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ANNUAL RYEGRASS RESPONSE TO LIMESTONE AND PHOSPHORUS

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SUMMARY

Annual ryegrass (Marshall cultivar) yield and leaf mineral response to applied limestone and concentrated triple superphosphate were evaluated on an acid, sandy soil over three years. Dry matter yield increased 100 to 750%, and 25 to 80% at the highest limestone and P rates, respectively. Lime and applied P increased leaf P, Ca, and Mg concentrations. In the second year, yield was less responsive to residual P at the highest limestone rate. This indicated that liming made soil P more plant available, or that applied P ameliorated at least part of the cause of acid soil infertility. Yield was positively related to soil test P, Ca, and Mg, and negatively related to soil K and Al in all years. By the last year, N fertilization caused soil pH at the high lime rate to decline to the level in unlimed check plots. Yield differences between limed and unlimed soil, however, were greatest in this year. Therefore, complex plant nutrient relations, rather than soil pH, were the primary factors affecting annual ryegrass yield in this acid soil.

INTRODUCTION

East Texas soils are becoming increasingly acidic. A summary of test results evaluated in the late 1960's revealed that 2% of these soils tested below pH 5.2. A similar evaluation in the mid 1980's indicated that 12% tested below pH 5.0. As soil pH declines, plant susceptibility to acid soil infertility and inadequate plant P increases. Cool season annual grasses and legumes are commonly interseeded into established Coastal bermudagrass pastures to extend the grazing season. These forages are generally less tolerant of soil acidity than Coastal bermudagrass. The objectives of this study were to evaluate the effects of limestone and phosphorus application on annual ryegrass yield and leaf mineral concentrations on a strongly acid, Lilbert soil.

PROCEDURES

This study was initiated in July, 1983 on a Lilbert loamy fine sand having an initial surface 6-inch depth soil pH of 4.7. Agricultural grade limestone (100% minus 8-mesh and 27% minus 100-mesh) treatments of 0, 0.3, and 1.7 tons/ac were applied as main plots to an established Coastal bermudagrass meadow.

Concentrated triple superphosphate was applied two separate times to split plots at rates of 0, 30, 61, 92, 123, 245, and 491 lb P_2O_5/ac in each application. All treatments were replicated 8 times in a randomized complete block arrangement. The lime and first P applications were roto-till incorporated into the soil in July 1983. The second P application was lightly disked into the soil in June 1984. Six-inch depth soil samples were taken in Nov. 1983, July 1985, and June 1987. Soil samples were analyzed according to Texas A&M University soil testing laboratory procedures. Nitrogen was uniformly broadcast on the plots prior to initiation of growth and following each harvest. Over the study period, a total of 1200 lb N/ac and 950 lb K_2O/ac were applied to the plots. Marshall ryegrass was interseeded into the Coastal bermudagrass sod in Oct. to Nov. of 1983, 1985, and 1986. Environmental conditions were sufficiently varied to affect forage growth from year to year. The plots were clipped twice in 1984 and 1987 and three times in 1986. Dry matter yields were calculated based on oven dried (120° F) weights. Chemical analysis of leaf tissue was determined after digesting dried, minus 40-mesh moisture determination samples in $LiSO_4$-$CuSO_4$-Se-H_2SO_4.

RESULTS

Marshall ryegrass dry matter yields were increased by lime and applied P each year (Fig. 1). In 1984, 0.3 ton lime/ac ameliorated most yield decreases caused by soil acidity. The capacity of 0.3 ton lime/ac to alleviate acid soil infertility diminished over the three study years and was ineffective the final year. In 1986, residual P increased yield at 0 and 0.3 ton lime/ac, but produced very little yield increase at 1.7 ton lime/ac. This implied liming either made soil P more plant available or that residual P alleviated some of source of acid soil infertility. The former was more likely because soil test P was higher in plots that had received the high lime rate in 1983 and 1985 (Table 1). In 1987, ryegrass was more responsive to residual P at the high lime rate. Soil test P declined between 1985 and 1987 in all plots (Table 2), but was lowest at the high rate of lime (Table 1). Soil P depletion occurred due to plant uptake and because soil P reverts to unavailable forms with time. Thus, soil P became limiting in 1987 because it had been depleted in earlier years.

Relative yield differences in the high lime plots compared to low lime plots increased over the three study years (Fig. 1) even though soil pH decreased to unlimed levels by the last year. Annual ryegrass yield response to lime did not occur just because soil pH increased. Limestone application simultaneously increased soil test P, Ca, and Mg and decreased soil K and Al levels. These soil test parameters were related to ryegrass yield in all years and indicated that complex mineral relationships exerted more effect on yield than active soil acidity (Table 3).

Lime and applied P increased leaf P, Ca, and Mg concentrations in all years (Table 4 and 5) and is desirable from the stand point of animal nutrition. Higher tissue P, Ca, and Mg concentrations were also related to increased forage production (Figs. 2 and 3), especially in 1987 when soil Ca and Mg had become depleted in unlimed soil. Although leaf Al concentration was not measured, excessive soil Al was also related to reduced yield (Fig. 4).

