PUBLICATIONS

1994

Forage Research in Texas, 1994

DAIRY MANURE AND LAGOON EFFLUENT APPLICATION ON COASTAL BERMUDAGRASS AND OVERSEEDED BERMUDAGRASS SYSTEMS

E. S. Chasteen, G. D. Alston, and M. A. Sanderson

Summary

Dairy wastes are frequently applied on Coastal bermudagrass [Cynodon dactylon (L.) Pers. Coastal] in North Central Texas. Concern has increased regarding excessive application of nutrients from dairy wastes and their impact on water quality. Forage systems of Coastal bermudagrass and bermudagrass overseeded with cool-season forages were evaluated for yield for three years. Soil loading of nitrate-nitrogen (NO_3-N) and extractable-phosphorus (ext.-P) were examined. Forage yields did not respond to manure application in Year 1 and 2. Overseeding forages provided vegetative cover during winter and early spring, but competed with Coastal bermudagrass during the spring and early summer. Soil NO_3-N and ext.-P were increased by dairy waste application.

Introduction

Improper management of dairy waste was cited as a contributing nonpoint source (NPS) pollutant in the Upper North Bosque River watershed in Erath and Hamilton counties of Texas (TWC and TSSWCB 1982). Water quality degradation is a concern when land is limited for waste disposal relative to the livestock density on open lot dairies. Solid dairy manure and manure-contaminated wastewater are frequently applied to cropland. Excessive loading of dairy waste on soils can result in $N0_3$-N leaching beyond plant roots, and increase N and P content in rainfall runoff from cropland (Power and Schepers 1989, and McLeod and Hegg 1984). Manure is a nutrient source and soil amendment that should be utilized on sustainable cropping systems to reduce potential NPS pollution (Chang et al. 1991). This experiment was conducted to compare three forage systems for efficient utilization of nutrients from dairy wastes and determine safe waste application rates.

Keywords: Dairy waste / overseeding / Coastal bermudagrass

Procedure

Experimental plots on Dairy-1, located on a shallow Windthorst series, fine sandy loam soil received four rates of solid manure. Plots on Dairy-2, located on a Blanket series, clay loam soil received four rates of lagoon effluent. During 1991, 1992, and 1993, manure and effluent were applied to Coastal bermudagrass only, bermudagrass overseeded in the fall with wheat [Triticum aestivum (L.)] at 90 lb/acre, or with tall fescue [Festuca arundinacea (Schreb.)], at 20 lb/acre. Tall fescue was replaced with annual ryegrass [Lolium multiflorum (L.)] at 30 lb/acre in 1992 and 1993. Dairy waste was applied at four rates designated as no manure (C), low (L), medium (M-2XL), and high (H-4XL). Freshwater was applied with the C, L, and M effluent rates when the soil was dry to equal the effluent rate. Effluent and freshwater were applied by a modified drip irrigation system equipped with an in-line flow meter. Solid manure treatments were weighed in a bucket and applied with a shovel and rake. Dairy waste samples were collected at each application, stored in a freezer, and analyzed for total N and P by the Texas Agricultural Extension Service Plant, Soil and Water Testing Laboratory at College Station. The amount of N and P applied in manure and effluent at each rate is in Tables 1 and 2.

Experimental design was a randomized complete block with strip-split-plot treatments in three blocks (Gomez and Gomez 1984). Three forage systems were randomized main plots with four waste treatments as sub-plots stripped across forage systems. Forages were harvested at boot-stage with a sickle mower (2 in. stubble height) and yield was determined on an oven-dry (131^{0}F for 48 hr) basis. Forage N was determined by near infrared reflectance spectroscopy (NIRS) (model 6250, NIR Systems, Silver Spring, MD) which was calibrated and validated according to Marten et al. (1989). Calibration and validation samples were analyzed colorimetrically (Baethgen and Alley 1989). Cool-season weeds in Coastal-only plots were controlled annually with glyphosate (Round-Up) at recommended rates.

Soil was sampled before initial waste application and annually each fall thereafter. Three cores were extracted from Coastal-only and Coastal-wheat plots at 0 to 6-, 6 to 12-, 12 to 24-, 24 to 36-, and 36 to 48-in. depths and composited by depth. Samples on Dairy-1 were limited to the top three depths because of a hard-pan inhibiting deeper sampling. Soil was analyzed for $N0_3$-N,and ext.-P according to TAEX Soil Water and Forage Testing Laboratory(1980).

Analysis of variance and least significant difference (LSD) were calculated by PC-SAS (SAS Institute, 1988) and standard errors (SE) were calculated according to Gomez and Gomez (1984).

