Poultry Litter as a Fertilizer for Bermudagrass: Effects on Yield and Quality

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ABSTRACT. Utilizing poultry litter as a fertilizer for bermudagrass (*Cyndon dactylon* (L.) Pers.) hay production may be an environmentally desirable disposal method, especially if yield and quality of the hay is maintained. A study was conducted on a Wynnville fine sandy loam (fine-loamy, siliceous, thermic Glossic Fragiudult), near Snead, AL, to determine the impact of poultry litter on bermudagrass yield and quality. Treatments included three rates of poultry litter (5.6, 11.2, and 22.4 Mg ha–1), three rates of ammonium-nitrate (112, 224, or 336 kg ha–1 in a split application), and a control. Hay was harvested in six cuttings over a two-year period. At the highest rates, no significant difference between poultry litter and ammonium-nitrate was observed with respect to average forage quality (mean of six cuttings) and two-year total yield. When examined by cutting, forage yield and quality were equal or greater with poultry litter than ammonium-nitrate at the first cutting each year, but were less at the second cutting. Apparent residual effects of poultry litter application resulted in increased yields and crude protein content in the second year of the study. It appears that fertilizing bermudagrass hay fields with poultry litter is an excellent sustainable agricultural practice.

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INTRODUCTION

Poultry production is growing rapidly in the U.S., especially in the Southeast, where production since 1986 has increased 48% in Alabama alone (Molnar and Wu, 1990). Alabama produces approximately 847 million broiler chickens annually, and production is expected to double by the end of the century. Most of this production is concentrated in the Sand Mountain region of northeastern Alabama. Associated with this production is a massive quantity (1.5×10^6 Mg yr^{-1}; Mitchell et al., 1989) of poultry litter (manure and cellulose material). Environmentally sound disposal of this material is essential to maintain the sustainability of the poultry industry.

In the Sand Mountain region of Alabama, disposal of poultry litter has traditionally been on relatively small areas of tall fescue (*Festuca arundinacea* Schreb.) pasture. Application of poultry litter on land used for forage production is an exemplary sustainable agricultural practice, which provides cycling of nutrients back into a productive form that can be utilized by farm animals. In addition to being a source of both micro- and macro-nutrients, land-applied poultry litter has been reported to increase soil organic N and C content, increase soil porosity, reduce soil bulk density, and enhance soil microbial activity (Power and Doran, 1984).

While land application is an excellent way to dispose of poultry litter and provide the nutritional requirements of tall fescue, repeated annual applications in excess of tall fescue needs in many cases, along with increasing litter production, has generated potential environmental problems (Kingery et al., 1991). Among the potential problems associated with excessive application are contamination of surface and ground waters with nitrate (NO_3) and phosphorus (P) and buildup of toxic levels of copper (Cu), iron (Fe), and zinc (Zn) in the soil (Aldrich, 1980; Long, 1979; Liebhardt et al., 1979; Anderson et al., 1991). Long-term application of poultry litter to fescue pastures has been shown to increase NO_3 leaching to bedrock and to promote excessive concentration of soil P, Cu, potassium (K), magnesium (Mg), and calcium (Ca) (Kingery et al., 1991).

Application of poultry litter to crops other than tall fescue could help relieve the problem of over application to a limited land area. However, because of both real and perceived problems, little of this material has been applied to row crops, summer pasture, or hay. In Alabama, more land area is devoted to hay production (304,000 ha) than any row crop (Barr, 1991). Therefore, application of poultry litter to land used for summer hay could provide increased land area for disposal as well as nutrients for the hay.

Because of its high yield potential and good forage quality, bermudagrass is an important hay crop in the southern U.S. (Ball et al., 1991). Bermudagrass could provide an excellent means of poultry litter disposal because of its high plant nutrient removal. Based on average yield and nutrient uptake for forages grown under normal production practices in the Southeast, bermudagrass will increase removal of N approximately 173% compared to tall fescue. Also, when compared to tall fescue, bermudagrass could provide an estimated 48, 116, and 50% increase in uptake of P, K, and Mg, respectively (Ball et al., 1991). Bermudagrass yield has responded to N applications as high as 1,200 kg ha^{-1}, with a linear yield response up to 600 kg N ha^{-1} (Wilkinson and Langdale, 1974). These findings suggest that bermudagrass could utilize high application rates of poultry litter.

The use of poultry litter as a fertilizer for bermudagrass could help abate the disposal problem. However, to become a widely accepted practice, application of poultry litter must maintain both yield and quality of bermudagrass. The objectives of this study were to (1) examine the impact of poultry litter as an alternative nitrogen source on bermudagrass hay yield and quality, and (2) to examine poultry litter effects on nutrient accumulations in bermudagrass tissue and in soil.

