PUBLICATIONS
1986

FORAGE AND LIVESTOCK RESEARCH - 1986

RESEARCH CENTER TECHNICAL REPORT 86-1

Texas A&M University Agricultural Research
and Extension Center at Overton

Texas Agricultural Experiment Station
Texas Agricultural Extension Service

Overton, Texas

April 24, 1986

RESPONSE OF COASTAL BERMUDAGRASS TO PHOSPHORUS
ON LIMED EAST TEXAS SOIL

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SUMMARY

Coastal bermudagrass response to limestone and phosphorus was evaluated on a strongly acid (pH 4.5) Lilbert loamy fine sand which tested low in phosphorus (P), calcium (Ca), and magnesium (Mg) and very low in potassium (K). Limestone treatments of 0, 600, and 3400 lb/ac were applied in early July, 1983. Phosphorus treatments were applied at this same time at rates of 0, 30, 61, 92, 123, 245, and 491 lb P_2O_5/ac. Two harvests of grass were made in 1983. The grass was killed by a freeze in December, 1983, and resprigged in 1984. The regrowth covered the plot area completely by mid-summer 1985.

Optimum yield of Coastal bermudagrass occurred at about 12 parts per million (ppm) residual soil P. Coastal bermudagrass grew equally well at pH levels of 4.51, 4.65, and 6.19, resulting from application of 0, 600, and 3400 lb/ac, followed by two years of nitrogen (N) fertilization. Phosphorus fertilization of this soil at rates from 0 to 982 lbs/ac in two applications increased soil P_2O_5 from 4.7 to 38 ppm at zero lime, and from 2.7 to 55 ppm at the 3400 lb/ac rate of limestone. Fertilizing with P_2O_5 lowered available manganese (Mn) and K in the soil. Liming, as expected, decreased soil Mn and increased Ca and Mg. Phosphorus taken up by Coastal bermudagrass continued to increase as the P fertilizer rate was increased. Phosphorus uptake at the zero P check was 5.3 lb P_2O_5/ton of dry matter, compared to 10.3 lb at the high rate of P fertilization. Limestone application increased Ca and Mg in the plant from 0.248 and 0.140 percent to 0.366 and 0.165, respectively.

OBJECTIVES

1. Determine the yield and quality of forage produced at varying levels of soil acidity (limestone rates).
2. Determine the effect of phosphorus rates on yield and quality of warm and cool season forages.

3. Determine the interactive effects of limestone and phosphorus on warm and cool season forage production.
4. Evaluate the effect of limed soil pH change on phosphorus availability to forage plants.

PROCEDURE

This study was initiated in July 1983, on a Lilbert loamy fine sand with a surface 6-inch depth pH of 4.5. Limestone and P_2O_5 rates are detailed below:

Limestone/P_2O_5	Limestone/P_2O_5	Limestone/P_2O_5
	lb/ac	
0/ 0	600/ 0	3400/ 0
0/ 30	600/ 30	3400/ 30
0/ 61	600/ 61	3400/ 61
0/ 92	600/ 92	3400/ 92
0/123	600/123	3400/123
0/245	600/245	3400/245
0/491	600/491	3400/491

Each of these treatment combinations was replicated eight times. Phosphorus was supplied as triple superphosphate. Limestone was applied as 100% minus 7-mesh and 27% minus 100-mesh agricultural grade limestone consisting predominantly of $CaCO_3$ with 10 to 15% $MgCO_3$. Limestone rates were main plots and P rates were sub plots of a split-plot design. Each plot was 9 ft wide by 15 ft long. Limestone treatment was planned for only one application. Phosphorus rates were applied twice. The soil test P level had an adequate range for evaluation of residual available soil P.

Samples were collected from the surface 6-inch soil depth in the spring of 1984. Soil pH was 4.71, 4.81, and 5.66 in response to limestone rates of 0, 0.3, and 1.7 tons/ac, respectively, averaged over all P levels. Soil P increases of 5.28, 5.53, 6.85, 8.79, 10.63, 13.54, and 39.78 ppm were measured in response to 0, 30, 61, 92, 123, 245, and 491 lb/P_2O_5/ac, respectively, averaged over three pH levels.

