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Cool-season Forage Crop Production on North Louisiana Coastal Plain Soil:

3 A Summary of Effects of Soil-Incorporated Rates of Nitrogen, Phosphate, Potash, and Sulfur as Broiler Litter and Commercial Fertilizer on Marshall Annual Ryegrass Grown on Bowie Soil

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ON THE COVER: Mid-winter Marshall annual ryegrass being stocked-piled on pasture for beef cattle grazing in the foreground; dormant Coastal bermudagrass pasture in the background.

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A Summary of Effects of Soil-Incorporated Rates of Nitrogen, Phosphate, Potash, and Sulfur as Broiler Litter and Commercial Fertilizer on Marshall Annual Ryegrass Grown on Bowie Soil

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Poultry litter is a renewable fertilizer resource that contains all the plant nutrients required for plant growth and reproduction. In north Louisiana, the poultry broiler industry generates more than 150,000 tons of broiler litter annually that could serve as a substitute for commercial fertilizers used on pastures. Beef and dairy producers in north Louisiana make fall plantings of annual ryegrass (*Lolium multiflorum* Lam.) for cool-season forage production on pastures. The variety Marshall is the most widely grown cold-tolerant annual ryegrass variety. Common fertilization practices on pastures consist of broadcasting a complete commercial fertilizer on the surface of the soil after planting, followed by broadcast applications of nitrogen fertilizer on the growing grass during late fall, winter and spring. Occasionally, broiler litter is broadcast on the surface and disked into the soil before planting or broadcast on the surface of the growing grass during the winter. Where commercial fertilizer or broiler litter is broadcast on the surface of ryegrass pastures, rainfall runoff from pastures may be a significant carrier of nutrients to surface area water bodies and may impair their designated uses. To minimize runoff pollution of surface water bodies, rates of commercial fertilizer or poultry litter, to meet the nutrient requirements for seasonal annual ryegrass forage production, should be broadcast on the soil surface and soil-incorporated before planting into a prepared seedbed.[3] Because information was limited on annual ryegrass responses to either soil-incorporated broiler litter or commercial fertilizers use rates on upland sandy Coastal Plain soils, a fertility study was initiated in the fall of 1996. Objectives were to determine the effects of soil-incorporated broiler litter and commercial fertilizer rates on: 1) annual ryegrass forage yields; 2) annual ryegrass forage nutrient concentrations and uptakes of nitrogen (N), phosphorus (P), potassium (K), and sulfur (S); 3) the soil fertility status in the presence of annual ryegrass cropping; and 4) the cost effectiveness of both fertilizer sources for annual ryegrass production when applied at varying rates.

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[3]NRCS.2000. Nutrient Management Code 590. Natural Resources Conservation Service Conservation Practice Standard, Louisiana.

Materials and Methods

An annual ryegrass fertility experiment was conducted for 3 years on a typical Coastal Plain soil that was previously cleared of pine timber and leveled to conform with the existing topography. The soil was classified as a Bowie (*fine-loamy, siliceous, thermic, Plinthic Paleudult*) fine sandy loam having a slope of 1% to 3%, and a cation exchange capacity (C.E.C.) less than 5 meq/100g. In mid-June of 1996, a composite soil sample at 0- to 6-inch depth was collected from the designated study area. The soil sample was analyzed at the LSU AgCenter's Soil Testing Laboratory, Baton Rouge, for analyses of soil reaction (pH), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), copper (Cu), zinc (Zn), and lime requirement to amend the soil reaction to pH 6.5. On 15 August, 1 ton/A of calcitic agricultural limestone was broadcast on the area and disked into the soil with a pulverizing disk set to a 6-inch depth. Thereafter, whole plots containing 14 sub-plots (6 ft X 17 ft), to receive one of seven designated soil-incorporated rates of broiler litter or commercial fertilizer annually for 3 consecutive years (1996-98), were arranged on the study area in a randomized complete block design with four replications. Whole plots and sub-plots were separated by 6-ft-wide alleyways. Concurrently, and in August of 1997 and 1998, broiler litter from an outside stored litter stack was acquired from a local broiler producer and stored in airtight containers inside a shed. The litter was analyzed at the LSU AgCenter's Plant Analysis Laboratory, Baton Rouge, for moisture content, total Kjeldahl nitrogen (N), P, K, and S. The results of these analyses provided an annual means for determining the commercial (inorganic) fertilizer characteristics of the broiler litter and formulation of a comparable commercial fertilizer blend on the basis of the ratio of N to P_2O_5 to K_2O to S in the broiler litter (Table 1). The commercial fertilizer blend was prepared each year with ammonium nitrate, diammonium phosphate, muriate of potash, and ammonium sulfate as sources of N, P_2O_5, K_2O, and S, with calcitic limestone as a filler.

Each September, the sub-plots were tilled with a tractor-mounted rotor tiller. For 3 years (1996-98), broiler litter rates of 0, 1, 2, 3, 4, 6, and 8 ton/A, and commercial fertilizer rates, to

Table 1. Fertilizer nitrogen (N), phosphorus (P), phosphate (P_2O_5), potassium (K), potash (K_2O), and sulfur (S) characteristics of stacked broiler litter incorporated into Bowie soil, 1996-98.