Results and Discussion

Both sites had been grazed heavily by dairy cattle before initiation of this experiment. We suspected residual nutrients from deposited manure were present, so in 1991 manure treatments were applied after winter forages were harvested and effluent application was delayed until August because of difficulty in developing an irrigation system. Considerable amounts of $N0_3$-N were applied to the C, L, and M effluent rates as fresh-water contained about 9.0 lb $N0_3$-N/acre-in. Fresh-water was applied when the soil was dry or when rainfall did not occur soon after effluent application. Annual rainfall was 43.0, 37.4, and 30.6 in. during 1991, 1992, and 1993, respectively.

Forage Yields From Manure (Dairy-1). Dry matter yields of wheat and fescue (harvest 1) were similar among manure rates in 1991 (Table 3) since manure was not applied until after they were harvested. Rescuegrass (Bromus catharticus Vahl.) also invaded overseeded plots. Coastal bermudagrass yields were reduced in harvest 2 ($P<0.05$) and 3 ($P<0.01$) of 1991 due to competition from overseeded forages, presumably for sunlight, moisture, and nutrients. Annual yield of the Coastal-only system outyielded ($P<0.05$) other forage systems. Manure rates did not significantly effect yield of forage systems in 1991.

Ryegrass yielded more than ($P<0.05$) wheat in harvest 1 of 1992 (Table 3). Coastal bermudagrass yields were reduced ($P<0.001$) by overseeded forages during harvest 2 and 3 of 1992, but total yield of all forage systems were similar (Table 3). Total yield of all forage systems were not affected by manure rates.

During 1993, ryegrass outyielded ($P<0.01$) wheat (harvest 1) (Table 3). Coastal bermudagrass yields were reduced in harvest 2 ($P<0.001$) and 3 ($P<0.01$) due to overseeding (Table 3). Total yields of Coastal-ryegrass were better ($P<0.05$) than Coastal-only, and Coastal-wheat yielded the least when averaged over manure rates in 1993 (Table 3). Yields averaged over all cropping systems significantly responded to manure rates during April, May, October and annually in 1993 (Table 4).

Forage Yields From Effluent (Dairy-2). Wheat and fescue (also invaded by rescuegrass) yields in harvest 1 were similar in 1991 (Table 5). Bermudagrass yields in the Coastal-wheat and Coastal-fescue plots were reduced by overseeded forages during harvest 2 ($P<0.001$) and 3 ($P<0.001$). Forage yields in the Coastal-wheat system were significantly lower than other forage systems in all harvests during 1991 (Table 5). Wheat and ryegrass yields were similar in harvest 1 during 1992. Bermudagrass yields following the cool-season grasses were significantly lower in 1992 (Table 5). Total yields averaged among effluent rates were similar in the Coastal-only, Coastal-wheat, and Coastal-ryegrass systems during 1992 (Table 5). Average dry matter yields responded to effluent treatments during June, August, September and annually in 1992 (Table 6). Higher yield response to effluent than manure in 1992 maybe due to extra water added in drip irrigation system. Ryegrass and wheat yielded similarly during harvest 1 in 1993 (Table 5). Bermudagrass yields were significantly lower in both multiple-cropping systems during harvest 2 ($P<0.01$) and 3 ($P<0.05$), but more ($P<0.05$) dry matter was produced annually by the Coastal-ryegrass, and Coastal-wheat systems compared to Coastal-only (Table 5). Average dry matter yields among forage systems significantly responded to effluent rates in all harvests during 1993 as yields increased annually under increasing effluent rate (Table 7).

Nitrogen Removal Following Manure Application (Dairy-1). Nitrogen removed annually by forage systems was similar among manure rates during 1991. Averaged among manure rates, the Coastal-only system removed more ($P<0.05$) N (368 lb N/acre/year) than Coastal-wheat (302 lb N/acre/year) and Coastal-fescue systems (319 lb N/acre/year). During 1992, average N removal among forage systems was greater ($P<0.05$) under higher manure rates except between the L and M treatments. Nitrogen removed by forage systems in 1992 averaged 169, 217, 189, and 270 lb N/acre/year (SE=28) under the C, L, M and H manure rates, respectively. Lower ($P<0.05$) annual N removal resulted from overseeding as an average of 235, 196, and 203 lb N/acre/year was harvested by Coastal-only, Coastal-wheat, and Coastal-ryegrass systems, respectively, among rates (SE=10). In 1993, N uptake was greater ($P<0.01$) under higher manure rates as 80, 141, 155, and 218 lb N/acre/year (SE=23) was removed under the C, L, M and H manure rates, respectively. The Coastal-only, Coastal-wheat, and Coastal-ryegrass systems removed an average of 155, 135, and 155 lb N/ acre/year (SE=3) among manure rates.