A second application of P_2O_5 rates was made in the spring of 1984. Soil samples were collected from the surface 6-inch depth in July of 1985 and analyzed for P, pH, Ca, Mg, K, and Mn.

The resprigged Coastal bermudagrass covered the site adequately for a first harvest in early June. Three harvests of grass were made in 1985 from only four of the eight replications. Grass in replications 1 through 4 had not fully covered the plot areas. Nitrogen treatments applied prior to grass growth for harvests 1 and 2 were 100 and 120 lb/ac from ammonium sulfate, respectively. For harvest three, the N rate was 160 lb/ac from urea.

RESULTS

Response of Coastal bermudagrass to residual soil P from previous years' fertilizer applications is indicated in Table 1.

TABLE 1. RESPONSE OF COASTAL BERMUDAGRASS TO RESIDUAL SOIL P. VALUES ARE AVERAGES OVER FOUR REPLICATIONS AND THREE LIMESTONE TREATMENT RATES

Residual	Dry Matter Yield[1]			
P_2O_5	Harvest 1	Harvest 2	Harvest 3	Total
ppm	lb/ac			
3.4	4017 A	2862 A	3127 A	10005 A
4.7	4351 A	3172 ABC	2964 A	10487 AB
7.6	4473 A	3169 AB	3639 AB	11281 BC
11.5	4530 A	3462 BCD	4437 B	12429 C
13.9	4133 A	3568 D	4447 B	12148 C
23.6	4306 A	3405 BCD	3789 AB	11501 BC
44.4	4224 A	3485 CD	4272 B	11981 C

1. Dry matter yields, within individual harvests, followed by the same letter are not statistically different at the $p<0.05$ level of probability.

Harvest 1 indicated there was no yield response to residual soil P. This could be misleading because there was probably sufficient lack of uniformity in the grass cover which resulted in no significant differences. This was the June harvest, and was actually the second time the grass was removed from this plot area. The first growth of grass was uniformly cut and removed from these plots because it did not appear to have grown to a uniform cover.

Succeeding harvests and the total yields indicated that the optimum, significant yield occurred in the range of 7.6 to 13.9 ppm of residual soil P extracted with 1.4 N NH_4OAc in 1 N HCl and 0.025 M

EDTA adjusted to pH 4.2. Texas A&M interpretation of this P soil test indicated that 0-5 ppm is very low, 5-10 ppm is low, 10-20 ppm is medium, 30-40 ppm is high, and 40+ ppm is very high. This first year test of residual soil P vs Coastal bermudagrass yield indicated that the Texas A&M soil test for P was calibrated at approximately the right level for Coastal bermudagrass growing in this acid, sandy soil. Data collected from Coastal bermudagrass and ryegrass response on these plots in future years will help substantiate this.

Response of Coastal bermudagrass to agricultural limestone rates is shown in Table 2. Mean comparisons for all harvests indicate that limestone had no significant effect, but by the last harvest, yields were nearly significant and differences are expected in 1986.

The interaction of P and limestone had no effect on Coastal bermudagrass dry matter yield. (Data not shown). The effect of limestone and P treatments on available soil P is shown in Table 3. At the lower rates of applied P there appeared to be a trend toward decreasing available soil P as the rate of applied lime was increased. At the higher levels of applied P this trend was reversed. At the 245 lb/ac rate of P_2O_5, available soil P was significantly increased from 19.85 to 31.38 ppm when the lime rate was increased from 600 to 3400 lb/ac. An even more dramatic increase in available soil P occurred due to increasing limestone rates at the 491 lb/ac rate of P_2O_5. These data indicated that limestone application can change available soil P from the medium to the high soil test level.