MATERIALS AND METHODS

A study was conducted for two years (1990-91) on a Wynnville fine sandy loam (fine-loamy, siliceous, thermic Glossic Fragiudult). The study site is contained within the Sand Mountain physiographic region and is located approximately 1 km from the community of Snead, Alabama (34° 5'N, 86° 25'W). Selected characteristics of the study site soil are given in Table 1. The study site had an established stand of Tifton 44 hybrid bermudagrass (4 years). Prior to initiation of the study, the bermudagrass

Table 1. Selected characteristics of the study site soil at initiation of the experiment (28 March 1990).

Depth	Sand	Silt	Clay	Texture	pH
cm	g kg^{-1}				1:1
0-5	475	450	75	Sandy Loam	4.2
5-10	455	470	75	Sandy Loam	4.8
10-20	350	575	75	Silt Loam	5.1
20-40	262	588	150	Silt Loam	4.6
40-60	325	525	150	Silt Loam	4.4
60-100	300	450	250	Loam	4.4

was managed for high quality hay production, including annual spring burning of stubble to minimize thatch buildup and disease. Yearly production practices included three cuttings and application of 336 kg N ha^{-1} as commercially available ammonium-nitrate fertilizer in a split application at green-up and following the first cutting. Cultural practices for the experiment (except for N application) were maintained as closely as possible to those used by producers in the area. Application of 39 kg P ha^{-1} and 74 kg K ha^{-1} was made annually to all plots. These rates were more than sufficient to meet the P and K requirements for bermudagrass hay production on the study site soil (Cope et al., 1980). In addition, 4.48 Mg dolomitic limestone ha^{-1} was applied at the initiation of the study to all plots. Individual plot areas were 2.4 by 9.1 m.

The experimental design was a randomized complete block with three replications. Nitrogen treatments included three rates of ammonium-nitrate and three rates of poultry litter. A control (0 kg N ha^{-1}) was also included in the experiment. Ammonium-nitrate treatments were 112, 224, or 336 kg N ha^{-1} in a split application with one half applied at spring green-up (28 March 1990 and 5 April 1991) and the remainder applied following the first cutting. Poultry litter was applied at a rate of 5.6, 11.2, and 22.4 Mg ha^{-1} at spring green-up.

The poultry litter used in this study was obtained from a broiler chicken production facility that used wood chips as bedding material. Litter was stockpiled under a pole-barn near the study site for a two-week period prior to application. Nutrient analyses of poultry litter used in the study are given in Table 2.

Bermudagrass was harvested for yield and forage quality analyses in six cuttings on 6 June, 2 September, 18 October and 10 June, 7 July, and 1 September, for 1990 and 1991, respectively. Harvest was achieved with a mechanized forage plot harvester; 1.2 by 5.8 m areas in the center of each plot were harvested. Forage samples were analyzed for crude protein, crude fiber, total digestible nutrients, and concentrations of Ca, K, Mg, P, Cu, Fe, Mn, Zn, and NO_3-N. Forage quality and mineral analyses were performed by the Soil Testing Laboratory, Auburn University, according to procedures outlined by Hue and Evans (1986).

Immediately prior to initiation of the experiment (28 March 1990), two soil cores per replication were collected from 0-5, 5-10, 10-20, 20-40, 40-60, and 60-100 cm depths and composited by depth increment across the study area. These soil samples were analyzed for particle size distribution by the hydrometer method (Gee and Bauder, 1986). In addition, pH of each sample was determined on 1:1 soil:H_2O slurries with a pH meter and a glass electrode.

Table 2. Analysis of poultry litter applied to bermudagrass in 1990 and 1991.

Plant Nutrient	per Mg		5.6 Mg		11.2 Mg		22.4 Mg	
	1990	1991	1990	1991	1990	1991	1990	1991
	(kg)							
N	25.7	27.7	144	155	288	310	576	620
NO_3-N	2.6	2.2	14	12	29	24	58	48
NH_4-N	1.6	6.4	9	36	17	72	35	144
P	7.3	9.6	41	54	82	108	163	215
K	11.6	12.2	65	69	130	137	261	274
Ca	11.2	12.5	63	70	125	140	250	281
Mg	3.0	2.9	17	16	34	33	67	66
Cu	0.1	0.2	1	1	1	3	3	5
Fe	0.1	0.4	1	2	1	4	1	8
Mn	0.1	0.2	1	1	1	2	2	4
Zn	0.1	0.2	1	1	1	2	2	5

