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Project Summary

Swine Manure and Lagoon Effluent Applied to Fescue

Philip W. Westerman, Larry D. King, Joseph C. Burns, and Michael R. Overcash

The utilization potential and the environmental effects of applying swine manure and swine lagoon effluent to tall fescue were evaluated for 4 years. Lagoon effluent was applied to 9 m x 9 m plots by weekly sprinkler irrigations during the growing season while swine manure slurry from an under-slat pit was applied to a similar plot four times per year. Application rates were based on nitrogen (N) and were about 600 and 1,200 kg N/ha/yr for the lagoon-irrigated plots and about 670 kg N/ha/yr for the manured plot. These treatments resulted in much higher applications of N, phosphorus (P), potassium (K) and other nutrients than is normally used for fescue pasture. These treatments were chosen to evaluate the acceptable maximum application rate, which is important when land area for application is limiting.

Forage yield, quality and stand persistence, soil nutrient levels, and water quality and quantity of runoff were evaluated. The treatments resulted in good dry matter yields but some problems were encountered with the forage shifting away from tall fescue to tropical annuals and perennials, and with high nitrate nitrogen (NO_3-N) levels in the forage.

The results indicated that swine manure and swine lagoon effluent can be excellent sources of nutrients for fescue, but water quality considerations, NO_3-N levels in the forage, stand persistence and long-term soil effects must be evaluated when determining acceptable maximum application rates.

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 using confinement housing increased in recent years. These systems normally dispose of the swine manure by (1) collecting the manure in a pit and using a tank wagon to spread the manure slurry taken from the pit, or (2) utilizing a lagoon for manure treatment and storage and pumping effluent from the lagoon to keep it from overflowing. Either disposal method has the potential for being an excellent utilization scheme for providing nutrients for growing crops.

The design of the lagoon and the requirements of the soil-plant receiver system depend largely on whether the producer's main objective is (1) manure treatment and disposal or (2) utilization of manure nutrients for useful crops. If the producer is limited by land, he may desire maximum lagoon treatment and apply lagoon effluent or manure slurry to the soil-plant receiver system at maximum rates, which could be sustained without causing toxicity to plants or animals fed the plants, failure of soil structure, or excessive degradation of ground water and rainfall runoff. On the other hand, if the producer is not land-limited and he desires to utilize lagoon effluent for crop irrigation and fertilization or manure for fertilization and soil amendment, he may design the system to minimize nutrient losses and apply effluent or manure at rates based on efficient crop utilization of nutrients. Then he 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, then additional N must be applied with commercial fertilizer or a manure-fertilizer blend might be utilized. Thus, depending upon the producer's objectives and the land and crop restrictions, a wide range of nutrient loading rates may be found in practice. A major question arises as to whether the maximum rate is limited by detrimental effects to crops, or soil, or by water quality of ground water and runoff.

One crop which is often utilized for application of manure and lagoon effluent is tall fescue *(Festuca arundinacea* Schreb). It can utilize large amounts of N which is normally considered the limiting constituent in land application of manure or lagoon effluent and fescue is water tolerant and responds well to irrigation. Fescue is a cool-season perennial, however, and the continued application of nutrients and/or irrigation during the summer may cause problems with maintaining stand. The peak production of fescue in the Southeast is March through May, and September through November

The objectives of this study were to:

(1) determine dry matter yield, elemental composition, digestibility, and stand persistence of fescue receiving swine manure or swine lagoon effluent at high rates.

(2) determine soil effects of high rates of manure or lagoon effluent applications.

(3) determine effects of the various treatments on quantity and quality of rainfall runoff.

Tall fescue on a Cecil sandy clay loam was utilized in this study as the plant-soil receiver system. Treatments included commercial fertilizer, swine lagoon effluent at two rates during the growing season, and swine manure slurry applied four times a year. Application rates were based on N, and the manure and lagoon effluent supplied from three to six times more N than the commercial fertilizer treatment which used a typical fertilizer rate for fescue pasture. Also, P, K and other nutrients were supplied in the manure or effluent at several times the normal fertilization rates. Results are presented for 4 years of monitoring irrigation applications, crop yield and composition, soil cores, and runoff.

Conclusions

Utilizing swine manure slurry and swine lagoon effluent for growing tall fescue resulted in good dry matter yields and high crude protein and digestibility, but the dry matter had excessive NO_3-N levels and vegetation shifted away from tall fescue to tropical annuals and perennials on the high-rate irrigation treatment, which indicated that the high annual rates of application and the continued application of effluent during the summer was not a good management scheme for tall fescue.