Year applied	Fertilizer nutrient N	P	P_20_5	K	K_20	S
			Dry matter concentration, %			
1996	4.93	1.22	2.80	2.82	3.39	0.64
1997	3.37	0.57	1.31	2.17	2.62	0.63
1998	3.77	1.11	2.54	2.63	3.17	0.53
Mean	4.02	0.97	2.22	2.54	3.06	0.60
			Ratio $N:P:P_2O_5:K:K_2O:S$ on dry matter basis			
1996	1	.25	.57	.57	.69	.13
1997	1	.17	.39	.64	.78	.19
1998	1	.29	.68	.70	.83	.15
Mean	1	.24	.55	.64	.77	.16
			Commercial fertilizer blend equivalent			
1996	18		10		12	2
1997	18		7		14	3
1998	18		12		15	3
Mean	18		10		14	3

provide equivalent amounts of N, phosphate (P_2O_5), potash (K_2O), and S applied at each litter rate (Table 2), were broadcast on the surface of the sub-plots, rotor tilled into the soil at 6-inch depth, and cultipacked. No other source of fertilizer was applied to any of the sub-plots throughout the remainder of each growing season. Marshall annual ryegrass seed was drill-planted in the center of each sub-plot at 30 lb/A in seven rows of 15-ft length, spaced 7 inches apart, with a tractor-mounted “Hege 80" research plot drill. Average planting date across years was 7 October, and average planting soil-depth was 1/2-inch.

Marshall annual ryegrass forage was harvested six times annually to 3-inch stubble height to simulate forage production on pasture as opposed to one or two harvests made in the spring to simulate balage and/or silage production. The initial harvest

Table 2. Annual applied rates of N-P_2O_5-K_2O-S as stacked broiler litter (SBL) and commercial fertilizer incorporated into Bowie soil across years, 1996-98.

Year 1996†			Year 1997†		
Treatment	Rate		Treatment	Rate	
N-P_2O_5-$K_2$0-S	SBL	18-10-12-2	N-P_2O_5-$K_2$0-S	SBL	18-7-14-3
lb/A	ton/A		lb/A	ton/A	
0-0-0-0	0	.00	0-0-0-0	0	.00
76-43-52-10	1	.21	50-19-39-9	1	.14
152-86-104-20	2	.42	100-38-78-18	2	.28
228-129-156-30	3	.64	150-57-117-27	3	.42
304-172-208-40	4	.85	200-76-156-36	4	.56
456-258-312-60	6	1.28	300-114-234-54	6	.84
608-344-416-80	8	1.70	400-152-312-72	8	1.12

Year 1998†			Mean over years 1996-98†		
Treatment	Rate		Treatment	Rate	
N-P_2O_5-$K_2$0-S	SBL	18-12-15-3	N-P_2O_5-$K_2$0-S	SBL	18-10-14-3
lb/A	ton/A	ton/A	lb/A	ton/A	ton/A
0-0-0-0	0	.00	0-0-0-0	0	.00
60-40-50-8	1	.17	62-34-47-9	1	.17
120-80-100-16	2	.34	124-68-94-18	2	.35
180-120-150-24	3	.50	186-102-141-27	3	.52
240-160-200-32	4	.67	248-136-188-36	4	.69
360-240-300-48	6	1.01	372-204-282-54	6	1.04
480-320-400-64	8	1.34	496-272-376-72	8	1.38

†Rate of N-P_2O_5-$K_2$0-S applied on the basis of stacked broiler litter containing 23%, 26%, and 21% moisture in 1996, 1997, and 1998, respectively, and 23% moisture over all years.

after planting was made when forage growth across most plots attained 12- to 14-inch height. Thereafter, the plots were harvested approximately monthly. Mean harvest dates over treatment years were 6 December, 18 January, 18 February, 17 March, 25 April, and 19 May. On each harvest date, forage wet-weight yields were recorded, percent dry matter determined, and dry matter yields calculated. Samples of forage collected from each sub-plot for dry matter determination were processed for chemical analyses and forwarded to the Plant Analysis Laboratory, Baton Rouge. Samples were analyzed for forage concentration levels of N, P, K, and S. Per acre uptakes of N, P, K, and S were determined as the product of dry matter yield and concentration of nutrient. Crude protein (CP) concentration of forage was the product of N concentration times 6.25. After the final May harvest, a composite soil sample, at 0- to 6-inch depth, was collected from each sub-plot and forwarded to the LSU AgCenter's Soil Testing Laboratory, Baton Rouge, for analyses of pH, P, K, Ca, Mg, S, Cu, and Zn.

Across years, plant and soil data were subjected to statistical analyses using PROC GLM (SAS 1989), and means were separated with Fisher's protected least significant difference procedure. Cost effectiveness of stacked broiler litter and commercial fertilizer use rates were determined on the basis of current custom-applied vendor prices.

Experimental plots used to evaluate Marshall annual ryegrass response to soil-incorporated broiler litter and commercial fertilizer rates.

Results and Discussion

Environmental conditions were favorable across years 1996-98 for Marshall annual ryegrass production. Each year, precipitation was sufficient in the fall for a December harvest and for subsequent harvests during the following winter and spring. Concurrently, temperatures were above normal throughout each growing season.

Forage yields

Annual forage yields of Marshall annual ryegrass were affected by soil-incorporated stacked broiler litter (SBL) rates and commercial fertilizer equivalent (CFE) rates applied at equivalent SBL rates of N, P_2O_5, K_2O, and S (Table 3). Across years, yield maximized ($P<0.05$) among soil-incorporated SBL rates at the 4 ton/A annual rate. Among CFE rates, yield maximized at 1.04 ton/A of soil-incorporated 18-10-14-3. Over all SBL and CFE rates, yield for CFE was highest ($P<0.05$).

Over years, soil-incorporated SBL and CFE rates had considerable impact on seasonal forage yields (Table 4). Across harvest months, yields increased, for the most part, as either soil-incorporated SBL rate increased from 0 ton to 8 ton/A or soil-incorporated CFE rate increased from 0 ton to 1.38 ton/A. Over all harvest months, yields ranged from 434 lb for 0 to 1,405 lb/A/harvest for 8 ton SBL/A and from 414 lb for 0 to 1,609 lb/A/harvest for 1.38 ton CFE/A. Maximum yield for SBL and CFE rates, 1,184 lb and 1,393 lb/A/harvest, respectively, occurred where 4 ton SBL/A and 1.04 ton CFE/A had been soil-incorporated annually. Over all soil-incorporated SBL and CFE rates, yield by harvest month was numerically ($P>0.05$) or significantly highest ($P<0.05$) in the presence of CFE rates.

