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Project Summary

Swine Lagoon Effluent Applied to Coastal Bermudagrass

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The utilization potential and the environmental effects of applying swine lagoon effluent to Coastal bermudagrass were evaluated for six years. Lagoon effluent was applied to 9 m x 9 m plots by weekly sprinkler irrigations during the growing season. A randomized block design with three application rates based on nitrogen (N) (about 335, 670 and 1,340 kg N/ha/yr) was utilized. The high rate treatment resulted in application of N, phosphorus (P) and potassium (K) at about five, thirteen, and eleven times, respectively, the normally recommended fertilizer application rates for high yields of hay.

Forage yield and quality, soil nutrient levels and water quality and quantity of runoff and subsurface lateral flow were evaluated. An intake trial with ewes was also conducted to determine animal acceptance of hay from lagoon-irrigated treatments.

The results indicated that swine lagoon effluent can be an excellent source of nutrients for Coastal bermudagrass, but water quality considerations, nitrate levels in the forage, and long-term soil effects must be evaluated when determining acceptable maximum application rates, which is important when land area for application is limiting.

This Project Summary was developed by EPA's Robert S. Kerr Environmental Research Laboratory, Ada, OK, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).*

Introduction

Swine production systems which utilize anaerobic lagoons usually require a land receiver system for lagoon effluent to avoid lagoon overflow. The ability of a soil-plant receiver system to utilize applied lagoon effluent depends primarily upon the crop and the soil chemical and physical properties. Climate, lagoon effluent application rate, and effluent composition also affect the utilization.

The design of the lagoon and the soil-plant receiver system depends largely on whether the producer's main objective is (1) manure treatment and disposal or (2) utilization of manure nutrients for useful crops. If limited by land, the producer would want maximum lagoon treatment and effluent applied to the soil-plant receiver system at maximum rates. The effluent rates could be sustained without causing toxicity to plants, failure of soil structure, or excessive degradation of ground water and rainfall runoff. Also, if the plants are to be fed to animals, the mineral and metal composition must not reach toxic levels. On the other hand, if land is not limited, and the producer utilizes the lagoon effluent for crop irri-

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gation and fertilization, the lagoon may be designed to minimize nutrient losses while effluent is applied at rates based on efficient crop utilization of nutrients. Then the producer must decide whether to base application rate on N, P or another element. Typically, if N is the base element, P and K are applied in excess of plant utilization. However, if P is the base element, additional N must be applied using commercial fertilizer. Thus, depending upon the producer's objectives and the land restrictions, a wide range of nutrient loading rates may be found in practice. Whether the maximum rate is limited by detrimental effects to crop, or soil, or by water quality of ground water and runoff must be determined.

One crop which is receptive to irrigation of swine lagoon effluent in the Southeast is Coastal bermudagrass (*Cynodon dactylon* L. Pers). This bermudagrass is a deep-rooted, long-lived perennial which grows well in hot weather and requires a well-drained soil. Also it can remove relatively large amounts of N which is often used as the base element for determining effluent application rates. In this study, the plant-soil receiver system was Coastal bermudagrass growing on a Norfolk sandy loam soil. Lagoon effluent was applied during the crop growing season to replicated plots at three N levels ranging from a fertilization rate normally recommended for high yields to a rate five times higher.

Results are presented for six years of monitoring irrigation applications, crop yield and composition, soil cores, and runoff. Also included is a 20-month period of monitoring subsurface flow on three plots. Because most studies of this type have covered only one to three years, the study demonstrates long-term effects which may not be evident in short-term studies, especially in regard to soil accumulation and water transport of possible pollutants.

Conclusions

Weekly irrigation of swine lagoon effluent to Coastal bermudagrass during the growing season resulted in excellent crop response. Yields increased with increased application rates, but there was little advantage in dry matter production from applying N above the medium rate (670 kg N/ha/yr). Applying N, P, and K up to five, thirteen, and eleven times, respectively, the normal recommended rates for high hay yields under non-irrigated conditions did not result in any significant problem with forage quality or soil physical structure for the six years of the study. The only exception was the possible hazardous animal intake levels of nitrate nitrogen (NO_3-N) in forage from the highest-rate treatment. Soil sampling results indicated that continued application at the two highest rates could cause some nutrient imbalances due to high P accumulation (e.g., reduced iron [Fe] uptake), and periodic liming would probably be needed to correct for calcium (Ca) and magnesium (Mg) losses from the topsoil and the decreased pH. The Ca and Mg deficiencies may occur even though large amounts of these and other minor elements are applied with the lagoon effluent.

