Elements left as potential pollutants following long-term application of swine effluent to coastal bermudagrass.

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INTRODUCTION

Initial consideration in disposing of animal waste places crop receivers as a major candidate. The application of waste onto a crop to be harvested provides a means of capturing elements in the plant tissue and, subsequently, removing them from the application site. The better adapted crop would be perennial, to avoid the need of annual planting, a high yielder, to remove maximum amounts of elements, and dependable in terms of stand survival and yield consistency. Ideally, the quantity of elements added in swine waste effluent would be taken up by the crop and removed in the harvested crop by the last harvest of the growing season. This would prevent the accumulation of certain elements in the soil of the spray field causing them to become potential pollutants.

In the case of swine production in confinement, waste is usually collected in anerobic lagoons and periodically delivered through an irrigation system onto a spray field planted to a receiver crop. This paper summarizes the quantity of elements applied in swine lagoon waste that are either removed as hay from a coastal bermudagrass receiver crop or left behind as potential pollutants in the soil after 11 years of application.

BACKGROUND

The study was conducted for 11 years with detail sampling of the forage, soil and water during years 1 through 6 (Burns et al., 1985; King et al., 1985; Westerman et al, 1985), followed by 4 years of effluent application and dry matter removal with detailed sampling resuming during the final or 11th year (Burns et al., 1990; King et al., 1990). In brief, the study was conducted about 10 miles east of Raleigh, NC on a Coastal Plain soil with three effluent loading rates in a randomized complete block design with three replicates (two were on a wagram loamy sand and the third further down the slope on a Norfolk loamy sand). Effluent was applied April through September from a secondary lagoon to deliver 300, 600, and 1200 lbs of N/acre. This was achieved by placing irrigation sprinklers at each corner of each of the nine plots (three rates x three replicates) that were 30 ft x 30 ft. The effluent was sprayed weekly to deliver 0.25, 0.5, and 1.0 inches of effluent for the 300, 600, and 1200 lbs/acre N loading rates, respectively. The plots were harvested by treatment each time bermudagrass reached 12 to 14 inches.

DRY MATTER YIELD

During the 11 year trial dry matter yields for the growing season averaged 9,905, 13,564, and 15,349 lbs/acre from the 300, 600, and 1200 lb/acre N loading rates (Figure 1). The seasonal yields from the 300 lb/acre N loading rate showed relatively small variation around the 11 yr mean line (Figure 1) compared with yields from the 600 and 1200 lb/acre N loading rates. The winter of 1976-77 was rather severe and considerable stand losses occurred from winter injury in the 600 and 1200 lbs N loading rates. This is reflected in the large reduction in dry matter yield for those two treatments (Figure 1). With the addition of sprigs to replicate three and stand recovery in replicates one and two, production returned to over 16,000 and 18,000 lbs/acre for the 600 and 1200 lb/acre N loading rates (Figure 1). While high yields could be obtained at the two higher N loading rates the system was unstable being variable from year to year.

EFFLUENT COMPOSTION

The effluent composition (collected in cups at the surface of the bermudagrass canopy) averaged 1.9 lbs of N/1,000 gallons of effluent (low = 1.7, and high = 2.9) for the 11 year study (Table 1). Phosphorus was about 32 % of the N content averaging 0.6 lbs/1,000 gallons of effluent. The content of the other elements determined in the effluent are also shown.

BERMUDAGRASS COMPOSITION

The concentration of elements in the forage was determined and are shown for the 1st, 6th and 11th year of the trial (Table 2). Nitrogen, Zn, Fe, and Na showed no change in concentration between the 6th and 11th year while P, K, Ca, Mg, Cl^-, S, and Cu showed increases (see Burns et al., 1985 for more detail).

DETERMINATION OF NUTRIENT RECOVERY
(yr 1 to 6)

An estimate of the quantity of each element recovered in the harvested forage was determined during the first 6 years of the trial. The recovery percentage for each element analyzed declined as N loading rate increased from the 300 (Table 3), to 600 (Table 4), and to 1200 (Table 5) lbs of N/acre. The quantity of each element not removed in the forage is noted at the bottom of each table as left behind and has potential to becoming a pollutant.

