Effects of Dairy Manure Compost and Supplemental Fertilizer on Forage Yield and Nutritive Value of Coastal Bermudagrass

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ABSTRACT

Research was conducted to compare the effects of composted dairy manure and raw dairy manure alone, or in combination with supplemental inorganic fertilizer, on Coastal bermudagrass [*Cynodon dactylon* (L.) Pers.] yield and quality. Composted dairy manure was surface applied at rates of 14 (125 kg N ha^{-1}), 29 (250 kg N ha^{-1}) and 57 (500 kg N ha^{-1}) Mg dry matter (DM) ha^{-1}, and raw dairy manure was surface applied at a rate of 54 (420 kg N ha^{-1}) Mg DM ha^{-1} to established bermudagrass. Selected compost and manure plots received supplemental inorganic N at rates of 56, 84 and 112 kg ha^{-1} cutting^{-1} or 112 kg ha^{-1} cutting^{-1} of supplemental N with supplemental inorganic phosphorus or potassium at rates of 112 kg P2O5 ha^{-1} yr^{-1} and 112 kg K2O ha^{-1} cutting^{-1}, respectively. Composted dairy manure (29 and 57 Mg DM ha^{-1}) or raw manure alone increased cumulative forage yields compared to the untreated check in both years of the study, but were less than those obtained using only inorganic fertilizer. Application of 56 kg N ha^{-1} cutting^{-1} or more of supplemental N to compost (29 and 57 Mg DM ha^{-1}) or manure produced forage yields that were equal to or greater than those obtained using inorganic fertilizer alone. Supplemental inorganic K improved forage yields for the low rate of compost and manure, but no yield response was observed when supplemental inorganic P was applied to compost or manure.

Tissue N concentrations tended to increase with increasing rates of supplemental N applied to compost or manure; however, uptake of N derived from compost or manure did not appear to be as efficient as it was from plots receiving only inorganic fertilizer. Significant yield and tissue K responses to applications of supplemental inorganic K were observed and indicated that application of compost and manure at low and intermediate rates may require supplemental inorganic K by the end of the first growing season and for the majority of the second season.

INTRODUCTION

The dairy industry in north central Texas faces significant environmental challenges related to management of livestock manure generated by concentrated animal feeding operations. Rapid growth during the 1980's made Erath County a major milk-producing county, which currently has over 41,000 dairy cows. At the same time, operations in this watershed shifted from relatively small dairies to large, concentrated animal feeding operations. The North Bosque River was included on the Texas Clean Water Act (CWA) 303(d) list in 1998 and identified as impaired under narrative water quality standards related to nutrients and aquatic plant growth. Subsequently, two P TMDLs were prepared and adopted by the Texas Commission on Environmental Quality for segments 1226 and 1255 of the North Bosque River.

Although removal and utilization of manure outside the Bosque watershed is a preferred solution, transportation costs limit the distribution radius and economic feasibility of this option. Other issues affecting the marketability of manure for land application are nuisance odor, pathogen concerns, insect larvae and viable weed seed content. One proposed strategy to address problems associated with manure management that has attracted the attention of farmers, waste-generators, public officials and environmentalists is composting. Composting manure produces a product that is more easily handled and stored because it reduces the total weight and volume of the material. Compost also has low odor and temperatures reached during the composting process kill most pathogens and viable weed seeds (Eghball and Power, 1999a). Like raw manure, compost can improve soil physical and chemical properties by increasing organic matter while providing plant nutrients (DeLuca and DeLuca, 1997). However, the effects of composting on release rates and plant availability of nutrients contained in manure are not well understood. This information is essential to determine proper application rates of compost and the need for supplemental fertilizer so that compost use may be both economical and environmentally sound.

MATERIALS and METHODS

A field study was conducted on an established non-irrigated Coastal bermudagrass field at the Texas A&M University Agricultural Research and Extension Center near Stephenville, Texas (N 32° 15', W 98° 12', altitude 395 m) in 2002 and 2003. Sixty-six plots, each 3- by 6-m, were established at the site and received treatments containing dairy manure compost or raw dairy manure, alone or in combination with supplemental rates of inorganic fertilizer N, P and/or K. Dairy manure compost was applied at 3 rates to supply N at 125 (14 Mg DM ha^{-1}), 250 (29 Mg DM ha^{-1}) and 500 (57 Mg DM ha^{-1}) kg total N ha^{-1}. Dairy manure was applied at a single rate of 420 (54 Mg DM ha^{-1}) kg total N ha^{-1}. Selected compost and manure plots received supplemental inorganic N at rates of 56, 84 and 112 kg N ha^{-1} cutting^{-1}. In addition, selected compost and manure plots receiving 112 kg N ha^{-1} cutting^{-1} also received supplemental P at a rate of 112 kg P2O5 ha^{-1} yr^{-1} applied at spring green-up or supplemental K at 112 kg K_2O ha^{-1} cutting^{-1}. An inorganic fertilizer treatment based on soil test recommendations (112 kg N ha^{-1} cutting^{-1}, 112 kg P_2O_5 ha^{-1} yr^{-1}, 112 kg K_2O ha^{-1} cutting^{-1}) and an unfertilized check also were included. Inorganic N, P and K sources were ammonium nitrate (34-0-0), triple superphosphate (0-46-0), and potassium chloride (0-0-60), respectively. Treatments were arranged in a randomized complete block design with three replications.