Transport of nutrients in surface runoff was relatively low because of the sandy topsoil and low slope of the plots. Greater transport generally occurred in subsurface drainage for this layered soil. Because the high nutrient concentrations in surface and subsurface flow and high transport of NO_3-N in subsurface flow from the highest two treatment rates is apt to be unacceptable in most situations related to water quality, water pollution concerns will probably govern the application rate for disposal of lagoon effluent. Keeping application rates near the low-rate treatment (near normal crop fertilization) would utilize a greater percentage of the nutrients and be more acceptable environmentally.

Recommendations

After six years of applying swine lagoon effluent to Coastal bermudagrass, no significant detrimental soil effects or nutrient imbalances in plant uptake were evident even when nutrients were applied at several times the normal fertilization rates. However, some trends indicated potential agronomic problems if high-rate applications continued, and the water quality of surface runoff and drainage from the plots receiving high-rate applications was of environmental concern. Some of these trends were not evident after the first two to three years, which is the normal duration of studies of this type. Thus, researchers and research funding agencies should set priorities to allow for some long-term studies of this type. Some recommended research areas are:

1. Studies of ten years or longer duration should be conducted to determine long-term effects of continuing excess applications of nutrients with livestock and poultry manures and lagoon effluent. Various plant-soil receiver systems should be studied because soil changes, plant nutrient imbalances, and water quality effects will vary with soil type, plant type and hydrologic conditions. Thus, the nutrient upon which application rates should be based can vary from system to system.
2. The application losses of N by NH_3-N volatilization and the soil reduction of NO_3-N by denitrification needs further study, particularly with lagoon effluent irrigation systems. NH_3-N losses and mineralization rate of organic nitrogen applied need further study in order to compare availability rates in these systems with that in agronomic systems using commercial inorganic fertilizer. Also, it is difficult to determine how much of the N in the soil is denitrified and how much is transported as NO_3-N by lateral soil-water flow and deep seepage and thus is a potential water quality problem.
3. Long-term studies of this type should be conducted with other crops, other soils, and other management strategies such as year-round irrigation, less frequent irrigation, and basing lagoon effluent application rate on P or K and adding supplemental N in commercial fertilizer. Economics of alternatives should be evaluated.
4. Actual field-size systems should be studied, including evaluation of impact on water quality of ground water and nearby streams.

Crop Response

The Coastal bermudagrass was evaluated for dry matter yield, elemental composition, and estimated nutritive value. One major goal was to determine the quantity of N and other constituents that could be deposited in Coastal bermudagrass forage without adversely affecting stands or forage quality.

Dry matter yields are shown in Figure 1. The highest N rate produced the greatest dry matter yields but was not statistically different from the medium rate. Both the high and medium rates produced greater yields than the low rate. The seven-year mean dry matter yields were 10,750, 14,230 and 15,810 kg/ha for the low, medium, and high treatments, respectively. The low N rate with irrigation showed about a 25% increase in yield over the non-irrigated plot receiving similar N amounts. Irrigated effluent amounts were approximately 12, 24 and 48 cm/yr for the low, medium, and high

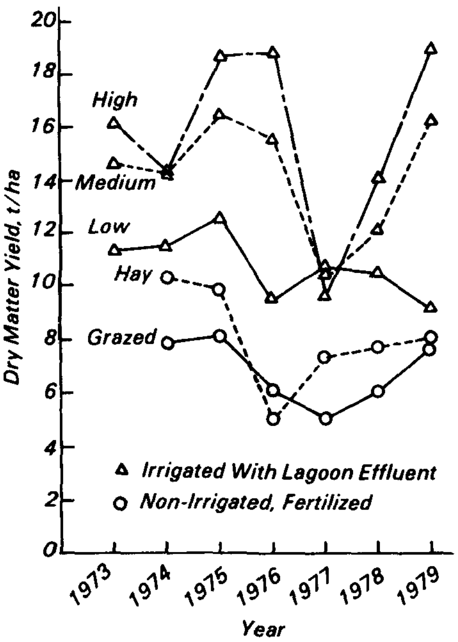

Figure 1. *Dry matter yields of Coastal bermudagrass.*

treatments, respectively, and irrigations were weekly from April through September. The simulated hay and grazed plots received 336 and 200 kg N/ha/yr, respectively. The yield data indicate little advantage in dry matter production from applying N above the medium rate (670 kg N/ha/yr). Also, there was some evidence that bermudagrass plots receiving the medium and high loading rates were more prone to winter injury, and would therefore require more re-sprigging to maintain stands.