Soil samples were collected at the conclusion of the study (15 September 1991) from 0-5, 5-10, 10-20, 20-40, 40-60, and 60-100 cm increments in the 336 kg N ha^{-1} ammonium-nitrate, 22.4 Mg poultry litter ha^{-1}, and control treatments. Ten-grams (oven dry basis) of each soil sample were extracted with 2*M* KCl, and NO_3-N analysis made on the extracts with a Lachat Autoanalyzer (Lachat Quik-Chem Systems, Mequon, WI) using standard colorimetric procedures (Keeney and Nelson, 1982). A portion of each soil sample was ground to pass a 0.15 mm stainless steel sieve. These finely ground subsamples were analyzed for organic N and C with a LECO CHN-600 analyzer (LECO Corp., Augusta, GA).

Bermudagrass biomass and nutrient concentration/content data were analyzed statistically as a randomized complete block having seven soil amendment treatments and three replications. Analyses of variance were conducted on data collected at each bermudagrass cutting and on two-year total biomass production and nutrient uptake data. Average biomass nutrient concentration data (average of the six cuttings) were also subjected to analyses of variance. Analyses of variance for soil organic C and N, and NO_3-N concentration data were conducted by depth as a randomized complete block. Analyses of variance were done with the SAS package (SAS Inst, 1982). Means were separated by Fisher's Protected LSD and by single degree of freedom contrasts. Unless otherwise noted, all statistical tests were performed at the $\alpha = 0.05$ level of significance.

RESULTS AND DISCUSSION

Bermudagrass Yield

The two-year total bermudagrass yield responses to applications of 5.6, 11.2, and 22.4 Mg poultry litter ha^{-1} were generally comparable to 112, 224, and 336 kg N ha^{-1} as ammonium-nitrate, respectively (Table 3). No statistically significant difference in yield was observed for the highest rates of poultry litter and ammonium-nitrate. However, ammonium-nitrate did perform better at the 224 kg N ha^{-1} rate compared to 11.2 Mg poultry litter ha^{-1}. Since 11.2 Mg ha^{-1} of poultry litter contained approximately 288-310 kg of total N (Table 2), the lower yield response was probably due to a lack of available N during some portion of the growing season. At the 22.4 Mg ha^{-1} poultry litter rate, ample N was apparently mineralized to provide N at a rate equivalent to 336 kg N ha^{-1} as ammonium-nitrate.

Examination of bermudagrass yield by cutting (Table 3) indicated that the split application of ammonium-nitrate benefitted bermudagrass yield. At the first cutting in 1990, there was no significant difference in the two highest rates of poultry litter and ammonium-nitrate. However, by the second cutting, greatest yields were achieved with the high rate of ammonium-nitrate. The 22.4 Mg poultry litter ha^{-1} treatment produced yields similar to 224 kg N ha^{-1} as ammonium-nitrate and a 17% decrease in yield compared to 336 kg N ha^{-1} as ammonium-nitrate. This was probably resultant of more N being available with the split application of ammonium-nitrate for plant uptake during peak periods following the first cutting. Below average rainfall prior to the second cutting in 1990 (Figure 1) could have retarded mineralization of litter-N, which, in turn, may have accounted for the yield reduction observed for litter amended bermudagrass. At the third cutting, drought conditions (Figure 1) resulted in greatly reduced yields and little or no differences among N rates regardless of N source.

Application of animal manure has been shown to have an appreciable residual effect on crop production (Bouldin et al., 1984). Such an effect was apparent in the second year of the study, with poultry litter showing a yield benefit compared to ammonium-nitrate (Table 3). In 1991, application of both 11.2 and 22.4 Mg poultry litter ha^{-1} at the first cutting (cutting 4) and 22.4 Mg poultry litter ha^{-1} at the second cutting (cutting 5) resulted in similar yields compared to the highest rate of ammonium-nitrate. At the third cutting of that year (cutting 6), 22.4 Mg poultry litter ha^{-1} resulted in significantly higher yield. These findings suggest that bermudagrass yields may benefit from the long-term use of poultry litter as a N source. However, climatic conditions appeared more favorable for litter-N mineralization

Table 3. Yield of bermudagrass as affected by N source and rate at Snead, AL during 1990 and 1991.