These data indicated that plant nutrients from CFE were more readily available to the ryegrass and stimulated more rapid early and late growth compared with SBL. The December yield at each rate of CFE was numerically higher than that for each equivalent rate of SBL, resulting in significantly more ($P<0.05$) forage harvested in December on average from CFE than from SBL. The only other month in which CFE stimulated more

Table 3. Annual yields of Marshall annual ryegrass as influenced by soil-incorporated stacked broiler litter (SBL) and commercial fertilizer equivalent (CFE) rates, 1996-98.

Annual treatment		Year			
Source	Rate	1996-97	1997-98	1998-99	Mean
	ton/A	Dry forage, lb/A			
SBL	0	3,192f*	2,188gh	2,431e	2,604e
SBL	1	3,388f	3,477fg	4,058cde	3,641e
SBL	2	4,813def	5,576de	4,995bcde	5,128d
SBL	3	4,414ef	5,128ef	5,848bcde	5,130d
SBL	4	6,858bcd	7,528abc	6,920abc	7,102bc
SBL	6	6,581bcde	7,853abc	7,568ab	7,334bc
SBL	8	7,883abc	9,144ab	8,255ab	8,427ab
CFE¶	0	3,005f	1,653h	2,792ed	2,483e
CFE	.17	6,326bcde	6,878cd	6,185bcd	6,463cd
CFE	.35	5,770cde	6,756cde	6,398abc	6,308cd
CFE	.52	6,120bcde	7,434bc	6,803abc	6,786c
CFE	.69	6,482bcde	7,677abc	8,137ab	7,432bc
CFE	1.04	8,247ab	8,715ab	8,120ab	8,361ab
CFE	1.38	10,026a	9,240a	9,693a	9,653a
		Overall SBL and CFE rates			
SBL	3.4	5,304B	5,842B	5,725B	5,624B
CFE	.59	6,568A	6,907A	6,875A	6,784A

*Means having a lowercase letter in common within a column of treatments or uppercase letter in common within a column of overall treatments are not different at the 5% level of probability.

¶CFE = N, P_2O_5, K_2O, S content of SBL on DM basis. CFE rates shown are 3-year means for an 18-10-14-3 complete fertilizer.

forage production than SBL was in April, when ryegrass was in its most actively growing period.

Overall, yield data (Tables 3 and 4) indicated that soil-incorporated SBL or CFE were highly acceptable fertilizer sources for Marshall annual ryegrass forage production on pastures. In an average year, ryegrass on pastures should attain a height of 12 to 14 inches (900 lb to 1,000 lb/A of dry matter) after planting before cattle grazing is initiated. To meet this production level in December, a 3 ton SBL/A or a .35 ton CFE/A was the minimum required soil-incorporated rate. Also, in an average year, per acre dry matter yields of 7,000 to 8,000 pounds are considered excellent for seasonal annual ryegrass production on pastures. This seasonal yield range was produced where either 4 ton SBL/A or .69 ton CFE/A was soil-incorporated annually.

Table 4. Three-year mean Marshall annual ryegrass seasonal yields as influenced by soil-incorporated stacked broiler litter (SBL) and commercial fertilizer equivalent (CFE) rates across harvest dates, 1996-98.

Annual treatment		Harvest months						
Source	Rate	Dec	Jan	Feb	Mar	Apr	May	Mean
	ton/A	Dry forage, lb/A						
SBL	0	76	22	78	143	1663	621	434e*
SBL	1	338	55	174	324	2061	688	607e
SBL	2	723	189	237	413	2744	822	855d
SBL	3	906	258	285	372	2449	860	855d
SBL	4	932	338	401	655	3739	1037	1184bc
SBL	6	1100	503	503	629	3493	1107	1222bc
SBL	8	1094	633	559	786	4172	1184	1405ab
CFE¶	0	134	18	97	156	1448	628	414e
CFE	.17	798	196	294	567	3766	840	1077cd
CFE	.35	1110	362	376	568	3114	778	1051cd
CFE	.52	1143	432	360	584	3416	850	1131c
CFE	.69	1326	518	482	634	3486	986	1239bc
CFE	1.04	1354	597	512	757	4014	1126	1393ab
CFE	1.38	1329	599	573	1061	4830	1216	1609a
		Overall SBL and CFE rates						
SBL	3.4	739B	286A	320A	475A	2903B	903A	937B
CFE	.59	1028A	389A	385A	618A	3439A	924A	1131A

*Means having a lowercase letter in common within a column of treatments or uppercase letter in common within a column of overall treatments are not different at the 5% level of probability.

¶CFE = N, P_2O_5, K_2O, S content of SBL on DM basis. CFE rates shown are 3-year means for an 18-10-14-3 complete fertilizer.

Nutrient concentrations in forage

Plant tissue concentration levels of N, P, K, and S in harvested forage of Marshall ryegrass were affected by both SBL and CFE soil-incorporated rates (Table 5). Among annual soil-incorporated SBL rates, N, P, K, and S tissue concentrations each increased as the rate increased, maximizing (P<0.05) over years, at 3.31% N (20.69% crude protein), .49% P, 3.67% K, and .31% S for the 8 ton/A rate. Concurrently, N, P, K, and S tissue concentrations of harvested forage also increased, for the most part, as the annual soil-incorporated CFE rates increased; maximizing (P<0.05) over years at 4.05% N (25.31% crude protein), .39% P, 3.72% K, and .31% S for the 1.38 ton/A rate. Over all soil-incorporated SBL and CFE rates, the N tissue concentration level was higher (P<0.05) for CFE rates, and the P tissue concentration was higher for SBL rates. K and S tissue concentrations were not different (P<0.05).