The potential recovery of additional N, P, and K in the soil profile was examined. Nitrogen present in the soil profile 6.9 ft deep from the spray-field soil, when compared to a control plot receiving 300 lbs/acre of N as ammonium nitrate showed no additional accumulation at the 300 lb/acre N loading rate, but showed an additional 27 and 714 lbs/acre for the 600 and 1200 lb/acre N loading rates, respectively (Table 6). This increased N recovery only 1 and 10 % units for the 600 and 1200 lb/acre loading rate. In essence the spray field with the receiver crop is an open-ended (both top and bottom) system in that elements can be lost either to the atmosphere or move over the surface or below the sampling depth. In the case of N, it would likely move below 6.9 ft.

Phosphorus showed a different response than N (Table 7). Considering only a 2.5 ft depth of soil an additional 49 % of the total P applied was recovered from the 300 lb/acre N loading rate, 54 % from the 600 lb/acre N loading rate and 48 % from the 1200 lb/acre N loading rate. This gave respective total recoveries of 90, 82, and 65 %.

Potassium recovery in the soil profile, in this case 10.8 ft deep, reflects the recoveries noted for P. Essentially all the K was recovered for the 300 lb/acre N loading rate but declined to 83 % and 61 % for the 600 and 1200 lb/acre N loading rates (Table 8).

QUANTITIES LEFT BEHIND AFTER 11 YEARS OF APPLICATION

Using the recovery rates determined for each element during the first 6 years of the study (Tables 3,4, and 5) and totaling the quantity of each element applied during the 11 year trial, permits an estimate of the quantity of each element not accounted for. The quantity of each element left behind probably either reside in the soil or are removed in the ground water. Nitrogen maybe an exception as some can escape into the atmosphere. In any case, elements left behind can become potential pollutants. At the 300 lb/acre N loading rate 945 lbs of N/acre was left behind and this increased to 2828 and 8682 lbs of N/acre at the higher N loading rates (Table 9). Phosphorus increased from 853 to 1966 to 4513 lbs/acre as N loading rate increased from 300 to 1200 lbs of N/acre. Elements as K and Na could accumulate in high quantities at the 600 and 1200 lbs/acre N loading rates (Table 10). Both Cu and Zn increased at increased N loading rates with quantities ranging from 6 to 26 lbs/acre for Cu and 3 to 21 lbs/acre for Zn (Table 11).

FORAGE NITRATE CONCENTRATION

Although nutritive value of the forage was reported elsewhere (Burns et al., 1985), it is worth noting that nitrate concentration in the forage was, generally, not a major concern relative to the use of the forage by ruminants. Bermudagrass is not considered a nitrate accumulator (Hajjati et al., 1972) and the nitrate concentrations found during this study reflect that (Table 12). In the 11th year of this study, however, consistent elevated $N0_3$-N concentrations, which approached or reached the toxicity threshold of 0.3 %, were noted at every harvest from the 1200 lbs/acre N loading rate. This indicates that $N0_3$-N can be accumulated in bermudagrass from a soil that has excessive amounts of nitrogen present. In this study it was not an issue at the 1200 lb/acre N loading rate during the first 6 years but was noted in the 11th year. No information is available for years 7 through 10.

SUMMARY

Coastal bermudagrass can serve as a receiver of swine waste and maintain its productivity. High rates of over 600 lbs of N/acre caused unstable conditions and considerable variation in bermudagrass stands and yield from year to year. The recovery of individual elements in the forage varied, but the percentage recovery of all declined as N loading rate increased. When determining the potential use of crops as a waste receiver consideration needs to be given to the elements present, and the quantity of each element that is not removed in the harvested dry matter. Those elements and the quantities that are left behind have the potential to become pollutants to the environment (air, soil, and water).

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Table 1. Element concentration in swine lagoon effluent collected in cups at the forage

Item	N	P	K	Ca	Mg	Na	Cl^-	Cu	Zn
	lb/1,000gal						g/1,000 gal.		
N Range									
Low	1.7	0.5	1.7	0.5	0.2	1.6	1.1	1.1	1.3
High	2.9	0.7	3.0	0.4	0.2	0.9	1.2	2.3	2.4
11 yr mean	1.9	0.6	2.0	0.4	0.2	1.0	1.3	1.4	1.7

Table 2. Element concentration in Coastal bermudagrass harvested in year one, six, and eleven.

