APPLICATION OF SWINE LAGOON WATER TO CORN AND ALFALFA

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Abstract: Increasingly more large swine production facilities are faced with the dilemma of being involved in a production system that can produce more waste that there is land available for distribution at agronomic rates. Alfalfa represents a crop that utilizes a large amount of nitrogen, has a deep rooting system, and provides a larger window for application than other crops. The goal of this study was to determine how much nitrogen could be applied to irrigated alfalfa without resulting in excessive nitrogen leaching losses. A line-source irrigation system was used to apply swine lagoon water at rates from 0 to 140% of the anticipated nitrogen utilization rate to corn and alfalfa. Later work included planting nonfixating alfalfa which appeared to have similar production capability. Lagoon water application above about 250 lbs. N per acre caused nitrate concentration of leaching waters to rise above 10 ppm. Buildup of potassium and phosphorus also occurred at the high lagoon water application rates.

INTRODUCTION

A substantial amount of manure is produced by midwest animal production facilities. Production statistics indicate that the five states of Colorado, Iowa, Kansas, Nebraska, and South Dakota typically produce nearly 13 million head of cattle, 8 million head of swine, 48 million chickens, and 60 million turkeys each year in confinement facilities (National Ag Statistics, 1999). Based on published values, these animals produce approximately 6.5 Tg ($6.5x10^{12}$ grams) of manure each year (Van Dyne and Gilbertson, 1978). The nutrient content of the manure is equivalent to approximately 0.3Tg of nitrogen, 0.09 Tg of phosphorus, and 0.16 Tg of potassium. Animal manures also contain micronutrients that are necessary for plant growth and development (National Research Council, 1993). Though storage and handling loss reduces the nitrogen content by 30 to 70%, failure to distribute these nutrients and utilize them in a cropping system can contribute to contamination of ground and surface water in the region and down stream (King et al., 1990; Rabalais, 1992).

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 have 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. Large concentrated hog production facilities commonly install water flush units in buildings for removing swine manure. Slatted floors allow manure to pass through to a sloped concrete floor poured below the slats. Large volumes of water are flushed over the concrete floor transporting manure into an exterior storage basin or lagoon. Typical designs utilize approximately 2000 gallons of flush water annually per head in confinement. A lagoon is an appropriate storage media for this dilute manure because it minimizes the surface area devoted to manure storage and climatic conditions can reduce the water volume by evaporating water into the atmosphere. The manure stored in lagoons is typically distributed via center pivot or knife applicator with an umbilical hose supply line. Though manure is commonly applied to crop land planted to corn, some producers use other crop rotations, corn for forage, or pastures as sites for application of swine manure. These factors have led to situations where ground and surface water quality are at risk of contamination.

Using alfalfa to substitute for nitrogen fertilizer in corn production has been calculated to have the potential to save 14% of the nitrogen applied to corn (Peterson and Russelle, 1991). Using alfalfa as a scavenger crop for nitrogen is proposed primarily since its deep rooting allows for moisture uptake from deeper in the soil profile than annual crops (Kiesselbach et al., 1929). Deeper rooting and moisture uptake increases nitrogen uptake (Mathers et al., 1975). These properties of alfalfa have been used to minimize nitrogen movement under abandoned feedlots (Mielke and Ellis, 1976; Schuman and Elliot, 1978). Researchers in Minnesota found that nonfixating alfalfa removed 31% more subsoil nitrogen than fixating cultivars suggesting that nonfixating cultivars would be useful for bioremediation of nitrogen contaminated sites.

In the south, research has been conducted to determine the cropping systems that maximize nitrogen removal with bermudagrass, ryegrass, and corn silage using liquid dairy manure (Johnson et al., 1991). They were able to achieve a maximum of 543 lb/acre nitrogen yield. Previous work has been conducted with a tall fescue, Kentucky bluegrass, and ladino clover mixture in North Carolina (Evans et al. 1984; Westerman et al. 1987; Burns et al. 1990; and King et al. 1990). Burns found that effluent rate was important since at high rates the forage mixture did not remove all applied nutrients. Most notably, the grass or forage mixture did not remove all the nitrogen, potassium or phosphorus applied with the irrigation water. Buildup of these and other nutrients is evidence of potential groundwater contamination. If groundwater contamination is to be minimized, a broader range of nutrients must be accounted for when investigating swine lagoon water application rates.

Animal waste can be applied using a variety of ground application equipment or via sprinkler irrigation. Sprinkler application offers a couple of advantages over other methods: 1) The timing of application can be geared more to crop requirements since the applicator can move freely over the crop without damage; and 2) Large volumes of water can be applied in a short period of time with a high degree of uniformity thus minimizing air and water quality concerns.

The goal of our research was to evaluate alfalfa as a nitrogen sink for nutrients contained in swine lagoon water. An established stand of irrigated alfalfa can remove more than 700 pounds of nitrogen per acre in the harvested hay. If alfalfa removed applied nitrogen at that level, producers could potentially reduce the land base for lagoon water distribution by over 50% when compared to the 200 pound removal rate for corn followed by winter rye. This could be beneficial to producers who do not have sufficient land to apply lagoon water at agronomic rates to row crops.

Advantages to alfalfa also include: 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; lagoon water 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 lagoon water rates to both alfalfa and corn. Figure 1 shows the distribution of the lagoon water and of fresh water. The experiment was designed so that the distribution patterns of both the fresh and lagoon water waters produce an even amount of water application. Therefore, only lagoon water rates changed. Rates of lagoon water 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 lagoon water 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 lagoon water so that at the end of the growing season both the corn and alfalfa would have plot areas with an excess of applied N. 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 anticipated nitrogen removal rates.

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 lagoon water application 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 irrigation need was minimal. 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 lagoon water 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 lagoon water 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 are 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 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 buildup was anticipated. However, continued buildup of soil potassium could cause soil structure problems in the future. At some point, lagoon water 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 tends 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 lagoon water 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.

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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
kg 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.