N Source	Cuttings						
	1990			1991			Two-year
	1	2	3	4	5	6	Total
				($Mg\ ha^{-1}$)			
No Fertilizer	1.46	1.12	0.40	1.08	0.72	0.94	5.76
Ammonium-Nitrate ($kg\ ha^{-1}$)							
112	5.02	5.15	0.63	5.44	4.35	1.16	21.86
224	8.69	7.17	0.43	7.91	4.97	1.99	32.79
336	9.07	8.76	0.63	8.83	6.94	3.32	37.30
Mean	7.59	7.03	0.56	7.39	5.42	2.16	30.65
Poultry Litter ($Mg\ ha^{-1}$)							
5.6	7.23	2.13	0.60	7.41	2.40	1.28	21.06
11.2	9.27	4.17	0.47	9.74	4.35	1.86	29.86
22.4	9.59	7.28	0.40	9.90	7.39	4.91	39.47
Mean	8.73	4.53	0.49	9.02	4.71	2.68	30.13
$LSD_{0.05}$	1.46	1.28	0.13	1.16	0.72	0.87	2.78
Contrasts†				$P > F$			
1	0.0001	0.0001	0.0844	0.0001	0.0001	0.0002	0.0001
2	0.0001	0.0001	0.0066	0.0001	0.0001	0.0028	0.0001
3	0.0138	0.0001	0.0715	0.0003	0.0001	0.0391	0.5031
4	0.0061	0.0003	0.6997	0.0049	0.0001	0.7825	0.5423
5	0.3997	0.0002	0.4448	0.0051	0.0001	0.7544	0.0498
6	0.4421	0.0274	0.0024	0.0688	0.1119	0.0016	0.1329

† Contrasts: 1 = control (C) v. poultry litter (PL); 2 = C v. ammonium-nitrate (AN); 3 = PL v. AN; 4 = 2.5 Mg PL ha^{-1} v. 100 kg N ha^{-1} as AN; 5 = 5 Mg PL ha^{-1} v. 200 kg N ha^{-1} as AN; 6 = 10 Mg PL ha^{-1} v. 300 kg N ha^{-1} as AN.

during the 1991 than the 1990 growing season (Figure 1). Thus, the apparent residual effect of litter on bermudagrass yield in 1991 may have been due, in part, to enhanced litter-N mineralization rates during the 1991 growing season. Even with the apparent residual effect of poultry litter application, a beneficial effect of the split ammonium-nitrate application was observed at the second 1991 cutting (cutting 5; Table 3).