TABLE 2. RESPONSE OF COASTAL BERMUDAGRASS TO AGRICULTURAL LIMESTONE. VALUES ARE AVERAGES OVER REPLICATIONS AND SEVEN PHOSPHORUS RATES

	Dry Matter Yield[1]			
Limestone Rate	Harvest 1	Harvest 2	Harvest 3	Total
		lb/ac		
0	4202 A	3517 A	3860 A	11580 A
600	4295 A	3062 A	3570 A	10891 A
3400	4411 A	3331 A	4001 A	11744 A

1. Dry matter yields, within individual harvests, followed by the same letter are not statistically different at the $p<0.05$ level of probability.

TABLE 3. EFFECT OF LIMESTONE AND PHOSPHORUS RATES ON AVAILABLE SOIL PHOSPHORUS

P_2O_5 [1] lb/ac	Limestone Rates, lb/ac 0	600	3400	
	ppm			
0	4.73	2.80	2.73	Split
30	5.13	4.08	4.83	plot
61	6.98	7.63	8.23	L.S.D.
92	10.48	11.25	12.70	(p=0.05)
123	14.32	11.67	15.55	= 4.47
245	19.50	19.85	31.38	
491	37.85	39.97	55.40	

Main Plot L.S.D. (p = 0.05) = 2.92

1. P_2O_5 rates indicated have been applied twice.

The effect of residual P and limestone on forage nutrient content is indicated in Tables 4, 5, and 6.

TABLE 4. EFFECT OF RESIDUAL PHOSPHORUS AND LIMESTONE ON FORAGE NUTRIENT CONTENT, HARVEST

Residual P	Plant Nutrient Concentrations[1] P	K	Ca	Mg	Mn
ppm	%				ppm
3.4	0.204 A	2.165 A	0.238 A	0.140 A	160 A
4.7	0.234 B	2.132 A	0.259 A	0.146 A	129 A
7.6	0.231 C	2.107 A	0.233 A	0.137 A	165 A
11.5	0.260 D	2.153 A	0.246 A	0.150 A	169 A
13.9	0.261 E	2.181 A	0.248 A	0.146 A	170 A
23.6	0.272 F	2.182 A	0.252 A	0.145 A	165 A
44.4	0.288 G	2.172 A	0.265 A	0.150 A	178 A
Limestone, lb/ac					
0	0.249 A	2.152 A	0.215 A	0.136 A	192 B
600	0.248 A	2.149 A	0.237 A	0.143 A	180 B
3400	0.253 A	2.166 A	0.294 B	0.155 B	115 A

1. Values within columns, followed by the same letter are not statistically different at the $p<0.05$ level of probability.

TABLE 5. EFFECT OF RESIDUAL PHOSPHORUS AND LIMESTONE ON FORAGE NUTRIENT CONTENT, HARVEST 2

Residual P	Plant Nutrient Concentrations[1]				
	P	K	Ca	Mg	Mn
ppm	%	%	%	%	ppm
3.4	0.213 A	2.521 A	0.296 A	0.140 B	133 A
4.7	0.227 B	2.471 A	0.299 B	0.139 A	125 A
7.6	0.247 C	2.607 A	0.313 C	0.142 C	138 A
11.5	0.267 D	2.596 A	0.331 F	0.150 E	128 A
13.9	0.271 E	2.472 A	0.330 E	0.151 F	134 A
23.6	0.290 F	2.498 A	0.322 D	0.149 D	138 A
44.4	0.331 G	2.437 A	0.340 G	0.153 G	151 A
Limestone, lb/ac					
0	0.257 A	2.491 A	0.254 A	0.136 A	164 B
600	0.262 A	2.508 A	0.287 B	0.142 A	145 B
3400	0.273 A	2.544 A	0.415 C	0.162 B	97 A

1. Values within columns, followed by the same letter are not statistically different at the $p<0.05$ level of probability.