Item	N	P	K	Ca	Mg	Cl^-	S	Cu	Zn	Na	Fe
	%							ppm			
Year1	2.2+	0.20	2.2	0.38	0.22	0.76	-	13	23	1406	220
Year 6	2.6	0.34	2.1	0.32	0.19	0.73	0.07	8	32	306	108
Year 11	2.7	0.38	2.5	0.39	0.27	0.84	0.26	9	33	341	92
Yr 6 vs Yr 11	NS	*	**	**	**	**	**	**	NS	NS	NS

+ values are the mean of three N loading rates and three replicates

NS, *, and ** = not significant, $P \leq 0.05$ and $P \leq 0.01$

Table 3. Recovery of elements from the 300 lb/acre N loading rate and quantity left behind based on quantity applied + and quantity removed in coastal bermudagrass hay.

Item	N	P	K	Ca	Mg	Na	Cl^-	Cu	Zn
Applied (lb/acre)	1810	418	1612	391	373	991	1092	2.4	2.4
Removed (lb/acre)	1323	171	1199	182	112	18	509	0.5	1.6
Recovery (%)	73	41	74	47	41	2	47	20	67
Left behind (lb/acre)	487	247	413	209	161	973	583	1.9	0.8

+values are the total for 6 yr and the mean of three replicates.

Table 4. Recovery of elements from the 600 lbs/acre N loading rate and quantity left behind

Item	N	P	K	Ca	Mg	Na	Cl^-	Cu	Zn
Applied (lb/acre)	3587	819	3197	701	546	1960	2158	4.8	4.5
Removed (lb/acre)	2045	230	1794	289	182	26	648	0.7	2.1
Recovery (%)	57	28	56	41	33	1	30	15	47
Left behind	1542	589	1403	412	364	1934	1510	4.1	2.4

+ values are the total for 6 yr and the mean of three replicates.

Table 5. Recovery of elements from the 1200 lb/acre N loading rate and quantity left behind

Item	N	P	K	Ca	Mg	Na	Cl^-	Cu	Zn
Applied (lb/acre)	7175	1612	6318	1510	1055	3909	4273	9.4	8.4
Removed (lb/acre)	2409	278	2835	348	209	28	589	0.8	2.6
Recovery (%)	34	17	32	23	20	< 1	14	9	31
Left behind	4766	1334	4283	1162	846	3881	3684	8.6	5.8

+ values are the total for 6 yr and the mean of three replicates.

Table 6. Nitrogen recovered considering that removed in the forage and recovered in 6.9 ft of

		In plant		In soil			Total	
N loading	Applieddd	Amt.	Recovery	Profilee	Adj.	Recovery	Recoveryed	Left
	lb/acre		%	lb/acre		%	%	lb/acre
Control +	1800	-	-	4658	-	-		
300	1810	1323	73	4283	-	-		487
600	3587	2045	57	4685	27	< 1	58	1507
1200	7175	2409	34	5372	714	10	44	4018

+ topdressed with 300 lb N/acre as ammonium nitrate

Table 7. Phosphorus recovered considering that removed in the forage and recovered in 2.5 ft

N loading		In plant		In soil		Total	
	Applied	Amt.	Recoveredd	Prof.ile	Recovered	Recoveredd	Left
(lb/acre)	lb/acre		%	lb/acre	%	%	lb/acre
300	418	171	41	207	49	90	42
600	819	230	28	442	54	82	98
1200	1612	278	17	767	48	65	564

Table 8. Potassium recovered considering that removed in the forage and recovered in 10.8 ft

N loading		In plant		In soil		Total	
	Applied	Amt.	Recovered	Profile	Recovered	Recovered	Left
(lb/acre)	lb/acre		%	lb/acre	%	%	lb/acre
300	1612	1199	74	464	29	103	-
600	3197	1794	56	870	27	83	543
1200	6318	2835	32	1838	29	61	2464

Table 9. Quantity of N, P, and K left behind after 11 years of swine lagoon effluent application to

N loading	N			P			K		
	Applied	Recovery	Left	Applied	Recovery	Left	Applied	Recovery	Left
(lb/acre)	lb/acre	%	lb/acre	lb/acre	%	lb/acre	lb/acre	%	lb/acre
300	3498	73	945	1446	41	853	4172	74	1085
600	6577	57	2828	2731	28	1966	7795	56	3430
1200	13154	34	8682	5435	17	4511	15608	32	10613