Table 5. Three-year mean nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) concentrations of harvested Marshall annual ryegrass as influenced by soil-incorporated stacked broiler litter (SBL) and commercial fertilizer equivalent (CFE) rates, 1996-98.

Annual treatment		Forage content			
Source	Rate	N	P	K	S
	ton/A		%		
SBL	0	2.51c*	.21f	2.57e	.26d
SBL	1	2.50c	.32e	2.88d	.27cd
SBL	2	2.71c	.37d	3.09c	.28bcd
SBL	3	2.74c	.41c	3.16c	.29bc
SBL	4	3.02b	.45b	3.41b	.30ab
SBL	6	3.12ab	.48ab	3.58ab	.30ab
SBL	8	3.31a	.49a	3.67a	.31a
CFE¶	0	2.47f	.26c	2.65d	.27b
CFE	.17	2.89d	.27bc	3.08c	.27b
CFE	.35	3.08d	.28bc	3.20bc	.27b
CFE	.52	3.24cd	.31b	3.24bc	.28b
CFE	.69	3.41c	.31b	3.32b	.28b
CFE	1.04	3.76b	.37a	3.63a	.31a
CFE	1.38	4.05a	.39a	3.72a	.31a
		Overall SBL and CFE rates			
SBL	3.4	2.86B	.40A	3.23A	.29A
CFE	.59	3.30A	.32B	3.29A	.28A

*Means having a lowercase letter in common by SBL or CFE sources within a column or uppercase letter in common within a column of overall sources rates are not different at the 5% level of probability.

¶CFE = N, P_2O_5, K_2O, S content of SBL on DM basis. CFE rates shown are 3-year means for an 18-10-14-3 complete fertilizer.

Overall, plant tissue data indicated that for Marshall annual ryegrass production on Bowie soil: a) fertilizer N from CFE was more readily available for plant absorption than fertilizer N from SBL, b) fertilizer P from SBL was more readily available for plant absorption than fertilizer P from CFE, and c) fertilizer K and S from either SBL or CFE was nearly equally available for plant absorption. Where maximum yield among annually soil-incorporated SBL rates was produced in the presence of the 4 ton/A rate, plant tissue concentrations of N, P, K, and S averaged 3.04%, .45%, 3.41%, and .30% respectively. Among annually soil-incorporated CFE rates, plant tissue concentrations of N, P, K, and S averaged 3.76%, .39%, 3.63%, and .31%, respectively, where maximum yield was produced at 1.04 ton CFE/A.

Nutrient uptake and removal of soil-incorporated rates

Uptakes of N, P_2O_5, K_2O,and S and removals of applied N, P_2O_5, K_2O, and S from SBL by Marshall annual ryegrass cropping are reported in Table 6. Results showed that as the rate of soil-incorporated fertilizer N, P_2O_5, K_2O, and S from SBL increased, uptake of N, P_2O_5, K_2O, and S each increased. Crop removal of fertilizer N, P_2O_5, K_2O, and S was erratic among soil-incorporated rates with narrow ranges of 28% to 44% N, 24% to 35% P_2O_5, 58% to 87% K_2O, and 22% to 33% S. Maximum removal of fertilizer N, P_2O_5, K_2O, and S for soil-incorporated SBL occurred at the 4 ton/A rate. Maximum yield also was produced at 4 ton SBL/A that, on average, provided 248, 136, 188, and 36 lb/A of N, P_2O_5, K_2O, and S, respectively. At this rate, 44%, 35%, 87%, and 33% of the soil-incorporated N, P_2O_5, K_2O, and S, respectively, was removed by cropping.

Uptakes of N, P_2O_5, K_2O, and S and removals of applied N, P_2O_5, K_2O, and S as CFE by Marshall annual ryegrass cropping are reported in Table 7. Results showed that as the rate of soil-incorporated CFE N, P_2O_5, K_2O, and S increased: a) uptake of N, P_2O_5, K_2O, and S each increased; and b) crop removal of fertilizer N, P_2O_5, K_2O, and S each decreased. Where an average .59 ton CFE/A as 18-10-14-3 provided 213, 117, 161, and 31 lb/A of soil-incorporated N, P_2O_5, K_2O, and S, respectively, cropping removed 69% of the N, 28% of the P_2O_5, 95% of the K_2O, and 37% of the S.

Table 6. Three-year mean nitrogen (N), phosphate (P_2O_5), potash (K_2O), and sulfur (S) uptakes and removal of soil-incorporated rates as stacked broiler litter (SBL) by Marshall annual ryegrass cropping on Bowie soil, 1996-99.

Annual treatment		N			P_2O_5		
Source	Rate	Rate	Uptake	Removal	Rate	Uptake	Removal
	ton/A	lb/A		%	lb/A		%
SBL	0	0	65d*	--	0	16e	--
SBL	1	62	86cd	35	34	27d	34
SBL	2	124	114c	39	68	38c	33
SBL	3	186	117c	28	102	43c	27
SBL	4	248	174b	44	136	63b	35
SBL	6	372	197b	35	204	71b	27
SBL	8	496	230a	33	272	82a	24
Mean	3.4	213	144	36	117	49	30
		K_2O			S		
		Rate	Uptake	Removal	Rate	Uptake	Removal
		lb/A		%	lb/A		%
SBL	0	0	96e	--	0	7e	--
SBL	1	47	129de	69	9	10d	33
SBL	2	94	172cd	81	18	13c	33
SBL	3	141	178c	58	27	13c	22
SBL	4	188	260b	87	36	19b	33
SBL	6	282	292ab	69	54	20b	24
SBL	8	376	333a	63	72	23a	22
Mean	3.4	161	209	71	31	15	28

*Means having a lowercase letter in common within a column of uptakes are not different at the 5% level of probability.