Nitrogen Removal Following Effluent Application (Dairy-2). As expected, annual N uptake by forage systems did not respond to effluent rates during 1991. Average N uptake among effluent rates was similar in the Coastal-only (340 lb N/acre/year), Coastal-wheat (303 lb N/acre/year), and Coastal-fescue (340 lb N/acre/year) systems. During 1992, averaged annual N uptake increased ($P<0.01$) under the M and H effluent rates. The Coastal-only, Coastal-ryegrass, and Coastal-wheat systems removed 447, 434, and 419 lb N/acre/year, respectively among effluent rates (SE=24).

In 1993, more N was removed under higher effluent rates as forage systems removed an average of 245, 303, 457, and 507 lb N/acre/year under the C, L, M and H rates. More ($P<0.01$) N was removed annually by multiple-cropping as 395, 385, and 354 lb N/acre/year was removed by the Coastal-ryegrass, Coastal-wheat, and Coastal-only systems, respectively (SE=11).

Residual NO_3-N and P Following Manure Application (Dairy-1). Soil NO_3-N levels were not effected by cropping systems in the fall of 1991; however manure rates increased ($P<0.05$) NO_3-N in the 0 to 24-in.profile. Nitrate-N was higher ($P<0.001$) in the 0 to 6-in. depth during the fall of 1991 and 1992, however NO_3-N was generally low among all cropping systems, manure rates and soil depths. In 1992, NO_3-N was affected by manure rate ($P<0.05$), cropping system by manure rate ($P<0.001$), soil depth ($P<0.001$), and manure rate by soil depth ($P<0.001$). In 1993, soil NO_3-N levels were affected by manure rates ($P<0.001$),soil depth ($P<0.001$), and manure rate by soil depth ($P<0.05$) (Table 8).

Extractable-P was similar among manure rates and cropping systems during the fall of 1991. Extractable-P measured in the fall of 1992 was significantly different among soil depths ($P<0.01$) and manure rate by soil depth ($P<0.05$). Extractable-P averaged among cropping systems was greatest in the 0 to 6 in. depth under the H manure rate (142 ppm). In the fall of 1993, extractable-P levels remaining were affected by manure rate ($P<0.001$), soil depth ($P<0.001$), and manure rate by soil depth ($P<0.001$) (Table 9).

Residual NO_3-N and P Following Effluent Application (Dairy-2). During fall of 1991, soil NO_3-N was similar among effluent rates and cropping systems. Soil NO_3-N averaged among cropping systems during fall 1992 was 3.0, 2.5, 1.0, and 1.0 in the 0 to 6-in. depth under the H, M, L, and C effluent rates ($LSD_{.05}$=0.3 ppm), NO_3-N was 1.0 ppm at the lower depths. Differences in soil NO_3-N resulted in the fall of 1993 among effluent rate ($P<0.001$), soil depth ($P<0.001$), and effluent rate by soil depth ($P<0.001$) (Table 10). By fall of 1993, extractable-P was similar among cropping systems and effluent rates.

Yield and N removal by forage systems may not respond to dairy manure or effluent application until the second or third year of application because of slow N mineralization. We also think N from surface applied wastes volatilized (in varied amounts) thus reducing N use efficiency. Overseeding winter annuals into Coastal bermudagrass may not always increase yield and N uptake due to competition problems during spring. However, overseeded winter forages (such as annual ryegrass) in Coastal bermudagrass was productive under effluent application and provided good vegetative cover while Coastal was dormant. Regardless of using a single or multiple-cropping system, soil NO_3-N and extractable-P levels may increase under continuous application (3-years) of high dairy manure or lagoon effluent rates.

Acknowledgements

Funding provided by the USDA Water Quality Initiative for the Upper North Bosque River Hydrologic Unit Project and the USDA-CRS Special Grants Water Quality Program. The authors thank Mary Goule for word processing and Chuck Dannheim for field and lab help.

Literature Cited

Baethgen, W. E., and M. M. Alley. 1989. A manual calorimetric procedure for measuring ammonium nitrogen in soil and plant kjeldahl digests. Commun. In Soil Sci. Plant Anal., 20: 961-969.