Initial compost, manure and inorganic fertilizer treatments were surface applied by hand at spring green-up with subsequent applications of inorganic fertilizer for selected treatments being applied after each harvest. Dairy manure compost and raw manure were applied only at the initiation of the study with the exception of the two C1 (14 Mg ha^{-1}) treatments, which were applied annually. A summary of all treatments applied is provided in Table 1.

Samples of the dairy manure compost and raw dairy manure were collected at the time of application to determine chemical characteristics. Three subsamples were obtained by collecting a minimum of ten grab samples from an 8-m^3 stockpile purchased for the study. Samples were analyzed in the Texas Cooperative Extension laboratory on a dry weight basis. Total N (TKN; colorimetric measurement using a Technicon Auto Analyzer II), P, K, Ca, Mg, Na, Zn, Fe, Cu, and Mn (Inductively Coupled Argon Plasma (ICP) spectrometry analysis) were determined using a modified Kjeldahl digestion procedure.

Table 1. Treatment summary.

Treatment	Rate	Supplemental Inorganic Fertilizer N	P$_2$O$_5$	K$_2$O
	Mg ha^{-1}	kg ha^{-1} cutting^{-1}	kg ha^{-1} yr^{-1}	kg ha^{-1} cutting^{-1}
Compost (C1)	14	56	—	—
Compost (C1)	14	112	—	—
Compost (C2)	29	—	—	—
Compost (C2)	29	56	—	—
Compost (C2)	29	84	—	—
Compost (C2)	29	112	—	—
Compost (C2)	29	112	112	—
Compost (C2)	29	112	—	112
Compost (C3)	57	—	—	—
Compost (C3)	57	56	—	—
Compost (C3)	57	84	—	—
Compost (C3)	57	112	—	—
Compost (C3)	57	112	112	—
Compost (C3)	57	112	—	112
Manure (M)	54	—	—	—
Manure (M)	54	56	—	—
Manure (M)	54	84	—	—
Manure (M)	54	112	—	—
Manure (M)	54	112	112	—
Manure (M)	54	112	—	112
Untreated Check (UC)	—	—	—	—
Inorganic Fertilizer (IF)	—	Soil Test Recommendation 112	112	112

The C:N ratio of manure and compost was determined using an Elementar Vario Max CN elemental analyzer (Elementar Americas, Inc., NJ). Compost and manure treatments were applied based on initial nutrient and moisture analysis and were not corrected for N availability or N volatilization losses from the manure.

All plots were harvested on approximately 28-day intervals using an ALMACO forage harvester (ALMACO; Nevada, IA) to cut a 1.32- by 6-m swath from the center of each plot. This allowed for 0.84-m buffers on either side of the swath as well as 1.32-m buffers on either end of the swath to minimize edge effect. Field plots were harvested four times each in 2002 and 2003. Harvest dates in 2002 were May 16, June 14, July 15 and October 2. Harvest dates in 2003 were May 19, June 18, July 17 and September 25. Forage sub-samples were collected from each plot for laboratory analysis, ovendried at 65°C, and weighed to determine moisture content. Data were analyzed by PROC GLM modified for repeated measures analysis in statistical analysis system (SAS Inst.) to determine analysis of variance (ANOVA), and means separated using Fisher's protected least significant difference (LSD) method at the 0.05 significance level.

Figure 1. Screening operation prior to shipping dairy manure compost.

RESULTS and DISCUSSION

There was a year by treatment interaction for forage yield. Where treatment by harvest interactions were observed, means within a harvest were analyzed. Without supplemental inorganic fertilizer, dairy manure compost applied at rates of 29 (C2) and 57 (C3) Mg ha^{-1} and raw dairy manure (M) applied at 54 Mg ha^{-1} produced cumulative forage yields significantly greater than the untreated check in both years of the study (Table 2). However, inorganic fertilizer (IF) produced cumulative forage yields greater than either rate of compost and dairy manure in both years. In contrast, Eghball and Power (1999b) reported corn grain yields from annual or biennial manure or compost applications were similar to the inorganic fertilizer treatment. Cumulative yields for C2 and C3 ranged from 9,781 to 11,844 kg DM ha^{-1} and were not different from the dairy manure treatment (M) in either year.