Results also showed that where 100% of the fertilizer N and K_2O was removed by cropping, soil-incorporated N rates less than 124 lb/A (.35 ton CFE/A) or K_2O rates less than 188 lb (.69 ton CFE/A) were insufficient to meet crop production requirements while maintaining the fertility status of the soil. Where maximum yield was produced at 1.04 ton CFE/A, CFE on average provided 372, 204, 282, and 54 lb/A of N, P_2O_5, K_2O, and S, respectively. At this rate, 57%, 21%, 89%, and 28% of the soil-incorporated N, P_2O_5, K_2O, and S, respectively, was removed by cropping.

Table 7. Three-year mean nitrogen (N), phosphate (P_2O_5), potash (K_2O), and sulfur (S) uptakes and removal of soil-incorporated rates as commercial fertilizer equivalent (CFE) of stacked broiler litter rates by Marshall annual ryegrass cropping on Bowie soil, 1996-99.

Annual treatment		N			P_2O_5		
Source	Rate	Rate	Uptake	Removal	Rate	Uptake	Removal
	ton/A	lb/A		%	lb/A		%
CFE¶	0.00	0	62e*	---	0	18e	--
CFE	0.17	62	152d	100	34	35d	49
CFE	0.35	124	163cd	81	68	37d	28
CFE	0.52	186	185cd	66	102	42cd	24
CFE	0.69	248	215c	62	136	48c	22
CFE	1.04	372	275b	57	204	61b	21
CFE	1.38	496	295a	47	272	77a	22
Mean	0.59	213	192	69	117	45	28
		K_2O			S		
		Rate	Uptake	Removal	Rate	Uptake	Removal
		lb/A		%	lb/A		%
CFE	0.00	0	94d	0	0	8c	--
CFE	0.17	47	213c	100	9	14b	67
CFE	0.35	94	226c	100	18	15b	39
CFE	0.52	141	243c	100	27	17b	33
CFE	0.69	188	274c	96	36	18b	28
CFE	1.04	282	344b	89	54	23a	28
CFE	1.38	376	412a	84	72	27a	26
Mean	0.59	161	258	95	31	18	36

*Means having a lowercase letter in common within a column of uptakes are not different at the 5% level of probability.
¶CFE = N, P_2O_5, K_2O,and S content of stacked broiler litter on DM basis. CFE rates shown are 3-year means for an 18-10-14-3 complete fertilizer.

Over all soil-incorporated rates of N, P_2O_5, K_2O, and S, data indicated that as a source of: a) N fertilizer, SBL was 33% less efficient than CFE; b) P_2O_5 fertilizer, SBL was as efficient as CFE; c) K_2O fertilizer, SBL was 24% less efficient than CFE; and d) S fertilizer, SBL was 8% less efficient than CFE. Thus, the organically bound N, K_2O, and S in SBL were not as readily available for annual ryegrass production as the inorganically bound N, K_2O, and S in CFE. P from either source appeared nearly equally available.

Fertilizer cost effectiveness

When applied on the basis of currently quoted vendor prices in north Louisiana, soil-incorporated SBL was, for the most part, more cost effective than CFE where annual ryegrass yield response to soil-incorporated use rates was nearly equivalent. As shown in Table 8, the fertilizer cost for a yield response of approximately 4,500 lb forage/A was 1.1 cent/lb of forage produced with SBL at 4 ton/A compared with 2.5 cent/lb of forage with CFE at .52 ton/A. Where the yield response was approximately 5,800 lb forage/A, the cost/lb of forage was 1.6 cents for SBL at 8 ton/A and 3.7 cents for CFE at 1.04 ton/A.

Table 8. Three-year mean Marshall annual ryegrass yield response and estimated cost associated with stacked broiler litter (SBL)and commercial fertilizer equivalent (CFE) use rates, 1996-99.

Fertilizer source		Annual ryegrass yield		
Rate	Cost	Actual	Response	Cost
ton/A	$/A	lb/A	lb/A	¢/lb
SBL†			SBL	
0	0	2604c*	0	0
1	12	3641c	1037	1.2
2	24	5128b	2524	1.0
3	36	5130b	2526	1.4
4	48	7102a	4498	1.1
6	72	7334a	4730	1.5
8	96	8427a	5823	1.6
CFE [18-10-14-3]‡			CFE [18-10-14-3]	
0.00	0	2483d	0	0
0.17	36	6463c	3980	.9
0.35	73	6308c	3825	1.9
0.52	109	6786c	4303	2.5
0.69	145	7432bc	4949	2.9
1.04	218	8361ab	5878	3.7
1.38	289	9653a	7170	4.0

*Means having a letter in common within a column by SBL or CFE treatments are not different at the 5% level of probability.
†Custom applied @$12.00/ton.
‡Custom applied @209.75/ton.