Chang, C., T. C. Sommerfeldt, and T. Enty. 1991. Soil chemistry after eleven annual applications of cattle feedlot manure. J. Environ. Qual. 20: 475-480.

Gomez, K. A. and A. A. Gomez. 1984. Statistical procedures for agricultural research. 2nd ed. John Wiley and Sons, USA.

Marten, G. C., J. S. Shenk, and F. E. Barton II, (ed.). 1989. Near infrared reflectance spectroscopy (NIRS): analysis of forage quality. USDA-ARS Agric. Handb. 643 (Revised) U.S. Gov. Print. Office, Washington, D.C.

McLeod, R. V., and R. O. Hegg. 1984 Pasture runoff water quality from application of inorganic and organic nitrogen sources. J. Environ. Qual. 13: 122-126.

Power, J. F., and J. S. Schepers. 1989. Nitrate contamination of groundwater in North America. Agric. Ecosystems Environ. 26: 165-187.

SAS Institute. 1988. SAS user's guide: statistics. Ver. 6.03. SAS Inst. Cary, NC

Texas Agricultural Extension Service. 1980. Soil testing procedures. 29p. Texas Agric. Ext. Serv. Soil Testing Lab. Mimeo. College Station, TX.

Texas Water Commission, and Texas State Soil and Water Conservation Board. 1988. Nonpoint source water pollution management report for the state of Texas. TWC and TSSWCB. June. p. 263.

Table 1. Rates of manure used and resulting amounts of N and P applied to forage systems during three years on Dairy-1.

Year	Rate	Dry basis	Wet basis	Total N	Total P
		...............ton/acre.........		...............lb/acre/year.....	
	L	4	9	204	34
1991[1]	M	9	18	407	69
	H	17	35	815	137
	L	6	10	155	62
1992[2]	M	12	21	311	122
	H	24	42	623	246
	L	11	17	237	109
1993[3]	M	23	34	476	219
	H	45	69	950	437

[1]Applied: 9 May.
[2]Applied: 12 March, 30 May, and 23 July in equal split applications.
[3]Applied: 28 Jan, 9 Mar, 2 June, and 13 July in equal split applications.

Table 2. Effluent rates used and resulting amounts of N and P applied to forage systems during three years on Dairy-2.

		Treatment		Sum of	Water	Effluent	
Year	Rate	Water		applied[1]	NO_3-N	Total N	Total
		........acre-in........		..............................lb/acre/yr...........			
	C	3.14	0.00	35	35	--	--
1991	L	2.36	.079	67	26	41	6
	M	1.57	1.57	100	18	82	11
	H	0.00	3.14	163	0	163	21
	C	5.54	0.00	48	48	--	--
1992[2]	L	4.16	2.61	120	36	84	25
	M	2.77	5.21	192	24	168	50
	H	0.00	10.43	336	0	336	100
	C	7.70	0.00	67	67	--	--
1993[3]	L	5.10	2.80	147	45	102	20
	M	3.80	5.60	238	34	204	39
	H	0.00	11.20	407	0	407	78

[1]NO_3-N in water + total N in effluent.
[2]Treatments applied in 3 split equal applications during 1992.
[3]Treatments applied in 7 split equal applications during 1993.

Table 3. Dry matter yield of cropping systems averaged across four manure rates on Dairy-1 during 1991, 1992, and 1993.

Year	Forage System	Harvest[1] 1	2	3	4	5	Total
		......................................lb/acre......................................					
	Coastal-only	--	3746	3978	3220	4085	15029
1991	Coastal-wheat	1652	3058	1350	2590	3704	12354
	Coastal-fescue	1619	2997	1497	2806	3909	12857
	SE[2]	NS	231*	282***	NS	NS	658*
	Coastal-only	--	3250	4788	3220	1707	12966
1992	Coastal-wheat	4255	1516	3067	2151	1769	12759
	Coastal-ryegrass	5443	1954	2614	2569	1944	14524
	SE	259*	188***	232**	NS	NS	NS
	Coastal-only	--	2186	1965	1562	1326	7039
1993	Coastal-wheat	2236	822	964	888	1347	6258
	Coastal-ryegrass	3086	876	1015	1097	1732	7806
	SE	111**	120***	164**	NS	NS	152*

[1]Means of three replicates and four manures rates
[2]SE=standard error.
*, **, ***, P<0.05, P<0.01, P<0.001 respectively, NS=not significant.

Table 4. Average dry matter yields[1] among Coastal-only, Coastal-wheat, and Coastal-ryegrass systems that received varing manure rates during 1993 on Dairy-1.

