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Beef Feedyard Effluent Application Effects on Nutrient Mass Balances for Three Cropping Rotations of Sorghum and Wheat

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Abstract. *Feedlot runoff was applied to 27 plots of winter wheat and forage sorghum over 24 months at the Agriculture Research Station located at Bushland, TX, 12 miles west of Amarillo. Each plot measured 16 m x 4.5 m to allow for access of farming implements. All plots were plowed with an offset disc, chiseled, and leveled with a laser plane before planting. Wheat was sown at the rate of 67 kilograms of seed per hectare. Sorghum was planted in 6 rows, 75 cm* *apart, at the rate of 11.25 kg/ha. Runoff was applied by flood irrigation on the level borders. Rates applied were as follows: 0 cm/cropping season (Treatment 1, control), 25 cm (Treatment 2), and 50 cm (Treatment 3). Cropping rotations of sorghum-fallow, wheat-fallow, and sorghum-wheat (two crops per year) were used for each TRT. Plots were irrigated every two weeks after plant emergence until the appropriate amount of effluent was obtained. The crop was then allowed to mature until the majority of the plants had reached an early boot stage. At this time, vegetative samples were collected and allowed to dry for three weeks, after which they were ground, mixed and analyzed in the laboratory. Soil samples were collected before planting and after harvest and also analyzed in the laboratory. Effluent samples were collected three times during each irrigation, composited, and analyzed. Nutrient mass balances were calculated for total N, plant–available P, K, Mg, Na, and Cl. Total N tended to have positive balances in year one and negative balances in year two. P had positive balances both years, but balances were smaller in year two. Both K and Na had large increases for both years.*

Keywords. Feedyard, beef, effluent, runoff, wheat, sorghum, land application

Introduction

The Texas Panhandle is home to approximately 7 million (Parker et al., 1997; SPS, 1999) head of beef cattle fed in confined animal feeding operations (CAFOs), with a one time capacity of about 3.5 million head. Each animal requires 16.72 – 20.44 m^2 per head (Rhoades, 1990) for housing space, which calculates to 58,520,000 to 71,540,000 m^2 of pen area involved in confined beef cattle feeding.

The Texas Panhandle is a semiarid region with a mean rainfall of 480 mm (19 in) per year. This calculates to 28,229,535 to 34,510,848 m^3 of precipitation that falls on CAFOs per year. Sweeten (1998) has calculated that 30% of this will be runoff. Every year 8,468,860 to 10,353,193 m^3 of feedyard runoff are accumulated in the region. The most popular way of controlling the runoff accumulations is through evaporation, as the annual pan evaporation rate for the Texas panhandle is 180 cm per year.

However, Title 30 Part I Chapter 321 Subchapter B of the Texas Administrative Code (TNRCC, 1999) rules regarding CAFOs states that the retention pond must have "sufficient available capacity to contain rainfall and rainfall runoff from a 25-year, 24-hour rainfall event. The [feedyard] operator is further responsible for restoring the capacity to store all runoff from a 25-year, 24-hour rainfall event or accumulation of wastes or process generated wastewater which reduces such capacity, weather permitting." The facility must de-water the retention pond within 21 days of the rainfall event (Sweeten, 1998).

Land application is another good way of de-watering the retention pond. Proper application rates that are beneficial to crops and friendly to the environment are important in this pursuit. Feedyard runoff is typically high in nutrients and salts, which can limit application rates on land and to specific crops (Sweeten, 1998).

Wheat and forage sorghum can be good crops for land application. They are both salt tolerant and can be utilized as a forage, greenchop, or baled as hay. Wheat and sorghum hay can be fed as supplements or roughage to beef cattle in conjunction with a high quality concentrate. Because of their worth as a cattle feed, wheat and sorghum are good choices to grow next to beef cattle feedyards. The objective of the research was to determine how the application of feedyard effluent to wheat and sorghum crop rotations affects soil nutrient balances.

Materials and Methods

Location

The experiment was located at the USDA-ARS at Bushland, Texas located 12 miles west of Amarillo, Texas on Interstate 40. The plots were located approximately 150 m east of the 384-head experimental feedyard runoff storage pond and directly northeast of a playa lake.

The plots were placed in level, terraced borders, with 27 individual plots measuring 16 m x 4.5 m with each separated by a 2 m border of soil. The plots were laid out in groups of 9 with an access road separating them (Table 1).