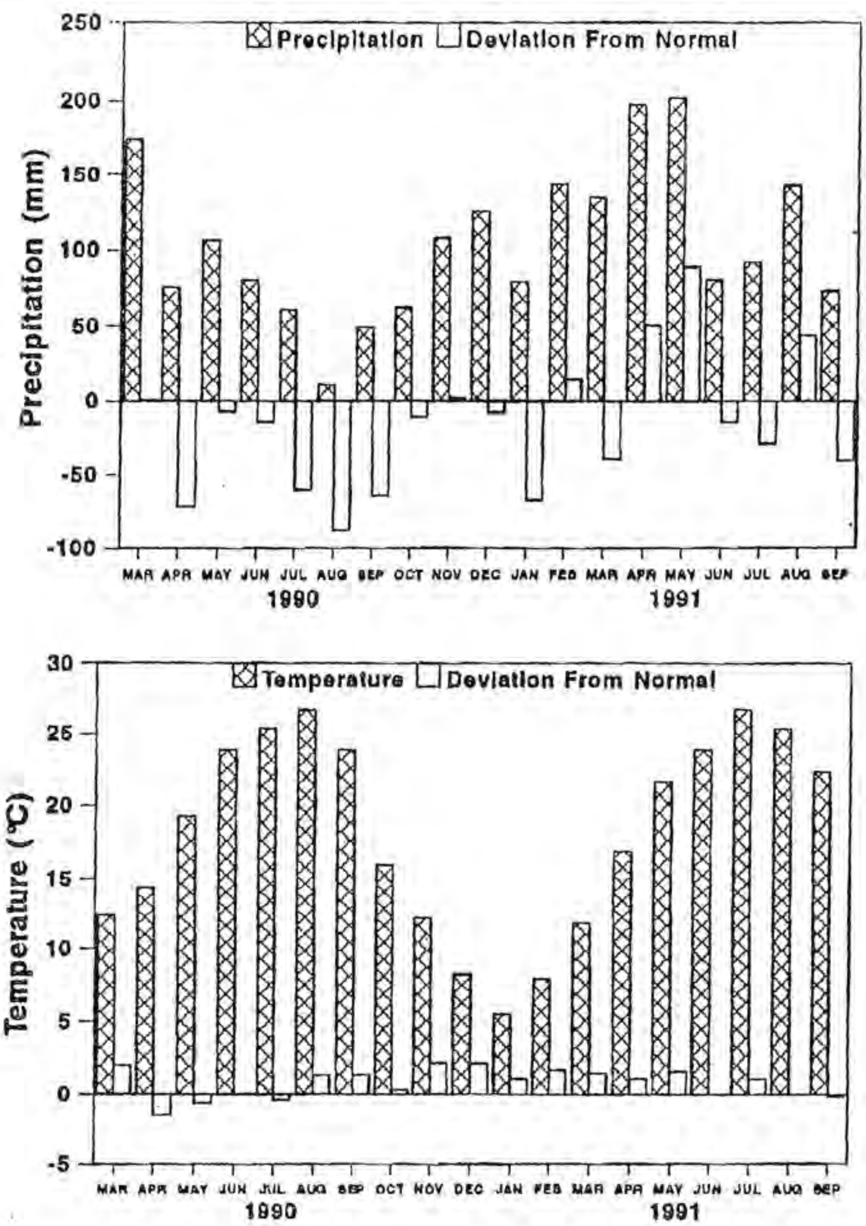

Figure 1. Monthly precipitation and mean monthly temperature at the study site during the experiment.

Bermudagrass Quality

Forage quality measurements, including crude protein (CP), total digestible nutrients (TDN), and crude fiber (CF) (Table 4), were changed significantly with N rate but not N source for the average concentrations over the two-year period. The TDN and CF responded similarly for individual cuttings (data not shown) and the average of the six cuttings (Table 4). Crude protein concentration of bermudagrass increased significantly

Table 4. Quality of bermudagrass (mean of six cuttings) as affected by N source and rate at Snead, AL.

N Source	Crude Protein ($g\ kg^{-1}$)	TDN‡ ($g\ kg^{-1}$)	Crude Fiber ($g\ kg^{-1}$)	NO_3-N ($mg\ kg^{-1}$)
No Fertilizer	80.6	555.3	306.1	211.7
Ammonium-Nitrate ($kg\ ha^{-1}$)				
112	87.4	550.6	309.2	189.3
224	103.4	536.9	312.1	190.7
336	121.6	525.7	325.4	229.3
Mean	104.1	537.7	315.6	203.1
Poultry Litter ($Mg\ ha^{-1}$)				
5.6	86.2	544.8	313.0	194.7
11.2	96.6	532.5	321.0	213.0
22.4	119.2	531.8	321.4	580.3
Mean	100.7	536.4	318.5	329.3
$LSD_{0.05}$	8.1	12.7	8.3	65.0
Contrasts†		P > F		
1	0.0001	0.0018	0.0019	0.0004
2	0.0001	0.0030	0.0027	0.7315
3	0.1350	0.6911	0.6952	0.0001
4	0.7534	0.3382	0.3397	0.8611
5	0.0913	0.4638	0.4587	0.4686
6	0.5426	0.3148	0.3079	0.0001

‡ TDN = total digestible nutrients

† Contrasts: 1 = control (C) v. poultry litter (PL); 2 = C v. ammonium-nitrate (AN); 3 = PL v. AN; 4 = 2.5 Mg PL ha^{-1} v. 100 kg N ha^{-1} as AN; 5 = 5 Mg PL ha^{-1} v. 200 kg N ha^{-1} as AN; 6 = 10 Mg PL ha^{-1} v. 300 kg N ha^{-1} as AN.

with increasing N application, with the highest rate of ammonium-nitrate closely matching the highest rate of poultry litter. While increasing N application rates increased quality by increasing CP concentration, TDN was decreased and CF was increased in the forage, indicating lower quality (Ensminger and Olentine, 1978). As with CP, the effect of N source on TDN and CF was similar, with the highest ammonium-nitrate rate closely resembling the highest poultry litter rate. While the effect of N application on TDN and CF was significant, ranging from 500 to 580 g kg^{-1} for TDN and 290 to 340 g kg^{-1} for CF, the range in values were not substantially less than the quality of bermudagrass typically used in southern U.S. production systems (Ensminger and Olentine, 1978; Ball et al., 1991).