The high-rate irrigation treatment resulted in very high NO_3-N levels in the soil and the manure and low-rate irrigation treatments also had higher NO_3-N levels than the fertilized plot. The 1200 kg N/ha/yr rate was too high and the 600 kg N/ha/yr rates were probably still too high to prevent excessive nitrate movement to the ground water and excessive NO_3-N uptake by the fescue. Maximum application rates which would be considered safe would be somewhat site specific and also depend on the amount of N lost during application and by denitrification.

No problems were encountered with nutrient imbalance of cations in the soil but continued P accumulation could eventually result in reduced iron (Fe) uptake. Periodic liming may be needed in some soils to correct for calcium (Ca) and magnesium (Mg) leaching where lagoon effluent is applied.

All treatments, including the fertilizer treatment, had some runoff events with high nutrient concentrations in runoff. Applications of manure or fertilizer without incorporation should be avoided if rain is predicted within a few days. Also, the 1200 kg N/ha/yr irrigation treatment and the manure treatment had noticeably higher total N and P transport than the other treatments. Keeping application rates near normal crop fertilization rates would utilize a greater percentage of the nutrients and would be more acceptable environmentally

Recommendations

Results of applying either swine manure slurry or swine lagoon effluent at high rates to tall fescue for 4 years indicated potential problems with applying three and six times the normally recommended fertilization rate based on N. Excessive NO_3-N levels resulted in the forage and in the soil when the N application was 600 or 1,200 kg/ha/yr. Also, some trends indicated potential agronomic problems if high-rate applications continued. Based upon these results the following recommendations are made:

1. Future studies should concentrate on fertilization levels in the range of 200 to 600 kg/ha/yr of N. Also, application rates of manure or lagoon effluent based on P or K should also be considered.
2. The application losses of N by NH_3-N volatilization and the soil reduction of NO_3-N by denitrification needs further study in order to better adjust application rates and determine the fate of N.
3. The potential problems of P accumulation need further investigation.
4. The effects of high-rate applications of manure or lagoon effluent on water quality of rainfall runoff and ground water should be studied for actual field-size systems where impact on receiving streams or impoundments could also be evaluated.
5. Other management options should be evaluated for irrigation of lagoon effluent on fescue such as using a lower application rate or no applications during the summer to help reduce stand loss of fescue to tropical annuals and perennials
6. The potential of mixing fescue having high NO_3-N levels with other forage having low NO_3-N levels for feeding livestock needs to be evaluated
7. Studies of this type should be conducted with various crops and soils, and different management strategies to determine which systems are best suited for utilizing manure and lagoon effluent at either normal fertilization rates or maximum disposal rates. Economics of alternatives should be evaluated. Some studies, particularly those with high application rates, should be of 5 to 10 years or longer duration to determine trends for long-term effects where systems are dedicated to disposal.

Crop Response

The fescue forage was evaluated for dry matter yield, elemental composition, and estimated nutritive value. The quantity of N and other constituents that could be harvested in fescue forage at high nutrient application rates without adversely affecting stands or forage quality was also of major interest.

The nutrient application rates were based on N and thus resulted in various ratios of other nutrients. The average nutrient application rates over the 4-year period are shown in Table 1. The N-P-K ratio of the applied manure was about 3.4-1-1.4. Compared to the normally-recommended fertilizer ratio of 9-1-4 for fescue, the manure was high in P (about 2.5 times) and all right for K in relation to N, whereas lagoon effluent was high in both P and K in relation to N. Both lagoon liquid and swine manure from the pit had substantial amounts of ammonia nitrogen (NH_3-N) and NH_3-N loss during and after application would increase the excess of P and K in relation to N.

Comparing the lagoon-irrigated treatment with the manure treatment receiving approximately the same amount of N, the irrigated treatment received much more (about four times) K, Na and Cl^- while the manure treatment received more P, Ca and Zn on an annual basis (Table 1). Other differences between the treatments were the amount of water received (about 10 to 25 cm more for the low-rate irrigated treatments) and the frequency of application (about 30 weekly irrigations, March to November, compared to four manure applications per year).