Planting

Forage sorghum (*sorghum bicolor*) G-W type Grazemaster was planted with a John Deere MaxEmerge 2 planter at the rate of 11.25 kg/ha on July 10, 1999, and again on June 23, 2000. Planting was done in 6 row 30's (76 cm between rows).

Wheat (*Triticum aestivum*, awnless variety, G-W type Grazemaster) was planted with a John Deere 540 planter at the rate of 67 kg/ha on November 2, 1999, and again on October 20, 2000. Planting was done in 15.25 cm rows east to west.

Cropping rotations were sorghum-fallow, sorghum-wheat, and fallow-wheat.

Effluent Application

Feedyard runoff from the 384-head research feedyard was applied to the crop via an 850-l/min pump located at the storage pond through a 20 cm (8 inch) diameter PVC pipeline. The crop was flood irrigated. Application was measured with a flow meter with accuracy to 0.38 m^3. Treatments (TRT) were effluent application rates of: 1) 0 cm/growing season (control), 2) 25 cm/growing season, and 3) 50 cm/growing season (Table 1). No other irrigation source was used.

Effluent was applied beginning with plant emergence and every two weeks thereafter, depending on the weather conditions. A total of three applications were made for each crop. Effluent samples were collected at the plots at the beginning, middle, and end of each irrigation event and composited.

Soil and Plant Sampling and Analysis

Soil sampling was done 2 weeks before each planting date and within 2 weeks of the harvest dates. Each plot was sampled at 3 locations within the plot at depths of 0 to15 cm, 15 to 45 cm, and 45 to 90 cm. Composites were made of the different depths for quality analysis. Soil samples were analyzed for Total N (Kjeldahl digest with a Technicon Auto Analyzer II), plant available P, K, Ca, Mg, Na (measured by ICP on ammonium acetate-ethylenediaminetetraacetic acid (NH_4OAC-EDTA) extracts)(Texas A&M University Agricultural Extension Service Soil Testing Laboratory Standard Method) (Hons et al., 1990), and Cl.

Plant sampling was done at harvest, where each crop was cut for hay. Two 1 x 1 m locations within the plots were randomly selected, each no less than 1 m from the edge or border of the plot. All the plants within the two areas were cut at 2.5 cm above the ground surface, bundled, weighed and allowed to air dry for 3 weeks. After drying, the bundles were again weighed and the samples within plots were composited and ground for quality analysis.

Statistical analysis was done using SPSS version 9.0. The plots were designed for a randomized complete block design (table 1), with all treatments being assigned randomly. Data was analyzed using analysis of variance (ANOVA) and least significant difference (LSD) at the 95% confidence level ($\alpha = 0.05$).

Results and Discussion

Effluent

The effluent used was applied from the feedyard runoff holding pond at Bushland. Nutrient concentrations were considerably less than commercial feedyard holding ponds (Table 4). Most nutrients were ¼ to ½ as concentrated as nutrient amounts found in commercial feedyard retention ponds, with the exception of electrical conductivity, which was approximately double.

Nitrogen

Overall, more N was removed in year 2 than in year 1, regardless of cropping rotation. This typically resulted in negative nutrient balances in year 1, and positive balances in year 2. This would indicate that more nutrients were available for uptake in year 2. The Sorghum-Fallow rotation tended to remove less than either the Wheat-Fallow or the Sorghum-Wheat rotations (Table 5).

Phosphorus (plant extractable)

Effluent applications in year 1 resulted in positive balances for TRT's 2 and 3, while TRT 1 had a negative balance, as was expected. More P was removed from the soil in year 2, with some cases removing up to 2 times the amount. The Sorghum-Fallow rotation tended to remove less than either the Wheat-Fallow or the Sorghum-Wheat rotations (Table 6).

Potassium

Effluent applications in year 1 resulted in positive balances for TRT's 2 and 3, while TRT 1 had a negative balance, as was expected. More K was removed from the soil in year 2. The Sorghum-Fallow rotation tended to remove less than either the Wheat-Fallow or the Sorghum-Wheat rotations (Table 7).

Sodium

Effluent applications in year 1 resulted in positive Na balances for TRT's 2 and 3, while TRT 1 had a negative balance, as was expected. More Na was removed from the soil in year 2 for all cropping rotations under TRT 3, with TRT's 1 and 2 removing approximately equal amounts for all cropping rotations in year 1 and again in year 2. Substantially more amounts of Na were applied than were removed, as was evidenced by visual observation of Na deposits on the soil surface for those plots receiving effluent applications. The Sorghum-Fallow rotation tended to remove less than either the Wheat-Fallow or the Sorghum-Wheat rotations (Table 8).