Summer forages cut for hay often have insufficient CP for ruminant diets when inadequately fertilized with N (Ball et al., 1991). When examined by cutting (Table 5), differences in CP concentrations were large enough to affect feeding quality of the hay. In addition, unlike CF and TDN, there were differences between N sources as well as N rate. At the first cutting (1990), the CP concentration of bermudagrass fertilized with poultry litter responded similarly to that fertilized with ammonium-nitrate, with the highest CP concentration resulting from 22.4 Mg poultry litter ha^{-1}. However, at the second and third cuttings, CP concentration was significantly reduced when poultry litter was used as a N source compared to ammonium-nitrate. Reduced CP concentrations of litter amended bermudagrass for cuttings 2 and 3 in 1990 may have been due to climatic conditions (Figure 1) that slowed litter-N mineralization rates. Similar results were obtained in 1991 (Table 5), with poultry litter resulting in a significant increase in CP concentration immediately following litter application and a reduction in CP concentration for subsequent cuttings. However, owing to the apparent residual effect of litter and perhaps to climatic conditions more favorable for litter-N mineralization, reduction in CP concentration was not as pronounced for later cuttings in 1991 as for those in 1990. Comparing the highest rates of litter and ammonium-nitrate, only a 12% reduction of CP occurred in 1991 compared with a 21% reduction in 1990.

Because of potential nitrate poisoning of farm animals, nitrate levels in feed are a quality concern. A significant increase in NO_3-N in the forage was observed with 22.4 Mg poultry litter ha^{-1}, with an average value of 580 mg kg^{-1} (Table 4). However, this level is well below the 1,150 mg NO_3-N kg^{-1} critical limit for feeding (Cheeke and Shull, 1985), suggesting that NO_3-N levels in bermudagrass fertilized with poultry litter should not affect feeding quality of hay under normal environmental conditions. These findings are consistent with previous work; in a review of N fertil-

Table 5. Crude protein concentration of bermudagrass as affected by N source and rate at Snead, AL.

	Cuttings					
	1990			1991		
N Source	1	2	3	4	5	6
	($g\ kg^{-1}$)					
No Fertilizer	68.9	64.6	84.9	93.9	99.7	71.6
Ammonium-Nitrate ($kg\ ha^{-1}$)						
112	76.4	66.9	81.7	103.0	123.3	73.2
224	94.8	78.7	108.9	114.4	140.6	83.2
336	111.5	84.4	141.3	137.6	158.4	96.2
Mean	94.2	76.7	110.6	118.3	140.8	84.2
Poultry Litter ($Mg\ ha^{-1}$)						
5.6	76.2	63.2	84.9	117.4	103.4	72.4
11.2	95.5	63.1	96.3	142.1	110.6	74.7
22.4	131.3	67.8	109.5	182.2	140.2	84.4
Mean	101.0	64.7	96.9	147.2	118.1	77.2
$LSD_{0.05}$	13.8	10.0	8.5	11.2	16.4	13.4
Contrasts†	$P > F$					
1	0.0001	0.9768	0.0045	0.0001	0.0113	0.3307
2	0.0004	0.0075	0.0001	0.0001	0.0001	0.0362
3	0.0990	0.0007	0.0001	0.0001	0.0002	0.0971
4	0.9753	0.4440	0.4234	0.0161	0.0203	0.9103
5	0.9097	0.0053	0.0021	0.0002	0.0018	0.2108
6	0.0088	0.0036	0.0001	0.0001	0.0318	0.0944

† Contrasts: 1 = control (C) v. poultry litter (PL); 2 = C v. ammonium-nitrate (AN); 3 = PL v. AN; 4 = 2.5 Mg PL ha^{-1} v. 100 kg N ha^{-1} as AN; 5 = 5 Mg PL ha^{-1} v. 200 kg N ha^{-1} as AN; 6 = 10 Mg PL ha^{-1} v. 300 kg N ha^{-1} as AN.

ization experiments conducted on bermudagrass, Wilkinson and Langdale (1974) found little documentation of hazardous tissue NO_3-N accumulation, even when the grass had been fertilized with 2,242 kg N ha^{-1} yr^{-1}.

In addition to N, poultry litter contains significant quantities of other plant nutrients (Table 2) that may result in increased plant growth. Many of these elements are also important for animal nutrition due to both deficient and toxic levels in the diet (i.e., Mg, Ca, P, Fe, Mn, K, Zn deficiency and Cu toxicity in ruminants; Ensminger and Olentine, 1978). With the exception of Ca and K, there were no significant or apparent differences in bermudagrass concentration of these elements due to N source.