Soil fertility

The fertility status of the Bowie soil, limed with 1 ton/A of calcitic limestone to amend the strongly acid soil (pH 5.3) to slightly acid (pH 6.2), was affected considerably by annual ryegrass cropping for 3 years in the presence of soil-incorporated rates of SBL and CFE providing similar amounts of N, P_20_5, K_20, and S. As shown in Table 9, among rates of SBL from 3 to 24 ton/A: a) soil acidity levels were, for the most part, within medium acid (pH 5.6 to 6.0) levels; b) soil P levels tended to increase as the rate increased with very high levels (>90 ppm) of P present at the 12 to 24 ton/A rates; c) soil K levels were not different (P>0.05), for the most part, with very low (<50 ppm) or low levels (50 to 80 ppm) present across rates; and d) soil S levels were at low levels (<8 ppm) regardless of rate. Among CFE rates of .51 to 4.14 ton 18-10-14-3/A: a) soil acidity levels tended to decrease as the rate increased with very strongly acid soil (pH 4.5 to pH 5.0) present across CFE rates from .51 to 3.12 ton/A and extremely acid soil (<pH 4.5) present at the 4.14 ton/A rate; b) low soil P levels (30 to 69 ppm) were present and not different (P>0.05) among CFE rates of .51 to 2.07 ton/A, and increased to high (70 to 90 ppm) and very high (>90 ppm) levels as the CFE rate increased to 3.12 ton and 4.14 ton/A, respectively; c) soil K levels were, for the most part, not different (P>0.05) among rates with very low K levels across treatments; and d) soil S levels were erratic with either low (<8 ppm) or medium (8 to 15 ppm) levels. When compared with ryegrass cropping without SBL (0 lb SBL/A) or CFE (0 lb CFE/A): a) soil acidity was not different (P>0.05) across SBL rates and higher (P<0.05) across CFE rates; b) soil P levels for SBL rates were higher, while soil P levels for CFE rates were not different except for the higher levels found in the presence of CFE rates higher than 3.12 ton/A; c) soil K levels tended to be higher with SBL rates and lower with CFE rates; and d) soil S levels were, for the most part, not different from those of the SBL or CFE rates. Moreover, when compared with the initial soil test levels before the application of lime and soil-incorporation of SBL and CFE rates: a) soil acidity decreased with SBL rates and increased with CFE rates; b) soil P rating levels increased for both SBL and CFE rates; c) soil K levels were not different for SBL rates but lower for CFE rates; and d) soil S rating levels were

Table 9. Effects of 3 years of soil-incorporated stacked broiler litter (SBL) and commercial fertilizer equivalent (CFE) rates and annual ryegrass cropping on soil reaction (pH), and levels of soil phosphorus (P), potassium (K), and sulfur (S) in Bowie soil, 0- to 6-inch depth, 1999.

Treatment, 3-yr		pH		P		K		S	
Source	Rate	PT†	1999	PT	1999	PT	1999	PT	1999
	ton/A					[Rating: VL=very low to VH=very high]ppm			
SBL	0	5.3	5.5ab*	[L]24	[L]17h	[L]55	[VL]40cde	[M]9	[L]5bcd
SBL	3	5.3	5.3bc	[L]24	[M]56gef	[L]55	[L]46bcd	[M]9	[L]5bcd
SBL	6	5.3	5.6ab	[L]24	[M]51efgh	[L]55	[L]57ab	[M]9	[L]4cd
SBL	9	5.3	5.9a	[L]24	[H]74def	[L]55	[L]50abc	[M]9	[L]4d
SBL	12	5.3	5.5bc	[L]24	[VH]105cd	[L]55	[L]50abc	[M]9	[L]5bcd
SBL	18	5.3	5.7a	[L]24	[VH]153ab	[L]55	[L]63ab	[M]9	[L]5cd
SBL	24	5.3	5.6ab	[L]24	[VH]186a	[L]55	[L]66a	[M]9	[L]7abc
CFE¶	0	5.3	5.3bc	[L]24	[L]25gh	[L]55	[VL]38cde	[M]9	[L]5cd
CFE	.51	5.3	5.0cd	[L]24	[M]31gh	[L]55	[VL]35cdef	[M]9	[L]6bcd
CFE	1.05	5.3	5.0cd	[L]24	[L]30gh	[L]55	[VL]31def	[M]9	[L]6bcd
CFE	1.56	5.3	4.8de	[L]24	[M]41fgh	[L]55	[VL]27ef	[M]9	[M]8ab
CFE	2.07	5.3	5.0cd	[L]24	[M]45efgh	[L]55	[VL]20f	[M]9	[L]6bcd
CFE	3.12	5.3	4.7de	[L]24	[H]79de	[L]55	[VL]20f	[M]9	[L]7abc
CFE	4.14	5.3	4.4e	[L]24	[VH]119bc	[L]55	[VL]33def	[M]9	[M]9a
						Overall SBL and CFE rates			
SBL	10.3	5.3	5.5	[L]24	[VH]91A	[L]55	[L]53A	[M]9	[L]5B
CFE	1.8	5.3	4.9	[L]24	[L]53B	[L]55	[VL]29B	[M]9	[L]7A

*Means having a either a lowercase or uppercase letter in common within a column are not different at the 5% level of probability.

¶CFE rates are 3-year totals for an 18-10-14-3 complete fertilizer.

†Prior to the application of 1 ton/A of calcitic limestone and treatments, 1996.

lower for all SBL rates, and, for the most part, also lower for CFE rates.

Over all SBL and CFE rates following 3 years of annual ryegrass cropping, soil acidity was lower ($P<0.05$) and P and K levels higher ($P<0.05$) in the presence of SBL rates. Soil S level for CFE rates was higher than that of the SBL rates. Soil levels of Ca, Mg, Cu, and Zn, as influenced by 3 years of annual ryegrass cropping and soil-incorporated rates of SBL and CFE, are reported in Table 10. Results showed that soil Ca, Mg, Cu, and Zn levels each tended to increase as the rate of SBL increased from 3 ton to 24 ton/A. Where CFE had been soil-incorporated at .51 ton to 4.14 ton/A, soil Ca and Mg levels each tended to decrease as the rate increased; soil Cu and Zn levels were each not different ($P>0.05$). When compared with cropping in absence of soil-incorporated SBL or CFE rates (0 lb/A of SBL or CFE), soil Ca, Mg, Cu, and Zn levels were higher ($P<0.05$) for all SBL rates of more than 6 ton/A. Soil Ca and Mg levels were lower ($P<0.05$) for all CFE rates of more than 1.56 ton/A, and Cu and Fe levels were not different from that cropped without CFE, regardless of CFE rate. Over all SBL and CFE rates, soil Ca, Mg, Cu, and Zn levels for SBL rates were higher ($P<0.05$) than those for the CFE rates. Soil test levels, however, were not different with very low levels of Ca and Mg (<500 ppm Ca, and <50 ppm Mg) across both CFE and SBL rates.