Chloride

Effluent applications in year 1 resulted in positive Cl balances for TRT's 2 and 3, while TRT 1 had a negative balance, as was expected. More Cl was removed from the soil in year 2 for all cropping rotations under all TRTs for all cropping rotations. The Sorghum-Fallow rotation tended to remove less than either the Wheat-Fallow or the Sorghum-Wheat rotations (Table 9).

Magnesium

Effluent applications in year 1 resulted in positive Mg balances for TRT's 2 and 3, while TRT 1 had a negative balance, as was expected. More Mg was removed from the soil in year 2 for all cropping rotations under TRT 3, with TRT's 1 and 2 removing approximately equal amounts for all cropping rotations in year 1 and again in year 2. The Sorghum-Fallow rotation tended to remove less than either the Wheat-Fallow or the Sorghum-Wheat rotations (Table 10).

Conclusions

Overall, more nutrients were removed during year two than in year one, regardless of cropping rotation. This was probably due to more nutrients being available the second year as opposed to the first. The Sorghum-Wheat rotation tended to remove the most nutrients per year, while the Sorghum-Fallow rotation removed the least. K, Na, and Cl tended to build up in the soil, especially at the higher application rates. With no other irrigation source for leaching purposes, this could be problematic for future crop production.

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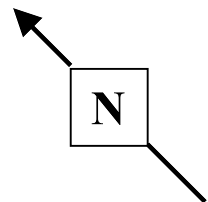
Table 1: Plot layout and application rates (cm/year)

Sorghum-Fallow	Sorghum-Wheat	Fallow-Wheat
50	25	25
0	50	0
25	0	50
0	0	0
25	50	25
50	25	50
25	0	0
50	50	50
0	25	25



*Blocks are denoted by solid outlines. Treatments were randomly assigned within blocks and are separated by dashed lines.

Table 2: Mean soil characteristics for six plots for each treatment

Parameter	0 cm/year	25 cm/year	50 cm/year
PH	8.1 a	8.1 a	8.1 a
Total N (ppm)	857 a	756 a	914 a
NO3-N (ppm)	11.0 a	11.9 a	10.7 a
NH4-N (ppm)	1.3 a	1.3 a	1.4 a
Total P (ppm)	172 a	180 a	165 a
Ext. P (ppm)	15.4 a	21.1 a	15.9 a
K (ppm)	404 a	405 a	414 a
Mg (ppm)	632 a	684 a	599 a
Na (ppm)	237 a	288 a	262 a
Cl (ppm)	24.5 a	36.5 b	37.7 b
Ca (ppm)	14,952 a	13,527 a	15,470 a
Sodium adsorption ratio	0.3821 a	0.4750 a	0.4149 a
Electrical conductivity (mmhos/cm)	0.2376 a	0.2432 a	0.2378 a

a,b Means in a row with different letters are significantly different using LSD comparison at α=0.05

Table 3: Means of nutrients removed by aboveground crop biomass for six plots

Effluent applied per year	Dry matter yield	Crude protein	ADF	TDN	N	P	K	Ca	Mg	Na	Cl
(cm/ha)	(kg/ha)	[------ % dry matter		----]	[----------------------		kg / ha				--------------------------]
0	3524 a	11.0 a	30.2 a	57.8 a	57.6 a	5.7 a	35.7 a	10.7 a	5.8 a	7.6 a	10.2 a
25	4563 a	9.2 a	37.0 a	55.9 a	61.6 a	7.6 a	59.4 a	15.3 a	7.5 a	10.1 a	29.3 b
50	5078 a	8.5 a	32.2 a	57.7 a	61.3 a	7.9 a	56.5 a	14.1 a	7.2 a	11.2 a	26.5 b

a,b Means in a column with different letters are significantly different using LSD at $\alpha = 0.05$

Table 4: Effluent Characteristics and Comparisons to Commercial Feedyard Holding Ponds

Parameter	Effluent applied	Texas High Plains	
		Holding Ponds*	Fresh Runoff*
N (ppm)	35.50	145	1083
P (ppm)	15.50	43.0	205.0
K (ppm)	243.50	445.0	1320.0
Mg (ppm)	36.00	72.0	199.0
Na (ppm)	176.50	256.0	588.0
Cl (ppm)	149.00	623.0	1729.0
Electrical conductivity (mmhos/cm)	1.4	4.5	8.4
Sodium adsorption ratio	4.18	4.6	5.3