Manure rate	Harvest Date 20 Apr.	24 May	23 Jun.	6 Sep.	8 Oct.	Total
	------------------lb/acre/yr------------------					
C	2070	861	872	952	619	4684
L	2347	1297	1462	1428	1409	7160
M	2860	1247	1115	1159	1788	7216
H	3368	1774	1810	1191	2057	9078
SE[2]	218**	199*	324^{NS}	341^{NS}	158***	976*

[1]Means of three replicates
[2]Standard error of the mean difference.
*, **, ***, P<0.05, P<0.01, and P<0.001 respectively, NS=not significant.

Table 5. Dry matter yield of cropping systems averaged among four manure rates on Dairy-2 during 1991, 1992, and 1993.

Year	Forage System	Harvest[1] 1	2	3	4	5	6	Total
		..................lb/acre..................						
1991	Coastal-only	--	4829	2937	3787	2514	--	14066
	Coastal-wheat	2544	2375	1278	3289	2927	--	12413
	Coastal-fescue	2809	2835	1753	3724	2881	--	14001
	SE[2]	NS	194***	164***	112*	76**	--	659*
1992	Coastal-only	--	6331	5062	4857	3756	--	20005
	Coastal-wheat	5955	3211	4070	4430	3555	--	21221
	Coastal-fescue	5169	4428	3531	4564	3825	--	21517
	SE	NS	181***	359*	NS	NS	--	NS
1993	Coastal-only	--	2715	2816	3788	2756	2344	14420
	Coastal-wheat	2538	1527	2197	3898	3198	2508	15866
	Coastal-ryegrass	3912	1993	1733	3734	2646	2443	16461
	SE	NS	179**	184*	NS	NS	NS	439*

[1]Means of three replicates and four manure rates
[2]SE=standard error. *, **, ***, $P<0.05$, $P<0.01$, $P<0.001$ respectively, NS=not significant.

Table 6. Average dry matter yields[1] among Coastal-only, Coastal-wheat, and Coastal-ryegrass systems that received effluent during 1992 on Dairy-2.

Effluent rate	Harvest Date 20 Apr.	3 June	6 July	13 Aug.	8 Oct.	Total
	..................lb/acre/yr..................					
C	5114	4366	4029	4439	2944	19188
L	4695	4105	3962	4102	3018	18318
M	6103	5043	4434	4978	4226	22750
H	6335	5111	4458	4948	4660	23401
SE[2]	832^{NS}	104**	343^{NS}	258*	461*	1279**

[1]Means of three replicates
[2]Standard error of the mean difference. *, **, $P<0.05$, and $P<0.01$ respectively; NS=not significant.

Table 7. Average dry matter yields[1] among Coastal-only, Coastal-wheat, and Coastal-ryegrass systems that received effluent during 1993 on Dairy-2.

Effluent	Harvest date						
rate	20 Apr.	24 May	23 June	23 July	1 Sep.	8 Oct.	Total
	.......lb/acre/yr.......						
C	2381	1553	1706	2767	2287	1512	11413
L	2607	1897	1810	3409	2498	2030	13822
M	3971	2309	2610	4346	3035	2963	17911
H	3940	2556	2870	4704	3646	3221	19624
SE[2]	310**	164**	210**	461*	393*	361**	1626**

[1]Means of three replicates
[2]Standard error of the mean difference. *, **, $P<0.05$, and $P<0.01$ respectively; NS=not significant.

Table 8. Average NO_3-N level among cropping systems at three soil depths under four manure rates on Dairy-1 during fall 1993.

Manure	Soil depth (in.)		
rate	0-6	6-12	12-24
	.......ppm NO_3-N.......		
C	2.5	1.0	1.0
L	5.7	1.7	4.0
M	9.0	3.3	4.7
H	18.8	13.2	19.0

Table 9. Extractable-P among cropping systems at three soil depths under four manure rates on Dairy-1 during fall 1993.

Manure	Soil depth (in.)		
rate	0-6	6-12	12-24
	.......ppm-ext-P.......		
C	86	12	3.7
L	198	23	3.7
M	232	26	4.8
H	448	26	3.3

Table 10. Average NO_3-N among cropping systems at five soil depths under four effluent rates on Dairy-2 during fall 1993.

Effluent rate	Soil depth (in.) 0-6	6-12	12-24	24-36	36-48
	ppm NO_3-N				
C	5.5	2.0	1.3	1.0	1.0
L	7.0	2.7	1.3	1.0	1.0
M	7.0	4.2	2.5	1.8	1.2
H	7.7	4.8	6.2	7.8	5.0