Concentrations of minerals in the bermudagrass generally increased with increased application rates of effluent. However, the concentration increases were generally nonlinear and showed a plateauing between the medium-rate and high-rate treatments. Elements which showed potential for increased concentrations with even higher effluent rates were P and manganese (Mn).

Nitrogen concentration in the forage averaged 2.24%, 2.77%, and 2.95% for the low, medium and high-rate treatments, respectively. However, it was expected that higher concentrations of N (3 to 4%) would result from the high loading rate. The increases in the N concentrations are important because of (1) interest in maximum crop uptake of N and (2) increased use of Coastal bermudagrass meal as a source of protein and vitamins in livestock and poultry feeds.

The concentrations of elements in the bermudagrass were generally adequate when compared to the requirements for growing and finishing steers. The crude protein values (11 to 20%) were adequate to meet N requirements for most ruminants. The nitrate nitrogen (NO_3-N) concentrations, monitored on a limited basis for one year, were in the toxic range on the high-rate treatment. More NO_3-N data is needed but the limited results indicate that forage from the high-rate treatment would probably need to be blended with other feeds to reduce the NO_3-N concentrations. Concerning forage acceptability, an intake trial with ewes showed no difference in hay intake between the control and the low, medium, and high treatments.

The average annual quantities of N and P removed in the bermudagrass are shown in Table 1. Although the amounts of N and P increased with increased effluent rates, the percentage recovery of N and P applied decreased. The amounts not recovered in forage were very high for the high-rate treatment and indicate potential problems with soil accumulation of P and movement of NO_3-N to groundwater.

Soil Effects

Soil levels of NO_3-N increased with increased loading rate (Figure 2). The sandy texture of the upper 30 cm of the profile resulted in little NO_3-N increase in this zone normally, but accumulation occurred in the subsoil. Accumulation of NO_3-N in the subsoil has been noted in soils of the Southeastern United States, and is thought to be a result of the weak adsorption of NO_3-N ions in acid subsoils high in aluminum (Al) and iron (Fe) oxides and a result of non-uniform water movement in the subsoil. However, the amount of N retained in the soil was a relatively small percentage of the N applied. Of approximately 6,800 kg/ha of N applied to the high-rate treatment during the six-year period, only about 12% remained in the soil and most of this was NO_3-N. Since crop removal averaged only 34% of the amount applied on the high-rate treatment, a large amount of N is lost by leaching, lateral subsurface flow, and/or denitrification when the application rate is this high.

The effect of effluent application rate on concentrations of dilute acid extractable soil P was generally in the order high rate > medium rate = low rate. By the sixth year, differences were significant in the 30-60 cm layer, indicating a significant downward movement of P. For this six-year period, application of P in excess of crop removal was about 1,500 kg/ha. Continual application of excess P could cause nutrient imbalance such as reduced Fe uptake.

Irrigation of effluent tended to decrease pH and levels of Ca and Mg in the topsoil. These changes could be counteracted by periodic additions of dolomitic limestone to the soil. Effluent applications had little or no effect on soil copper (Cu), zinc (Zn) and Mn.

Potassium and sodium (Na) accumulated in the subsoil on the high-rate treatments. However, the low pH (4.2 - 4.6) and low exchangeable Na (approximately 6% NA saturation) in the zone of

Table 1. *Amounts of N and P in Forage*

Identification	*Non-Irrigated Treatment*	*Irrigated Treatments*		
		Low	*Medium*	*High*
		N		
		kg/ha		
Amount applied	336	338	670	1,337
Amount in harvested forage	174	247	382	450
Amount not recovered	162	91	288	887
		%		
Percent recovered in forage	52	73	57	34
		P		
		kg/ha		
Amount applied	37	78	153	301
Amount in harvested forage	16	32	43	52
Amount not recovered	21	46	110	249
		%		
Percent recovered in forage	43	41	28	17