Table 10. Quantity of Ca, Mg, and Na left behind after 11 years of swine lagoon effluent application

N loading	Ca			Mg			Na		
	Applied	Recovery	Left	Applied	Recovery	Left	Applied	Recovery	Left
(lb/acre)	lb/acre	%	lb/acre	lb/acre	%	lb/acre	lb/acre	%	lb/acre
300	785	47	416	553	41	326	2097	2	2055
600	1490	41	879	1062	33	712	4025	1	3985
1200	2927	23	2254	2088	20	1670	8040	1	7960

Table 11. Quantity of Cl^-, Cu, and Zn left behind after 11 years of swine lagoon effluent application

N loading	Cl^-			Cu			Zn		
	Applied	Recovery	Left	Applied	Recovery	Left	Applied	Recovery	Left
(lbs/acre)	lb/acre	%	lb/acre	lb/acre	%	lb/acre	lb/acre	%	lb/acre
300	2766	47	1466	7	20	6	9	67	3
600	5238	30	3667	14	15	12	16	47	9
1200	10530	14	9056	28	9	26	31	31	21

Table 12. Nitrate-Nitrogen$^+$ concentration in Coastal bermudagrass hay during the growing

N loading rate	June	July	August	Sept.	After frost
	%				
6th year mean					
300	0.03	0.02	0.02	0.03	0.01
600	0.08	0.10	0.19	0.11	0.03
1200	0.11	0.19	0.22	0.19	0.05
11th year mean					
300	0.07	0.06	0.08	0.06	0.01
600	0.24	0.22	0.17	0.2	0.03
1200	0.33	0.27	0.32	0.28	0.10

$^+$ Toxicity threshold = 0.3%$N0_3$-N

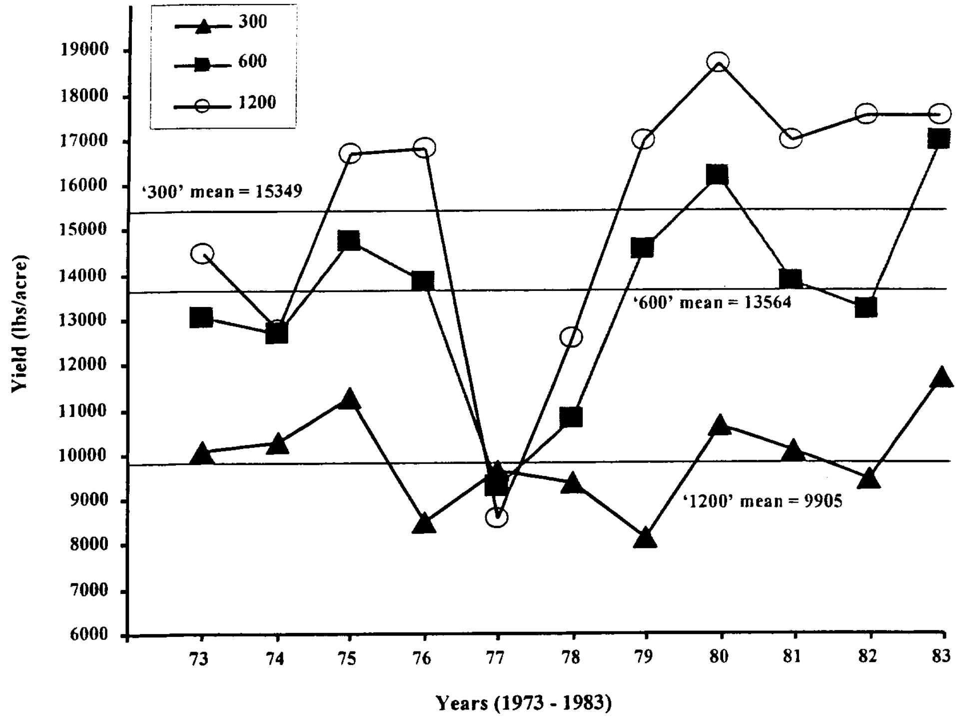

Fig.1. Annual dry matter yields of coastal bermudagrass when used as a receiver of swine lagoon effluent applied at three nitrogen loading rates of 300, 600, and 1200 lbs of N/acre (11 year study).

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