Overall, soil data indicated the following where annually soil-incorporated SBL rates of 1 ton to 8 ton/A or CFE rates of .17 ton to 1.38 ton 18-10-13-3/A were applied for 3 years and cropped with Marshall annual ryegrass. The test site was a strongly acid Bowie soil, limed with 1 ton calcitic limestone/A, with a very low, low, medium, very low, and very low soil test rated levels of P, K, S, Ca, and Mg.

1. Soil acidity was reduced from strongly acid to a more favorable moderately acid range with increased levels of available Ca and Mg where SBL rates were applied.

2. Soil acidity was increased from strongly acid to a more unfavorable very strongly acid range with decreased levels of available Ca and Mg where CFE rates were applied.

Table 10. Effects of 3 years of soil-incorporated stacked broiler litter (SBL) and commercial fertilizer equivalent (CFE) rates and annual ryegrass cropping on soil levels of calcium (Ca), magnesium (Mg), copper (Cu),and zinc (Zn) in Bowie soil, 0- to 6-inch depth, 1999.

Treatment, 3-yr		Ca		Mg		Cu		Zn	
Source	Rate	PT†	1999	PT	1999	PT	1999	PT	1999
	ton/A	[Rating: VL=very low to VH=very high]ppm						lb/A	
SBL	0	[VL]217	[VL]325cd**	[VL]34	[VL]23ef	.36	.28ef	.70	.20e
SBL	3	[VL]217	[VL]304d	[VL]34	[VL]28de	.36	.58de	.70	.76de
SBL	6	[VL]217	[VL]419ab	[VL]34	[VL]42bc	.36	.98d	.70	1.40cd
SBL	9	[VL]217	[VL]399bc	[VL]34	[VL]38cd	.36	1.50c	.70	2.02c
SBL	12	[VL]217	[VL]408abc	[VL]34	[VL]48bc	.36	2.22b	.70	3.50b
SBL	18	[VL]217	[VL]437ab	[VL]34	[M]51b	.36	3.22a	.70	4.82a
SBL	24	[VL]217	[VL]494a	[VL]34	[M]65a	.36	3.22a	.70	5.38a
CFE¶	0	[VL]217	[VL]322cd	[VL]34	[VL]29de	.36	.20ef	.70	.44d
CFE	.51	[VL]217	[VL]278ed	[VL]34	[VL]23efg	.36	.24ef	.70	.42d
CFE	1.05	[VL]217	[VL]292d	[VL]34	[VL]19efgh	.36	.16ef	.70	.24e
CFE	1.56	[VL]217	[VL]203ef	[VL]34	[VL]14fgh	.36	.14ef	.70	.24e
CFE	2.07	[VL]217	[VL]177f	[VL]34	[VL]10gh	.36	.08f	.70	.12e
CFE	3.12	[VL]217	[VL]177f	[VL]34	[VL]10h	.36	.16ef	.70	.38de
CFE	4.14	[VL]217	[VL]177f	[VL]34	[VL]12fgh	.36	.22ef	.70	.36de
Overall SBL and CFE rates									
SBL	10.3	[VL]217	[VL]398A	[VL]34	[VL]42A	.36	1.78A	.70	2.58A
CFE	1.8	[VL]217	[VL]232B	[VL]34	[VL]16B	.36	.16B	.70	.30B

*Means having either a lowercase or uppercase letter in common within a column are not different at the 5% level of probability.

¶CFE rates are 3-year totals for an 18-10-14-3 complete fertilizer.

†Prior to the application of 1 ton/A of calcitic limestone and treatments, 1996.

3. Soil P levels increased where both SBL and CFE rates were applied with higher levels of soil P in the presence of SBL rates.

4. Soil available K levels remained essentially similar where SBL rates were applied but decreased where CFE rates were applied.

5. Soil S levels were generally lower where both SBL and CFE rates were applied.

6. Soil Cu and Zn levels increased with applied SBL rates and decreased with applied CFE rates.

No supplemental winter feed is required by cattle grazing Marshall annual ryegrass pasture.

Forage Crop Results

Annual rates of a complete fertilizer (N-P_2O_5-K_20-S) as SBL (stacked broiler litter) and CFE (commercial fertilizer equivalent) were soil-incorporated into a Bowie soil and cropped for 3 years, 1996-99, with Marshall annual ryegrass. The Bowie soil was strongly acid and contained low levels of P and K, a medium level of S, and very low levels of Ca and Mg. After soil-incorporation of 1 ton/A of calcitic limestone, rates of a complete fertilizer ranging on average from 62-34-47-9 lb to 496-272-376-72 lb of N-P_2O_5-K_20-S/A from 1 ton to 8 ton SBL/A or from .17 ton to 1.38 ton CFE as 18-10-14-3/A were soil-incorporated annually before planting. No other fertilizer source of plant nutrients was applied during the growing season. After planting, Marshall annual ryegrass was managed to simulate forage production on pastures. Over years, results revealed the following:

Stacked broiler litter

1. Maximum forage yield, about 7,000 lb/A of dry forage, was produced at a fertilizer cost of 1.1 ¢/lb of forage where 248-136-188-36 lb of N-P_2O_5-K_20-S/A was soil-incorporated as SBL at 4 ton/A; a $48/A cost with an SBL cost of $12/ton.

2. Seasonal forage production at the 4 ton/A soil-incorporated SBL rate was sufficient from December through May for livestock grazing, and, on average, contained levels of crude protein (18.9%) and minerals P (.45%), K (3.41%), and S (.30%) that would meet or exceed the nutritional requirements of all classes of beef cattle.