The treatments resulted in good dry matter yields, good estimated digestibility (*in vitro* dry matter digestibility, IVDMD) and high crude protein concentrations (20 to 23%). The major mineral (P, K, Ca and Mg) concentrations in the forage were somewhat higher for the lagoon effluent and manure treatments than normally found in forage tissue but should not be a problem. The only fraction that was considered to be an animal health hazard was the NO_3-N levels (0.64 to 1.2% as nitrate (NO_3-) of treatments receiving either lagoon effluent or manure. Because of the high quality (high IVDMD and N concentrations (3.2 to 3.7%) of the dry matter produced, a possible use of this forage would be a blend with another feed generally low in N.

Dry matter yields for the four treatments are shown in Figure 1. The 4-year average dry matter yield of the manure plot (7,600 kg/ha) was similar to the mean yield of the two fertilized plots (7,900 kg/ha). The mean yield of the three low-rate irrigation plots (11,200 kg/ha) was higher than the manure plot which received approximately the same N rate. The high-rate irrigation plot had the highest average yield (12,500 kg/ha) but the forage on the plots shifted to mainly tropical annuals and perennials. Also, N recovery as percent of N applied was much lower on the high-rate irrigation treatment than for other treatments.

The average annual quantities of N and P removed in the fescue forage are shown in Table 2. The low-rate irrigated treatment had a higher percent recovery of N and P than the manure treatment, which could be a result of both lower availability of

Table 1. *Comparing Application Amounts of Nutrients for Treatments*

Treatment	*Number of plots*	*Annual application*, kg/ha* N	P	K	Ca	Mg	Na	Cl^-	Cu	Zn
Fertilizer	2	200	35	65	-	-	-	-	-	-
Manure	1	670	195	275	295	65	100	190	0 44	4 3
Low effluent	3	590	120	1,065	140	55	540	665	0.31	1.2
High effluent	1	1,210	240	2,240	280	120	1,095	1,290	0 62	2.4