Both the two-year average concentration and two-year total uptake of Ca and K were affected by N source (Table 6). With the application of ammonium-nitrate, there was no difference in Ca concentration in the forage, compared to the control, while a significant increase in Ca concentration occurred with 11.2 and 22.4 Mg poultry litter ha^{-1} compared to the control and ammonium-nitrate. This concentration increase resulted in a significant increase in Ca uptake with 22.4 Mg poultry litter ha^{-1} (Table 6). The beneficial effect of poultry litter compared to ammonium-nitrate was more evident with K than Ca levels in the forage (Table 6). The concentration of K in the forage was reduced with increasing rate of ammonium-nitrate application, while increased poultry litter rate resulted in a significant increase in bermudagrass K concentration, and a significant increase in K uptake with increasing poultry litter rates. The lowest rate of poultry litter (5.6 Mg ha^{-1}) resulted in K uptake statistically equivalent to the highest rate of ammonium-nitrate. Apparently, the use of poultry litter as a N source could improve bermudagrass hay quality due to higher levels of Ca and K for animal diets. However, the bermudagrass Ca and K concentrations observed in this study were all within the range considered adequate for beef cattle diets (Reid and Jung, 1974).

Effect on Soil C and N

Because of potential benefits of poultry litter on soil properties (Power and Doran, 1984), concentrations of soil organic C and N were examined for the high rates of ammonium-nitrate and poultry litter and compared to the control (0 kg N ha^{-1}). Although numerically greater soil organic C and N concentrations were found in the upper 5 cm of soil with poultry litter than with ammonium-nitrate or the control (Figure 2), no statistically significant differences for these parameters were observed for any of the soil depths. Perhaps with long-term application of poultry litter the soil condition will be improved via accumulation of soil organic C and N. In another study in the Sand Mountain region of Alabama, we have observed significant accumulations of soil organic C and N to a depth of 30 cm under tall fescue pastures amended with poultry litter for 15 to 28 yrs (Kingery et al., 1992).

Because of the potential problem of NO_3 leaching below root zones

Table 6. Calcium and potassium concentration (mean of six cuttings) and uptake (total in six cuttings) in bermudagrass as affected by N source and rate at Snead, AL.

	Calcium		Potassium	
N Source	Concentration ($g\ kg^{-1}$)	Uptake ($kg\ ha^{-1}$)	Concentration ($g\ kg^{-1}$)	Uptake ($kg\ ha^{-1}$)
No Fertilizer	2.6	15.3	10.4	59.4
Ammonium-Nitrate ($kg\ ha^{-1}$)				
112	2.6	58.6	10.3	234.6
224	2.5	81.8	8.9	300.8
336	2.6	93.0	8.5	334.8
Mean	2.6	77.8	9.2	290.1
Poultry Litter ($Mg\ ha^{-1}$)				
5.6	2.6	58.3	12.9	319.1
11.2	2.8	86.7	14.3	504.1
22.4	3.1	121.1	17.3	754.1
Mean	2.8	88.7	14.8	525.8
$LSD_{0.05}$	0.2	8.5	0.9	40.7
Contrasts†		P > F		
1	0.0083	0.0001	0.0001	0.0001
2	0.7885	0.0001	0.0053	0.0001
3	0.0004	0.0011	0.0001	0.0001
4	0.7427	0.9335	0.0001	0.0017
5	0.0197	0.2896	0.0001	0.0001
6	0.0002	0.0001	0.0001	0.0001

† Contrasts: 1 = control (C) v. poultry litter (PL); 2 = C v. ammonium-nitrate (AN); 3 = PL v. AN; 4 = 2.5 Mg PL ha^{-1} v. 100 kg N ha^{-1} as AN; 5 = 5 Mg PL ha^{-1} v. 200 kg N ha^{-1} as AN; 6 = 10 Mg PL ha^{-1} v. 300 kg N ha^{-1} as AN.

with high rates of poultry litter (Kingery et al., 1991), soil NO_3-N concentration was examined. Nitrate-N levels in the 0 to 5 cm depth ($P > F = 0.021$, $LSD_{0.05} = 0.3\ mg\ kg^{-1}$) and in the 5 to 10 cm depth ($P > F = 0.009$, $LSD_{0.05} = 0.1\ mg\ kg^{-1}$) were increased with both ammonium-nitrate and poultry litter, with the poultry litter resulting in the highest level of NO_3-N in the upper 5 cm (Figure 2). Unlike the results reported by Kingery et al.