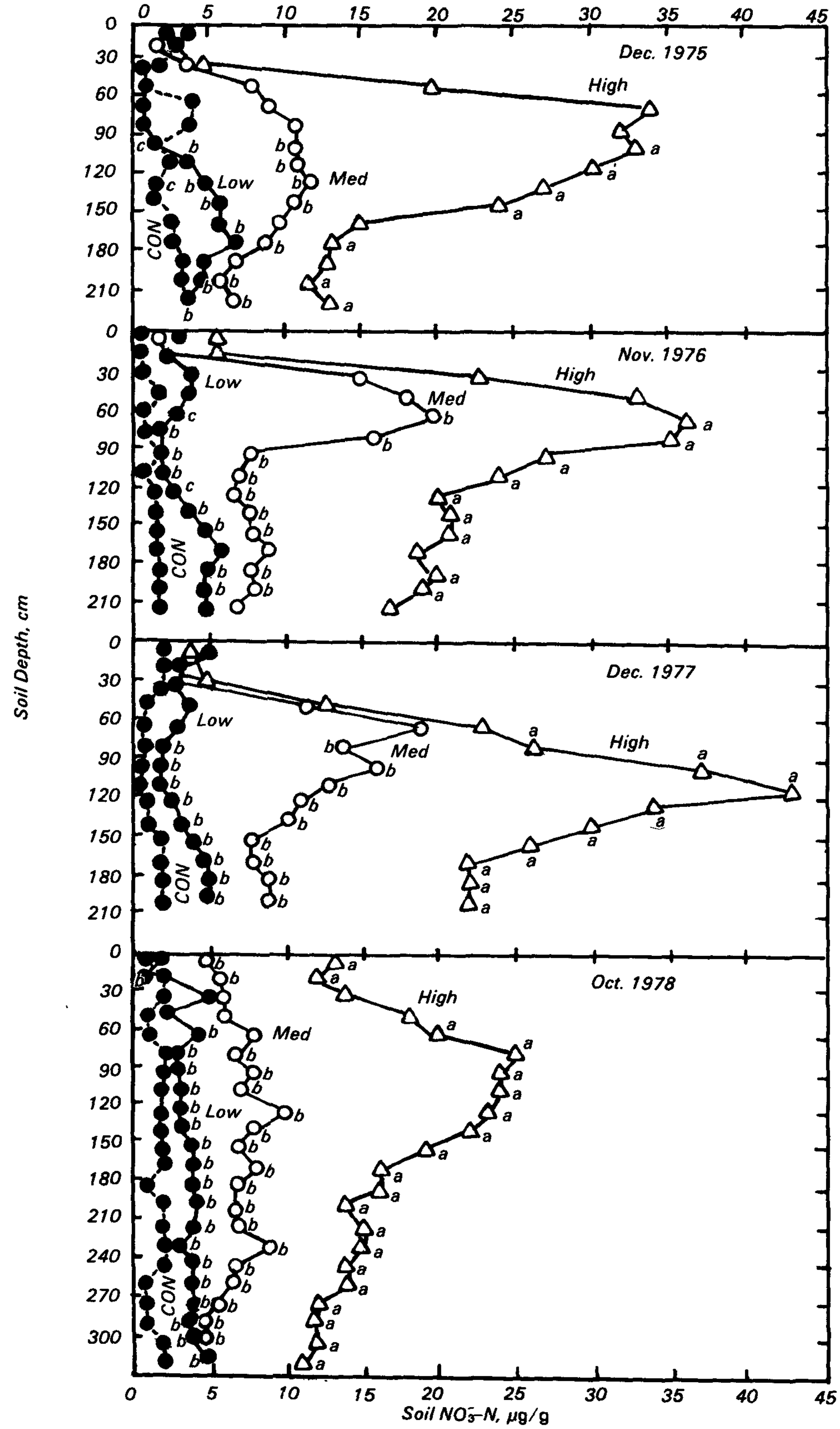

Figure 2. *Effect of lagoon effluent irrigation rates on soil NO_3-N. Treatments with same letter (at same depth) are not significantly different at the 5% level. The control sample (CON) was obtained from adjacent, non-irrigated area fertilized at maintenance levels.*

highest Na concentration (40 ppm at 210-240 cm) precluded any loss of soil hydraulic conductivity due to Na induced clay dispersion, even though calculation of the ratio of Na and K applied to total salts applied would predict possible dispersion problems.