Table 2. Effects of dairy manure compost, raw dairy manure and inorganic fertilizer alone compared to untreated check on Coastal bermudagrass yields.

Treatment†	H1	H2	H3	H4	Cumulative
2002 (Yield, kg ha^{-1})					
C2	2,448	1,723	2,967	2,643	9,781 b‡
C3	3,503	2,275	3,166	2,899	11,844 b
M	2,847	1,951	3,283	2,646	10,727 b
IF	4,274	3,327	4,367	4,088	16,056 a
UC	1,451	932	2,323	1,871	6,577 c
					***
2003 (kg ha^{-1})					
C2	3,418	2,320	2,290	2,646	10,674 b‡
C3	3,671	2,374	2,511	2,785	11,342 b
M	4,140	2,571	2,969	3,250	12,931 b
IF	5,915	3,793	4,380	5,064	19,153 a
UC	2,505	1,520	1,574	1,557	7,156 c
					***

†Abbreviations: C2, compost 29 Mg ha^{-1}; C3, compost 57 Mg ha^{-1}; M, manure 54 Mg ha^{-1}; IF, inorganic fertilizer (112 kg N ha^{-1}; 112 kg P_2O_5 ha^{-1} yr^{-1}; 112 kg K_2O ha^{-1}); UC, untreated check.

‡Means within a year and column followed by the same letter are not significantly different.

*,**,*** P ≤ 0.05, P ≤ 0.01 and P ≤ 0.001; NS = not significant; (Fishers Protected LSD).

There was a N rate by compost or manure rate interaction on forage yields in both years. In 2002, application of supplemental inorganic N at 56 kg ha^{-1} cutting^{-1} to the manure (M) treatment produced yields that were significantly greater than those in the IF treatment for the second harvest, and a similar trend was observed for harvest 4 although differences were not significant (Table 3). Compost at the highest rate (C3, 57 Mg ha^{-1}) with supplemental N (56 kg N ha^{-1}) produced yields equal to IF for all three harvests in 2002 and a similar result was observed for the 29 Mg ha^{-1} (C2) rate of compost for harvests 3 and 4. Even with supplemental N, the low rate of compost (C1, 14 Mg ha^{-1}) produced significantly lower yields than IF and other treatments for most harvests. In contrast, in 2003 supplemental fertilizer applied at 56 kg N ha^{-1} cutting^{-1} to all three rates of compost and raw manure produced cumulative yields that were not different from each other or IF. Cumulative forage yields for compost and manure treatments in 2003 ranged from 17,530 to 19,274 kg DM ha^{-1} compared to 19,153 kg DM ha^{-1} for IF. Application of 84 kg ha^{-1} cutting^{-1} of supplemental N to compost or manure plots produced cumulative forage yields that were not different from IF in either 2002 or 2003 (data not shown). Cumulative forage yields in 2002 ranged from 11,782 to 13,999 kg DM ha^{-1} and in 2003 yields ranged from 19,153 to 20,550 kg DM ha^{-1}. A similar response was observed in both years when 112 kg N ha^{-1} cutting^{-1} was applied to the three rates of compost and manure.

Supplemental inorganic P (112 kg P2O5 ha^{-1} cutting^{-1}) did not improve bermudagrass yields in plots receiving compost at 29 or 57 Mg ha^{-1} or those receiving raw dairy manure at 54 Mg ha^{-1} in either year (data not shown). When compost was applied at 29 Mg ha^{-1}, supplemental K (112 kg K2O ha^{-1} cutting^{-1}) increased forage yields at the fourth harvest in 2002 and the third harvest in 2003, and a similar trend was observed for the second and fourth harvests in 2003 (Table 4). In contrast, there was no apparent response to supplemental K in either year when compost was applied at 57 Mg ha^{-1}. In plots receiving manure, supplemental K increased cumulative yields in 2002 and harvest 2 yield in 2003, with similar trends for harvests 3 and 4 in the second year (data not shown).

Table 3. Effects of dairy manure compost and raw dairy manure with supplemental N at 56 kg ha^{-1} cutting^{-1} compared to inorganic fertilizer alone on Coastal bermudagrass yields.