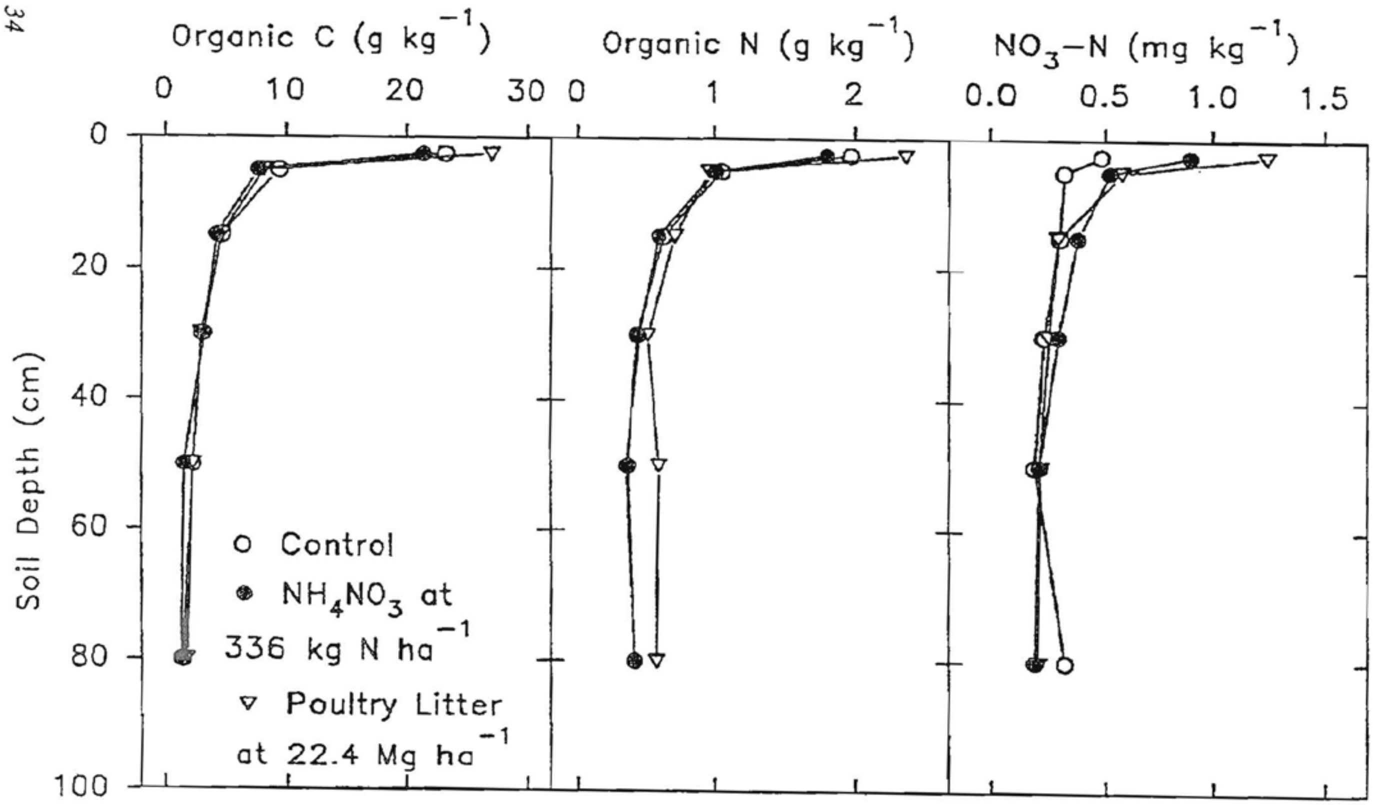

Figure 2. Soil organic C and N, and NO_3-N by depth at conclusion of the study.

(1991) for long-term application of poultry litter to tall fescue, however, no differences in NO_3-N levels could be detected below 10 cm. Apparently, application of 22.4 Mg poultry litter ha^{-1} to bermudagrass does not promote buildup of excessive subsoil NO_3-N that could leach into groundwater. However, it should be noted that soil sampling was done after the period of maximum N uptake by bermudagrass (15 September 1991), which may have biased the soil NO_3-N results. Unfortunately, data that would allow determination of NO_3-N movement through the soil profile during bermudagrass dormancy (winter) were not collected. In addition, soil sampling was only done to a depth of 1 m. In a recent study (Kingery et al., 1992), where soil sampling was done in early spring to a depth of 3 m or lithic contact, we found large accumulations of NO_3-N below 1 m under litter amended fescue pastures in the Sand Mountain region of Alabama.

CONCLUSIONS

The results from this study indicate that poultry litter can be used as an alternative N source for bermudagrass hay production. While the conventional fertility practice of split application of ammonium-nitrate could result in higher yield and crude protein levels in late season cuttings, apparent residual effects of poultry litter may result in both increased yields and hay quality with long-term application. Therefore, judicious use of poultry litter as a N source for bermudagrass hay production should represent both an economical and environmentally sound method of disposing of this waste product, and constitute a sustainable practice.

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