**Mean annual application rate for 4-year period.*

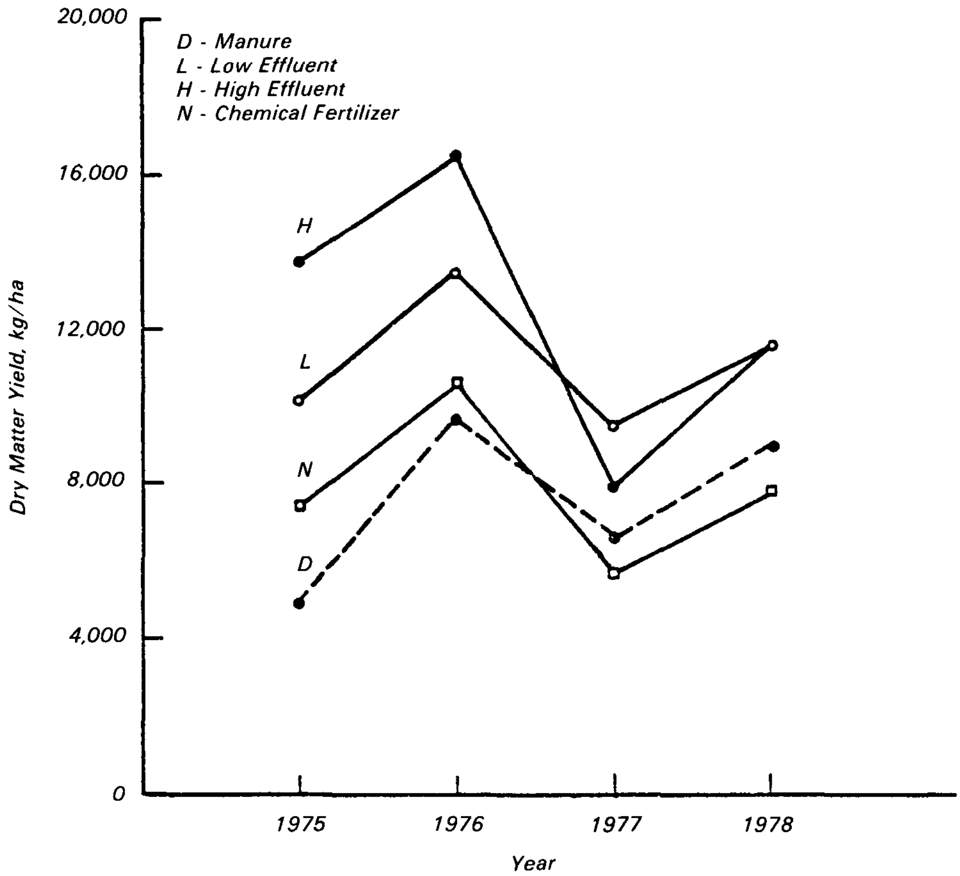

Figure 1. *Annual dry matter yield.*

Table 2. *Amounts of N and P in Forage*

Identification	*Fertilizer treatment*	*Manure treatment*	*Lagoon-irrigated treatments* Low-rate	*High-rate*
			N	
			kg/ha	
Amount applied	200	670	590	1,210
Amount in harvested forage	260	280	380	430
Amount not recovered	-60	390	210	780
			%	
Percent recovered in forage	130	42	64	36
			P	
			kg/ha	
Amount applied	35	195	120	240
Amount in harvested forage	25	30	45	50
Amount not recovered	10	165	75	190
			%	
Percent recovered in forage	71	15	38	21

nutrients in the manure and higher losses of nutrients from the manure during and after application. Also, the additional water applied when using lagoon effluent could increase utilization of nutrients. The amounts of N and P not recovered in the forage were high and indicate potential problems with soil accumulation of P and movement of NO_3-N to ground water.

The manure plot and the irrigated plots had a striking shift away from tall fescue to tropical annuals and perennials, with greater shifts occurring on the plots receiving effluent. Further, these treatments had major insect infestations resulting in appreciable bare ground at times. Fescue performance would probably be better if a greater portion of the nutrients were applied during the peak growth periods and much less during the summer. The scheme of application which was used is more conducive to tropical grasses, or perhaps tropical grasses grown in sequence with annual grasses.

Soil Effects

Accumulation of some nutrients in the soil was evident with the manure and irrigated treatments. The high-rate irrigation treatment had high potential for ground-water pollution because of excess NO_3-N in the soil profile, while the low-rate irrigation and manure treatments could also potentially contribute excess NO_3-N to the ground water.

The high application rates of K, Na and N (mostly as NH_3-N) and the relatively low application rates of Ca and Mg with irrigated effluent suggest that a nutrient imbalance may develop, but none had developed after 4 years, probably because of the high levels of Ca and Mg initially in the soil and the rather high soil buffering capacity due to the clay content. Long-term irrigation of lagoon effluent should be supplemented with applications of dolomitic limestone. Nutrient imbalance would be less likely to occur from manure applications than from effluent applications because lagooning the manure results in settling or precipitation of Ca and Mg such that ratios of (Ca + Mg)/(monovalent cations) in the lagoon effluent are low.

Manure applications and the low irrigation rate supplied adequate P, whereas chemical fertilizer did not supply enough and the high irrigation rate supplied an excessive amount. Continued application of excessive P could result in reduced Fe uptake, but due to the large amount of Fe in this soil, an Fe deficiency would take a long time to develop.

