolerance rule could be applied, these levels are within the range recorded for crops fertilized with commercial fertilizer. Leaching losses would be reduced if subsurface drainage could be reduced by irrigation management strategies that allow plants to lower soil water content near the end of the season. Another beneficial practice would be to leave room in the soil profile for rainfall by accounting for the deep rooting depth of the crop. Both of these practices were not possible during this research due to timely rainfall events and the need to apply 6-7 inches of lagoon water.

In 1996, the non-nodulating alfalfa nitrogen harvest was 70 percent of the nodulating alfalfa at the zero effluent rate, but equal to the nodulating alfalfa at the higher nitrogen rates. Due to it being a crop establishment year, sufficient rainfall, and the use of irrigation scheduling, the maximum nitrogen applied in

1996 was 75 lbs total nitrogen/acre. Actual N removal in the forage was within 10 lb-N per acre for the non-nodulating and nodulating isolines (Table 4).

A severe winter in 1996 caused winter kill in the experiment, so the alfalfa was replanted in 1997. Subsequent work continues to support the notion that non-nodulating alfalfa will produce forage of the same quality and quantity as nodulating alfalfa if N is applied to meet crop needs. Failure to apply sufficient N tends to reduce plant stand by allowing weed competition, and it appears to increase the potential for winter-kill in the isoline we tested. Plant breeding efforts will likely reduce the winter-kill problems.

DISCUSSION

Documenting the environmental effects of swine effluent application is the major objective of this research. Two indicators have been monitored 1) soil nutrient levels in the spring and fall and 2) nitrate leaching.

Using book-values, 9 tons of alfalfa would remove about 500 lb-N, 135 lb-P_2O_5, 540 lb-K_2O per acre. In 1994, laboratory analysis of the dry matter indicated that about 700 lb-N were removed in the forage. Field data indicate that alfalfa can remove more applied N than a more traditional crop like corn. Thus, the lagoon water can be distributed over fewer acres of land when alfalfa is used as a scavenger crop.

Soil samples taken in the spring of 1997 indicated that a buildup of both phosphorus and potassium at the higher application rates was occurring (Table 5). The phosphorus levels were increasing despite removal at rates up to 50 lb-P_2O_5 per acre greater than the application rate. Research evaluating the long term impacts of manure applications have suggested that manures high in NH_4-N can change soil pH sufficiently to allow additional phosphorus to enter the available pool from the organic pool. In addition, increased microbial activity tends to increase P mineralization rates. Both of these factors are likely present in fields where swine lagoon water is applied. Thus, long term application of swine lagoon water may need to account for the additional P in the management plan.

Potassium application was in excess of the removal rate so a buildup was anticipated. However, continued buildup of soil potassium could cause soil structure problems in the future. At some point, effluent might need to be reduced until potassium levels decrease.

Leaching of nitrate may occur when drainage through the soil profile occurs. When irrigation scheduling techniques are used correctly, drainage is held to a minimum. When rainfall is greater than crop use, drainage is inevitable. Research using commercial fertilizer applications tend to suggest that off-season losses are a definite concern in Nebraska. So even if good irrigation management is practiced, over application of N may lead to leaching losses. This is of particular significance where manure storage capacity considerations necessitate land application regardless of soil water availability, thus, increasing the risk of a drainage and N leaching event.

Application of swine effluent to alfalfa shows considerable promise based on the results of this research. Alfalfa uses large amounts of nutrients contained in animal manures and provides ample opportunities to spoon feed applications in much the same was as commercial fertilizers. Further development of the non-nodulating alfalfa isolines will enhance the value of alfalfa as a crop suitable for use in crop rotations used by animal producers.

Acknowledgments

Research funded by Burlington Northern Endowment. The non-nodulating alfalfa was donated by Joanne Lamb at the USDA Dairy Forage Laboratory in Minnesota. Previous funding for this project included support form the Nebraska Pork Producer's Council and the UNL Water Center.

Table 1. Nutrient concentrations of monthly water samples collected from the swine lagoon in parts per million. Concord, NE.

Year	No. Sample	Total N	NH_4-N	P_2O_5	K_2O	S	Zn	Na	Ca	Mg
		-------	-------	-------	ppm	-------	-------	-------	-------	-------
1993	12	400	310	9.8	401	4.1	0.13	103	59	23
1994	12	420	371	12.8	554	2.1	0.14	114	65	26
mean		410	340	11.3	472	3.1	0.13	108	62	24

Table 2. Mean dry matter yields as affected by swine effluent application in1994. Concord. NE.

Effluent N Rate	Alfalfa Harvests per Season 3x	4x	5x	Mean
lb N / acre	----------	tons DM per acre	----------	----------
0	8.5	9.3	8.9	8.9
90	8.3	9.7	9.1	9.0
210	8.4	10.4	9.5	9.4
340	8.4	10.0	9.7	9.3
450	8.7	10.7	10.0	9.8
560	8.8	10.1	10.3	9.7

Table 3. Total nitrogen harvested after irrigation with swine effluent as alfalfa hay and in a corn/rye system. Concord, NE.

Year	Alfalfa type	Nitrogen	Crop	Nitrogen
		lbs/acre		lbs/acre
1993	Nodulating	230 - 250	Corn/rye	154
1994	Nodulating	680 - 745	Corn/rye	213
1995	Nodulating	337 - 520	Corn/rye	162
1996	Nodulating	270 - 383	Corn	205
1996	Non-nodulating	189 - 396		

Alfalfa was established in 1993 and 1996.
Rye cover crop did not survive winter in 1996.

Table 5. Effect of swine effluent application on drainage, leachate nitrate nitrogen and nitrate nitrogen leached. 1994. Concord, NE..

Effluent N-Rate	Drainage	Nitrate-Nitrogen Concentration	Nitrate-Leaching
(lb/ac)	(inches)	(ppm)	(lb/ac)
0	6.3	4.9	7.0
90	5.7	8.2	10.6
210	5.5	8.2	10.2
340	6.3	10.0	14.2
450	4.7	19.9	21.2
560	3.9	37.1	33.1
Mean	5.4	14.1	16.0

Table 4. Effect of lagoon water on soil phosphorus and potassium after four years of irrigation with swine effluent. Concord, NE.

Swine Effluent Application Intensity	Soil P	Soil K
% of estimated N removal	----------ppm-------------	
0	31	188
35	42	213
70	51	306
105	70	383
140	66	364

Soil sampled spring 1997; corn grown 1996-97 and alfalfa 1993-95.

Figure 1. Field layout, water distribution and porous cup installation. Concord. NE.