TABLE 6. EFFECT OF RESIDUAL PHOSPHORUS AND LIMESTONE ON FORAGE NUTRIENT CONTENT, HARVEST 3

Residual P	Plant Nutrient Concentrations[1]				
	P	K	Ca	Mg	Mn
ppm	%	%	%	%	ppm
3.4	0.161 A	1.899 E	0.280 A	0.141 A	203 A
4.7	0.176 B	1.916 F	0.276 A	0.144 A	208 A
7.6	0.194 C	1.968 G	0.316 A	0.152 A	222 A
11.5	0.203 E	1.856 D	0.312 A	0.154 A	206 A
13.9	0.202 D	1.803 B	0.304 A	0.153 A	211 A
23.6	0.221 F	1.806 C	0.287 A	0.154 A	210 A
44.4	0.241 G	1.740 A	0.303 A	0.157 A	183 A
Limestone, lb/ac					
0	0.206 A	1.929 B	0.248 A	0.140 A	261 B
600	0.199 A	1.856 AB	0.277 A	0.147 A	229 B
3400	0.194 A	1.780 A	0.366 B	0.165 B	128 A

1. Values within columns, followed by the same letter are not statistically different at the $p<0.05$ level of probability.

As expected, an increase in residual soil P increased the plant concentration of P at all harvests. Deficient plant concentrations of P appeared to have occurred below about 0.25% based on harvest 2 data.

Limestone treatment had no significant effect on P concentrations in Coastal bermudagrass.

Plant potassium content was not affected by residual P or limestone at harvests 1 and 2. Limestone and P appeared to have indirectly caused a reduction in K content of the grass at harvest 3. This may have occurred due to increased uptake, and reflects the reduction in soil K indicated by the soil test (Table 7).

Residual soil P significantly increased Ca and Mg content of Coastal bermudagrass only at harvest 2. Limestone significantly increased Ca and Mg content of the grass at the 3400 lb/ac lime rate. Six hundred pounds of limestone tended to increase the Ca and Mg content of the grass, but the amount of the increase was insufficient to be significant.

Residual P had no effect on plant concentration of Mn, but, as expected, limestone application decreased plant Mn concentration significantly at each harvest.

Soil pH and nutrient concentration changes relative to P and lime treatments are indicated in Table 7. Phosphorus had no effect on soil

TABLE 7. EFFECT OF PHOSPHORUS AND LIMESTONE TREATMENTS ON pH, AND CONCENTRATIONS OF SELECTED PLANT NUTRIENTS IN SOIL SAMPLES COLLECTED IN JULY, 1985

Treatment	Soil pH and Plant Nutrient Concentrations					
P_2O_5	pH	Mn	P	K	Ca	Mg
lb/ac		ppm				
0	5.11 A[1]	15.8 D	3.4 A	129 C	263 A	14.2 A
30	5.18 A	14.6 CD	4.7 AB	121 BC	314 A	15.1 A
61	5.12 A	14.1 C	7.6 B	116 AB	277 A	13.9 A
92	5.10 A	13.8 BC	11.5 C	114 AB	303 A	14.3 A
123	5.13 A	13.4 ABC	13.9 C	109 AB	304 A	15.7 A
245	5.11 A	12.2 A	23.6 D	109 AB	335 A	14.1 A
491	5.07 A	12.3 AB	44.4 E	107 A	320 A	14.4 A
Limestone, lb/ac						
0	4.51 A	16.3 B	14.1 A	117 A	143 A	10.2 A
600	4.65 B	16.6 B	13.9 A	117 A	184 A	11.4 B
3400	6.19 C	8.2 A	18.7 B	111 A	580 B	21.9 C

1. Values within columns, followed by the same letter are not statistically different at the $p<0.05$ level of probability.

pH but did significantly lower DTPA extractable Mn. As expected, P fertilization dramatically increased available soil P. This highly significant, linear increase is expressed by the equation $Y = 2.993 + 0.0423(X)$ with an $R^2 = .998$. Y equaled yield and the X value represented two times the P_2O_5 rates indicated in Table 3, because these rates were applied twice. This response indicated that at low available soil P levels, about 45 lb P_2O_5/ac was needed to increase available soil P by 1 ppm in this Lilbert loamy fine sand. At the higher soil test levels of available P, 25 lb P_2O_5/ac will increase available soil P by 1 ppm.