*from Clark et al, 1975

Table 5: TKN Balance*

	Year One								
	TRT 1			TRT 2			TRT 3		
	Added	Removed	Balance	Added	Removed	Balance	Added	Removed	Balance
Wheat-Fallow	0	84	-84	58	79	-21	116	83	33
Sorghum-Fallow	0	26	-26	84	49	35	169	51	118
Sorghum-Wheat	0	89	-89	142	105	37	285	120	165
	Year Two								
Wheat-Fallow	0	129	-129	68	181	-113	149	255	-106
Sorghum-Fallow	0	34	-34	39	39	0	103	78	25
Sorghum-Wheat	0	178	-178	106	181	-75	252	324	-72

*Balances are measured in kg

Table 6: Plant-available Phosphorus Balance*

	Year One								
	TRT 1			TRT 2			TRT 3		
	Added	Removed	Balance	Added	Removed	Balance	Added	Removed	Balance
Wheat-Fallow	0	7	-7	25	8	17	51	10	41
Sorghum-Fallow	0	5	-5	17	8	9	34	8	26
Sorghum-Wheat	0	12	-12	43	17	26	85	20	65
	Year Two								
Wheat-Fallow	0	12	-12	25	21	4	49	43	6
Sorghum-Fallow	0	8	-8	6	7	-1	16	20	-4
Sorghum-Wheat	0	22	-22	31	34	-3	66	47	19

*Balances are measured in kg

Table 7: Potassium Balance*

	Year One								
	TRT 1			TRT 2			TRT 3		
	Added	Removed	Balance	Added	Removed	Balance	Added	Removed	Balance
Wheat-Fallow	0	49	-49	399	78	321	798	79	719
Sorghum-Fallow	0	67	-67	323	129	194	645	125	520
Sorghum-Wheat	0	93	-93	721	145	576	1443	187	1256
	Year Two								
Wheat-Fallow	0	158	-158	612	254	358	1205	416	789
Sorghum-Fallow	0	81	-81	280	66	214	747	254	493
Sorghum-Wheat	0	252	-252	892	322	570	1952	669	1283

*Balances are measured in kg

Table 8: Sodium Balance*

	Year One								
	TRT 1			TRT 2			TRT 3		
	Added	Removed	Balance	Added	Removed	Balance	Added	Removed	Balance
Wheat-Fallow	0	10	-10	289	11	278	578	16	562
Sorghum-Fallow	0	1	-1	170	1	169	341	1	340
Sorghum-Wheat	0	9	-9	459	13	446	919	12	907
	Year Two								
Wheat-Fallow	0	6	-6	408	9	399	816	18	798
Sorghum-Fallow	0	9	-9	178	6	172	475	26	449
Sorghum-Wheat	0	10	-10	586	21	565	1291	37	1254

*Balances are measured in kg

Table 9: Chloride Balance*

	Year One								
	TRT 1			TRT 2			TRT 3		
	Added	Removed	Balance	Added	Removed	Balance	Added	Removed	Balance
Wheat-Fallow	0	16	-16	244	42	202	488	36	452
Sorghum-Fallow	0	12	-12	132	17	115	265	40	225
Sorghum-Wheat	0	15	-15	392	53	339	785	84	701
	Year Two								
Wheat-Fallow	0	26	-26	397	110	287	773	199	574
Sorghum-Fallow	0	22	-22	125	31	94	333	114	219
Sorghum-Wheat	0	46	-46	513	128	385	1170	374	796

*Balances are measured in kg

Table 10: Magnesium Balance*

	Year One								
	TRT 1			TRT 2			TRT 3		
	Added	Removed	Balance	Added	Removed	Balance	Added	Removed	Balance
Wheat-Fallow	0	8	-8	49	9	40	118	9	109
Sorghum-Fallow	0	7	-7	43	11	32	85	12	73
Sorghum-Wheat	0	14	-14	102	19	83	203	19	184
	Year Two								
Wheat-Fallow	0	7	-7	88	10	78	185	19	166
Sorghum-Fallow	0	10	-10	32	8	24	85	34	51
Sorghum-Wheat	0	14	-14	120	26	94	270	47	223

*Balances are measured in kg

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