Treatment†	H1	H2	H3	H4	Cumulative
2002 (Yield, kg ha^{-1})					
C1	—	2,542 d‡	3,723 b	3,345 b	9,610
C2	—	2,990 c	4,267 a	4,505 a	11,762
C3	—	3,563 ab	4,467 a	3,446 b	11,475
M	—	3,740 a	4,433 a	4,607 a	12,779
IF	—	3,327 b	4,367 a	4,088 ab	11,782
		***	*	*	
2003 (kg ha^{-1})					
C1	5,389	3,907	3,835	4,398	17,530‡
C2	5,717	4,128	4,215	4,599	18,657
C3	5,927	4,224	4,277	4,792	19,219
M	6,058	3,961	4,273	4,981	19,274
IF	5,915	3,793	4,380	5,064	19,153
					NS

†Abbreviations: C1, compost 14 Mg ha^{-1}; C2, compost 29 Mg ha^{-1}; C3, compost 57 Mg ha^{-1}; M, manure 54 Mg ha^{-1}; IF, inorganic fertilizer (112 kg N ha^{-1}; 112 kg P_2O_5 ha^{-1} yr^{-1}; 112 kg K2O ha-1).

‡Means within a year and column followed by the same letter are not significantly different.

*,**,*** P ≤ 0.05, P ≤ 0.01 and P ≤ 0.001; NS = not significant; (Fishers Protected LSD).

Table 4. Effects of two rates of supplemental K applied to composted dairy manure (29 Mg ha^{-1}) receiving 112 kg ha^{-1} cutting^{-1} supplemental N compared to inorganic fertilizer along on Coastal bermudagrass yields.

Treatment†	K_2O	H1	H2	H3	H4	Cumulative
2002 (Yield, kg ha^{-1})						
C2	0	—	3,524‡	4,736 a	4,081 b	12,340
C2	112	—	3,465	4,871 a	5,089 a	13,424
IF		—	3,326	4,367 b	4,088 b	11,782
			NS	*	*	
2003 (kg ha^{-1})						
C2	0	6,617 a	4,160	4,605 b	4,746	20,129
C2	112	6,391 a	4,541	5,040 a	5,515	21,485
IF		5,915 b	3,793	4,380 b	5,064	19,153
		*	NS	*	NS	

† Abbreviations: C2, compost 29 Mg ha^{-1} + 112 kg N ha^{-1} cutting^{-1}; K, 0 and 112 K_2O ha^{-1} cutting^{-1}; IF, inorganic fertilizer (112 kg N ha^{-1}; 112 kg P_2O_5 ha^{-1} yr^{-1}; 112 kg K_2O ha^{-1}).

‡ Means within a year and column followed by the same letter are not significantly different.

*, **, *** P ≤ 0.05, P ≤ 0.01, and P ≤ 0.001; NS = not significant; (Fishers Protected LSD).

Tissue N concentrations tended to increase with increasing rates of supplemental N fertilizer applied to compost or manure (Table 5). Although forage yields equivalent to inorganic fertilizer were obtained with 56 kg ha^{-1} cutting^{-1} of supplemental N, tissue N concentrations in compost and manure treatments were lower than IF for the majority of harvests. When supplemental N rates were increased to 84 or 112 kg N ha^{-1} cutting^{-1}, tissue N concentrations generally were not different from IF. Total apparent N recovery from dairy manure compost and dairy manure ranged from 23 to 57% of the total amount applied compared to 70% from inorganic fertilizer alone. Overall, uptake of N derived from compost or manure did not appear to be as efficient as it was from plots receiving only inorganic fertilizer.

Dairy manure compost applied at 29 Mg ha^{-1} and raw dairy manure applied at 54 Mg ha^{-1} with 112 kg N ha^{-1} cutting^{-1} produced significant yield and tissue K responses to applications of supplemental inorganic K (Table 6). Apparent K recovery ranged from 15 to 57% and tended to increase with increasing supplemental N rate to 84 kg N ha^{-1} cutting^{-1}. Lower total K uptake in forage from C2 and M treatments compared to C3 suggests that application of compost and manure at these rates may require supplemental inorganic K by the end of the first growing season and for the majority of the second season.

There were no yield responses to supplemental inorganic P for C2, C3 and M with 112 kg N ha^{-1} cutting^{-1} in either year (data not shown). Application of supplemental P tended to increase tissue P concentrations compared to compost or manure alone, and to produce levels equal to or greater than IF. Greater responses to supplemental P were observed for the 29 Mg ha^{-1} rate of compost and 54 Mg ha^{-1} rate of manure. Total apparent P recovery ranged from 13 to 60% and tended to increase with increasing rate of supplemental N to 84 kg N ha^{-1} cutting^{-1}. In general, P recovery from compost and manure appeared to be adequate to supply crop demands throughout both growing seasons.