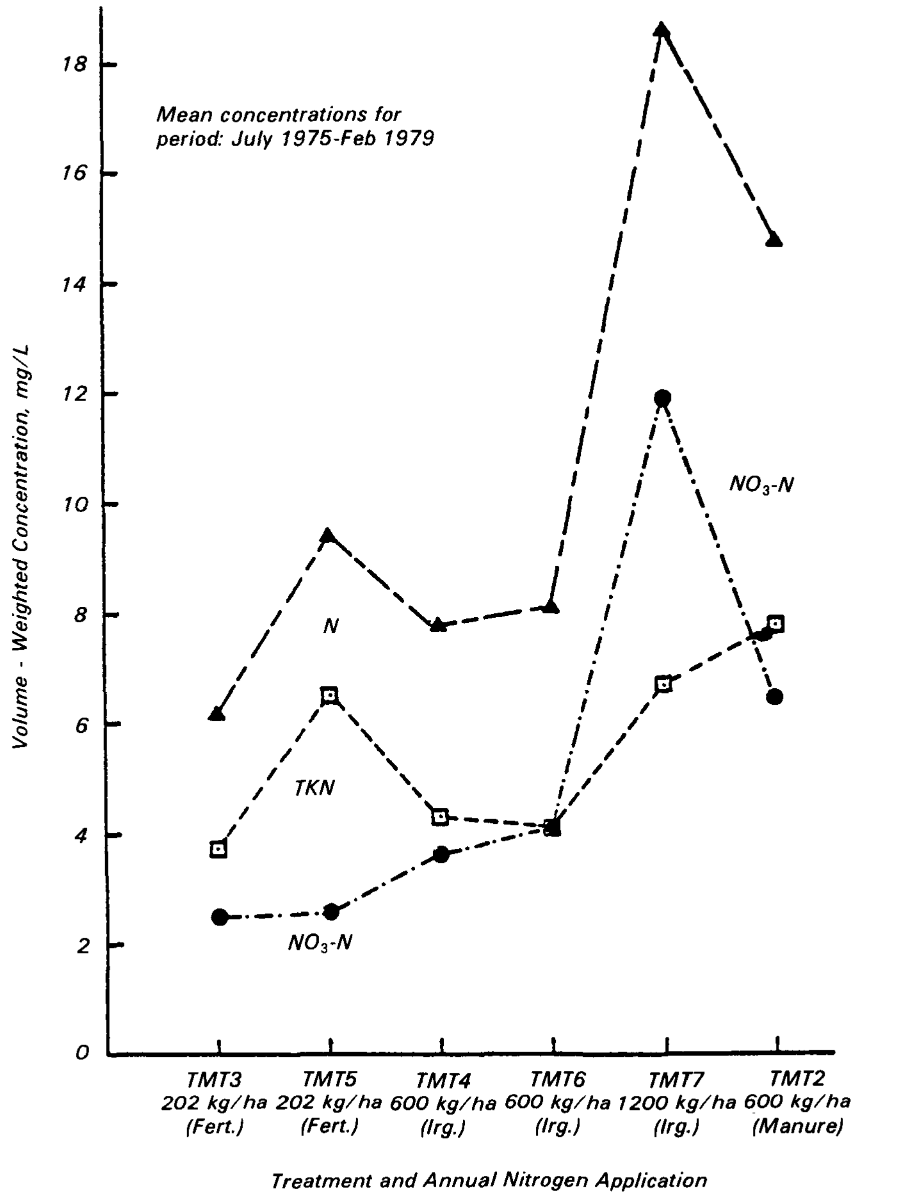

Figure 2. Effect of treatments on mean concentrations of N, TKN, and NO_3-N in rainfall runoff for entire period.

Rainfall Runoff

Rainfall runoff was relatively low during the 44-month period, averaging 2.4% to 7.8% of rainfall for the various treatments. The high-rate irrigation treatment had the largest amount of runoff but there were no other evident effects of slope or treatment. A statistical design with replicates would be needed to better investigate differences in runoff volume.

Volume-weighted concentrations and mass transport of nutrients in rainfall runoff were highest for the manure and high-rate irrigation treatments. Mean concentrations of NO_3-N, total Kjeldahl nitrogen (TKN) (not including NO_3-N) and N (including NO_3-N) in rainfall runoff are shown in Figure 2. Concentrations of N in runoff from the low-rate irrigation treatments were not much different from those of the fertilizer treatments. Because of generally low runoff amounts, the mass transport of nutrients was also low. The highest transport of N was for the high-rate irrigation plot and the manure plot, but the amounts transported were only about 1.3% of the N applied to those treatments.

The mean concentrations of P in runoff increased as loading rate of P increased, being in the range of about 0.5 to 1.5 mg/l for the fertilized and low-rate irrigation treatments, and about 6 and 7 mg/l for the manure and high-rate irrigation treatments, respectively. Overall, the manure and high-rate irrigation treatments had higher pollution potential than the fertilizer treatment and the low-rate irrigation treatment which had similar nutrient transport in runoff.

The highest pollution potential for a particular runoff event was just after an application of manure, effluent or fertilizer. A significant runoff event soon after application of any of these materials could account for a large portion of the annual nutrient transport in runoff. Manure and fertilizer seemed more available for runoff transport than did lagoon effluent just after application because they remained mostly on the soil surface for several days while lagoon effluent infiltrated quickly.

Variation of rainfall intensity, runoff rate and concentrations during a runoff event was investigated for some periods. For a particular plot, the concentrations remained fairly constant throughout an event, but the mean concentration varied from one event to another. For one large event a few days after a manure application, there seemed to be some variation in concentration in response to variation in rainfall intensity and runoff rate, but this was not evident for other events.

Philip W. Westerman, Larry D. King, Joseph C. Burns, and Michael R. Overcash are with North Carolina State University, Raleigh, NC 27650.
R. Douglas Kreis *is the EPA Project Officer (see below).*
The complete report, entitled "Swine Manure and Lagoon Effluent Applied to Fescue," (Order No. PB 83-259 861; Cost: $16.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Robert S. Kerr Environmental Research Laboratory
U.S. Environmental Protection Agency
Ada, OK 74820

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Cincinnati OH 45268