3. Cropping removal of soil-incorporated plant nutrients N, P, K, and S as SBL on the basis of uptake averaged 36%, 30%, 71%, and 30%, respectively, over all rates. At the 4 ton/A soil-incorporated rate, removal of N, P, K, and S was 44%, 35%, 87%, and 33%, respectively.

4. Soil-incorporated use rates of SBL had a moderating effect on soil acidity, and increased soil P, Ca, Mg, Cu, and Zn levels; soil S levels decreased.

Commercial fertilizer

1. Maximum forage yield, approximately 8,500/A of dry forage, was produced at a fertilizer cost of 3.7 ¢/lb of forage where 372-204-282-54 lb of N-P_2O_5-K_20-S/A was soil-incorporated as CFE 18-10-14-3 at 1.01 ton/A; a $218.14/A cost with a CFE cost of $209.75/ton.

2. Seasonal forage production at the 1.01 ton/A soil-incorporated 18-10-14-3 rate was more than sufficient from December through May for livestock grazing, and, on average, contained levels of crude protein (23.5%) and minerals P (.37%), K (3.63%), and S (.31%) that would meet or exceed the nutritional requirements of all classes of beef cattle.

3. Cropping removal of soil-incorporated plant nutrients N, P, K, and S as CFE on the basis of uptake averaged 69%, 28%, 95%, and 36%, respectively, over all rates. At the 1.01 ton 18-10-14-3/A soil-incorporated rate, removal of N, P, K, and S was 57%, 21%, 89%, and 28%, respectively.

4. Soil-incorporated use rates of CFE increased soil acidity and soil P level, and decreased soil K, Ca, Mg, Cu, and Zn levels; soil S levels were not affected.

Poultry litter vs. commercial fertilizer

1. Crop production

Commercial fertilizer significantly outyielded broiler litter where similar rates of N-P_2O_5-K_20-S/A (on the basis of SBL content) were soil-incorporated. Plant nutrient N in the commercial fertilizer was more readily available for Marshall annual ryegrass production. Thus, for a highly acceptable seasonal annual ryegrass yield of 7,000 lb/A of dry forage on pasture, .35 ton (700 lb)/A of CFE as 18-10-14-3 providing 124-68-94-18 lb of N-P_2O_5-K_20-S/A at a fertilizer cost of 1.9 ¢/lb of forage/A, was nearly equally as effective as 4 ton/A of SBL providing 248-136-188-36 lb of N-P_2O_5-K_20-S/A at a fertilizer cost of 1.1 ¢/lb of forage/A.

2. Nutrient management

A. Use of soil-incorporated SBL alleviated need for subsequent application of agricultural limestone for amending soil acidity and providing Ca and Mg for crop production. Use of soil-incorporated CFE will require subsequent agricultural limestone application for amendment of soil acidity and as a source of Ca and Mg.

B. Where soil P level increased to a very high level in the presence of either SBL or CFE soil-incorporated rates, cropping in absence of any P fertilization practices may be required. On the basis of nutrient uptake data, soil-incorporation of 200-0-300-28 lb/A of N-P_2O_5-K_20-S/A would meet the requirements for a 7,000 lb dry forage annual ryegrass crop and maintain soil K and S levels.

C. Use of soil-incorporated SBL provided sufficient amounts of essential micro-nutrients Cu and Zn to meet crop production requirements and increased soil Cu and Zn levels. For soil-incorporated SBL rates of 1 ton to 8 ton/A, soil annual loading rates ranged from .07 lb to .95 lb/A of Cu; Zn ranged from .02 lb to 1.56 lb/A. The maximum Bowie-type soil loading rate for Cu and Zn is 125 lb and 250 lb/A, respectively, (USEPA, US Code, Reference 40 CFR, Parts 403 and 503). Use of soil-incorporated CFE provided insufficient amounts of essential plant nutrients Cu and Zn for crop production.

3. Impact

Annual ryegrass is an important forage crop in Louisiana that provides winter grazing for beef and dairy cattle. Profitable beef and milk production is related to optimum growth of ryegrass forage that requires adequate levels of plant nutrients, especially nitrogen. Nitrogen must be applied as economically as possible. In north Louisiana, broiler litter is a readily available plant nutrient source, which our data show is more economical for ryegrass production than commercial fertilizer where equivalent nitrogen rates are applied. This is attributed not only to broiler litter's less expensive cost per pound of forage produced, but also because its use moderates soil acidity and alleviates the need for application of agricultural limestone. Broiler litter also provides certain micro-nutrients, particularly copper and zinc, that are required for optimum forage, as well as beef and milk production.

There are, however, two primary drawbacks to broiler litter use as the only plant nutrient source. First, our data indicate that the availability of nitrogen from broiler litter rates less than 4 tons per acre may not be rapid enough to stimulate adequate growth of ryegrass by December. Fall management of ryegrass, before grazing initiation, is related to stockpiling of forage, which ensures an adequate forage supply through the winter months. To achieve adequate fall growth of ryegrass after planting with soil-incorporated broiler litter at rates less than 4 tons per acre, a low rate of inorganic commercial nitrogen fertilizer may be both beneficial and economical. More research is needed to determine what the appropriate additional nitrogen fertilization practice would be. Second, continued use of broiler litter caused a rapid buildup of phosphorus in the soil, which may result in the impairment of designated surface water use from elevated phosphorus levels in exiting runoff. Data indicate that broiler litter as a fertilizer source for annual ryegrass production should be practiced only on soils having "soil test" P levels below very high levels. Under these circumstances, use of recommended commercial inorganic fertilizers containing no phosphate would be considered an environmentally friendly practice. More research is needed to determine the number of annual ryegrass cropping years without applied phosphate that would be required to reduce very high levels of soil P to acceptable levels, at which time broiler litter would become a viable fertilizer source.

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