Surface Runoff

The sprinkler irrigation system was usually activated each week of the growing season without regard to rainfall. Consequently, some irrigation runoff and irrigation-rainfall mixed runoff occurred, and this runoff was very high in nutrients and oxygen demand. This type of runoff could probably be avoided by withholding irrigation when soil moisture is high or when rainfall is expected.

Total runoff (including any irrigation runoff) averaged less than 10% of annual rainfall plus irrigation, which was reasonable for these plots with low slope (1-3%) and sandy topsoil. However, concentrations of nutrients in runoff were high compared to most agricultural runoff. The mean concentrations of total N, NO_3-N and P in rainfall runoff (without irrigation runoff) over the six-year period are given in Table 2. Although there was generally an increase in concentration of all nutrients with higher effluent rates, only P had a significant increase at the 5% level for the high-rate treatment.

Annual mass transport of nutrients in runoff was variable and treatment effects were seldom significantly different. Mass transport by rainfall runoff (no irrigation runoff) was very low compared to nutrient loading rates, e.g. generally less than 1% for N.

The overall potential environmental impact of runoff of the quality measured for the irrigation treatments would depend on the particular hydrologic situation and whether concentration or mass transport was the more important. Nutrient concentrations were sometimes high

Table 2. *Rainfall Runoff Volume-Weighted Concentrations*

	Concentration, mg/l		
Nutrient	*Low Tmt.*	*Medium Tmt.*	*High Tmt.*
Total N	7.3 a§	10.2 a	17.3 a
NO_3-N	2.7 a	4.2 a	9.8 a
P	2.0 b	3.4 b	6.0 a

§Treatments with same letter are not significantly different at the 5% level.

but total runoff and total nutrient mass transport were relatively low.

Subsurface Runoff

Subsurface lateral flow collected in drain tubes at the interface of the A and B horizons on three plots was much greater in volume than surface runoff for a 20-month period of data. Estimated annual subsurface runoff for a two-year period averaged about 30-45 cm; surface runoff averaged about 1 cm. For layered soils, quality of subsurface lateral flow should be evaluated since it represents a larger flow volume than surface runoff.

Duration of individual subsurface runoff events ranged from one to eight days. For a 20-month period, subsurface flow occurred about 15% of the period and volume was about 25% of rainfall plus irrigation during this period.

Monthly mean concentrations of NO_3-N increased with increased loading rate of effluent. Concentrations from the medium-rate and high-rate treatments were usually between 10 and 30 mg/l. The relative impact of this subsurface flow on quality of water in the surrounding area would depend mainly upon dilution ratios and denitrification rates. Concentrations from the low-rate treatment were less than 10 mg/l.

Phosphorus concentrations were usually in the range of 0.1 to 0.3 mg/l for the low-rate and medium-rate treatments, and in the range of 0.3 to 1 mg/l for the high-rate treatment. High applications of effluent promoted P movement in subsurface flow.

Annual mass transport of NO_3-N, Cl^- and P in subsurface flow (Table 3) are based upon the 20 months of data. Mass transport of NO_3-N was about 8% of applied N for all three treatments. For the high-rate treatment, the estimated annual NO_3-N transport was 115 kg/ha. This represents a high nutrient transport, but the relative water quality impact would depend on the particular hydrologic situation. The P:N ratio in subsurface flow was about 3:100, but was variable.

Overall, the nutrient concentrations and mass transport measured for subsurface drainage from the interface of the A and B horizons indicate that applying swine lagoon effluent at fertilization rates of 670 and 1,340 kg N/ha would likely be detrimental to quality of soil-water interflow and ground water in the area. Nitrate nitrogen would probably be the limiting factor, but long-term applications could result in considerable P movement.

Table 3. *Annual NO_3-N, Cl^- and P Transport in Subsurface Runoff*

	Estimated Annual Transport kg/ha/yr		
Nutrient	*Low Tmt.*	*Medium Tmt.*	*High Tmt.*
NO_3-N	18	58	115
Cl^-	37	60	108
P	0.9	1.0	3.7

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***R. Douglas Kreis** is the EPA Project Officer (see below).*
The complete report, entitled "Swine Lagoon Effluent Applied to Coastal Bermudagrass," (Order No. PB 83-152 264; Cost: $19.00, subject to change) will be available only from:
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