Increasing fertilizer P decreased extractable soil K. It was not certain what caused this decrease in K, but possibly part of the decrease could be attributed to plant uptake due to higher grass production, or may be due to insoluble precipitation or fixation of some K. Increasing fertilizer P had no effect on the levels of extractable soil Ca or Mg.

Limestone, as expected, had a dramatic effect on soil pH. The 600 lb/ac rate was expected to increase pH more than 0.14 units. Extractable Mn was lowered by the high rate of limestone. This also was expected. It is noteworthy that the high rate of limestone significantly increased the level of available soil P, but this is also a well-known response. Limestone significantly increased extractable Ca and Mg.

APPLICATION OF RESULTS

Coastal bermudagrass continued to increase in yield as the soil test phosphorus level increased up to approximately 12 ppm. Dry matter yield remained relatively constant as the soil phosphorus level increased above 12 ppm. This indicated that a level of 12 ppm soil test phosphorus was adequate for optimum yields of Coastal bermudagrass on this acid, Lilbert, loamy fine sand. Phosphorus uptake by Coastal bermudagrass was approximately 4.3 lb P (10 lb P_2O_5) per ton of 12% moisture hay produced. Application of 45 lb P_2O_5/ac increased soil test P by one ppm.

With these values in mind, a Coastal bermudagrass hay crop of 4.5 tons/ac will, theoretically, reduce the soil test level of P by 1 ppm. Likewise, a 9 ton/ac hay crop should reduce the soil test P level by 2 ppm. If the soil test for P is well above 12 ppm, fertilization with

P_2O_5 could be omitted for one year. However, if soil test P is only a few ppm above 12, it would be wise to continue fertilizing with phosphorus each year until a greater buildup has occurred. These statements are theoretical, based on only one year of data, and therefore need several years more evaluation to verify that they are accurate.

Limestone treatment dramatically increased the soil test P level when soil P was already high. When soil test P was in the very low, low, and medium ranges, limestone treatment had only a small effect on increasing soil test P level.

Coastal bermudagrass used 43 lb of potassium per ton of dry matter (46 lb K_2O/ton of 12% moisture hay) produced in this study. This verifies the importance of continued high application rates of potash for optimum hay production. Decreased yields of grass due to low potash fertilization will probably not be evident the first few years of hay production because the soil is able to supply the potassium needs of the plant. Once the soil has been depleted of its potassium reserves, Coastal bermudagrass production will decline rapidly.

At pH 4.5, Coastal bermudagrass tolerated soil acidity. At this pH level, limestone application did not increase dry matter yield. This does not imply that Coastal bermudagrass does not need to be limed. This grass can grow in extremely acid soils, but the nutritional quality of the grass deteriorates as the soil becomes more acid. A pregnant yearling (750 lb) heifer gaining 1.9 lb/day needs a calcium concentration of 0.26 to 0.37% in the forage. A lactating cow requires 0.30% calcium in its forage diet. That same cow requires 0.2% magnesium in her diet during early lactation. Unlimed Coastal bermudagrass did not meet these calcium and magnesium requirements. Coastal bermudagrass limed with 3400 lb low Mg-lime/ac contained an adequate level of calcium for this cow. However, the magnesium concentration was not increased to the level considered adequate to meet her requirements, but this can be accomplished by feeding mineral supplements.

Numerous experiments have demonstrated that calcium utilization is affected by the amount of P in the diet. Long-term experiments with pregnant heifers showed better absorption of both calcium and phosphorus when fed a 2:1 compared to a 1:1 ratio of these two elements. In this study, liming at the 3400 lb/ac rate resulted in a 1.8:1 ratio compared to a 1.2:1 ratio for the unlimed check.

Magnesium absorption by cattle is enhanced by increasing Mg and Ca intake. Magnesium absorption was depressed on low Mg rations when inorganic phosphorus replaced organic P supplementation.

Winter pastures of small grains, ryegrass, or clovers, sod seeded into Coastal bermudagrass will not tolerate acid soils. Soils must be limed to pH 6.0 or above if a farmer is to be successful at producing cool season forages. Phorphorus efficiency is significantly improved by liming acid soils.