Table 5. Effects of composted dairy manure (57 Mg ha^{-1}) with four rates of supplemental N compared to inorganic fertilizer alone on tissue N concentrations in Coastal bernudagrass.

Treatment†	N rate	H1	H2	H3	H4
2002	kg ha^{-1}	g kg^{-1}			
C3	0	—	18 c‡	17 c	12 b
C3	56	—	21 b	20 bc	15 a
C3	84	—	22 b	21 ab	16 a
C3	112	—	25 a	22 ab	16 a
IF		—	26 a	24 a	15 a
			***	*	***
2003		g kg^{-1}			
C3	0	15 b	15 c	15 d	14 c
C3	56	16 b	20 b	19 c	19 b
C3	84	21 a	25 a	22 b	20 b
C3	112	22 a	28 a	24 ab	24 a
IF		25 a	28 a	25 a	23 a
		**	***	***	***

†Abbreviations: C3, compost 57 Mg ha^{-1}; N, (0, 56, 84 and 112 kg N ha^{-1} cutting^{-1}); IF, inorganic fertilizer (112 kg N ha^{-1}; 112 kg P_2O_5 ha^{-1} yr^{-1}; 112 kg K_2O ha^{-1}).

‡Means within a year and column followed by the same letter are not significantly different.

*,**,*** P ≤ 0.05, P ≤ 0.01 and P ≤ 0.001; NS = not significant; (Fishers Protected LSD).

Table 6. Effects of two rates of supplemental K applied to composted dairy manure (29 Mg ha^{-1}) receiving 112 kg ha^{-1} cutting^{-1} supplemental N compared to inorganic fertilizer alone on tissue K concentrations in Coastal bermudagrass.

Treatment†	K_20	H1	H2	H3	H4
2002	kg ha^{-1}	g kg^{-1}			
C2	0	—	20‡	17	13
C2	112	—	22	19	15
IF		—	21	16	12
			NS	NS	NS
2003		g kg^{-1}			
C2	0	14 b	12 b	9 b	10
C2	112	19 a	18 a	18 a	14
IF		22 a	19 a	18 a	14
		**	*	*	NS

†Abbreviations: C2, compost 29 Mg ha^{-1} + 112 kg N ha^{-1} cutting^{-1}; K, 0 and 112 kg K_2O ha^{-1} cutting^{-1}; IF, inorganic fertilizer (112 kg N ha^{-1}; 112 kg P_2O_5 ha^{-1} yr^{-1}; 112 kg K_2O ha^{-1}).

‡Means within a year and column followed by the same letter are not significantly different.

*,**,*** P ≤ 0.05, P ≤ 0.01 and P ≤ 0.001; NS = not significant; (Fishers Protected LSD).

CONCLUSIONS

Raw and composted manures generally act as slow release nutrient sources which can improve nutrient stability in the event of significant rainfall, but also may affect their ability to support rapidly growing, warm season crops. Forage yields produced by compost (29 and 57 Mg ha^{-1}) and raw dairy manure (54 Mg ha^{-1}) alone were significantly greater than the untreated check, but less than IF in both years. Supplemental inorganic fertilizer rates as low as 56 kg N ha^{-1} cutting^{-1} applied to compost and manure treatments produced yields that were not different from those obtained using inorganic fertilizer alone at the recommended rate. Increasing supplemental N fertilizer rates to 84 or 112 kg N ha^{-1} cutting^{-1} produced forage yields in compost and manure plots that were equal to or greater than IF, but may not be adequate to offset increased input costs.

Dairy manure compost applied at 29 Mg ha^{-1} and raw dairy manure applied at 54 Mg ha^{-1} with 112 kg N ha^{-1} cutting^{-1} produced significant yield responses to applications of supplemental inorganic K. The responses to supplemental K indicate that application of compost and manure at these rates may require supplemental inorganic K by the end of the first growing season and for the majority of the second season. There were no yield responses to supplemental inorganic P for C2, C3 and M with 112 kg N ha^{-1} cutting^{-1} in either year. In general, P recovery from compost and manure appeared to be adequate to supply crop demands throughout both growing seasons. Dairy manure compost applied at rates of 29 or 57 Mg ha^{-1} was an effective nutrient source for production of Coastal bermudagrass. However, the application of supplemental inorganic N for each harvest and supplemental K for the lowest compost rate were necessary to produce yields comparable to those achieved using inorganic fertilizer alone.

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