In summary, annual ryegrass productivity in a typical acid, sandy East Texas soil was dramatically increased by applying limestone and P. The effect of lime on forage yields lingered beyond its ability to neutralize soil acidity. Active soil acidity was not the principal factor limiting yield in unlimed soil. Lime altered soil P, K, Ca, Mg, and Al availability, which in turn affected annual ryegrass growth and mineral composition.

TABLE 1. SOIL TEST PARAMETERS AS AFFECTED BY APPLIED LIMESTONE IN 1983, 1985 AND 1987

Limestone Rate (tons/ac)	Soil Test Parameter					
	pH	P	K	Ca	Mg	Al
		ppm				
			1983			
0	4.72	14.6	82	109	6.4	23.4
0.3	4.80	14.6	81	201	9.0	19.6
1.7	5.66	17.7	70	762	18.7	8.9
			1985			
0	4.51	14.1	117	143	10.2	17.2
0.3	4.65	13.9	117	184	11.4	11.4
1.7	6.19	18.7	111	580	21.9	0.3
			1987			
0	4.50	9.0	72	162	†	23.9
0.3	4.49	9.7	73	169		23.4
1.7	4.61	7.6	59	296		13.1

† Soil test Mg not applicable in 1987.

TABLE 2. SOIL TEST PARAMETERS AS AFFECTED BY APPLIED P IN 1983, 1985 AND 1987

P_2O_5 Rate (lb/ac)	Soil Test Parameter pH	P	K	Ca	Mg	Al
		ppm				
			1983			
0	5.12	7.9	90	367	11.9	16.6
30	5.11	9.9	84	442	12.3	17.2
61	5.10	10.0	84	315	11.2	18.1
92	5.05	12.0	78	368	10.9	16.5
123	5.04	13.8	74	290	10.4	15.8
245	5.02	16.6	70	364	11.0	19.8
491	4.97	39.3	62	356	11.9	16.8
			1985			
0	5.11	3.4	129	263	14.2	9.7
61	5.18	4.7	121	314	15.1	9.5
123	5.12	7.6	116	277	13.9	9.8
184	5.10	11.5	113	303	14.3	10.5
245	5.13	13.8	109	304	15.7	9.5
491	5.11	23.6	109	335	14.0	9.3
982	5.07	44.4	107	320	14.4	9.1
			1987			
0	4.52	3.6	75	197	†	20.6
61	4.54	3.9	73	195		19.6
123	4.57	5.3	72	199		19.4
184	4.56	5.8	67	214		19.7
245	4.53	7.5	64	196		19.6
491	4.57	12.5	64	243		19.7
982	4.44	23.1	61	216		22.3

† Soil test Mg not application in 1987.

TABLE 3. SIMPLE CORRELATIONS (r^2) BETWEEN SOIL PARAMTERS MEASURED IN 1983, 1985 AND 1987 AND MARSHALL RYEGRASS DRY MATTER YIELD (DMY) AND MEAN TISSUE MINERAL CONCENTRATION

	Soil Parameter						
	pH	P	K	Ca	Mg	Al	Mn
				1984			
Plant P	-0.06	0.70***	-0.37***	-0.01	-0.02	0.03	-0.01
Plant K	0.04	-0.03	0.25*	-0.06	-0.10	-0.07	-0.21
Plant Ca	0.63***	0.19	-0.14	0.52***	0.57***	-0.40***	-0.14
Plant Mg	0.39***	0.17	-0.07	0.34**	0.45***	-0.34**	-0.01
Plant Mn	-0.19	-0.12	0.36***	-0.20	-0.34**	0.11	0.12
DMY	0.55***	0.23*	-0.04	0.35**	0.49***	-0.42***	-0.12
				1986			
Plant P	0.39***	0.80***	-0.27***	0.45***	0.33***	-0.39***	-0.52***
Plant K	-0.08	-0.13	0.35***	-0.15	-0.18*	0.03	0.18*
Plant Ca	0.92***	0.26**	-0.22**	0.87***	0.86***	-0.85***	-0.70***
Plant Mg	0.86***	0.29***	-0.30***	0.83***	0.84***	-0.76***	-0.68***
Plant Mn	-0.79***	-0.23**	0.22**	-0.76***	-0.75***	0.64***	0.72***
DMY	0.81***	0.22***	-0.27***	0.76***	0.76***	-0.81***	-0.56***
				1987			
Plant P	0.02	0.70***	-0.31***	0.21**	†	-0.19*	0.03
Plant K	0.04	0.23**	0.24**	-0.20*		0.18*	-0.36***
Plant Ca	0.26***	0.01	-0.59***	0.62***		-0.71***	0.77***
Plant Mg	0.26***	0.12	-0.61***	0.60***		-0.68***	0.65***
Plant Mn	-0.11	0.12	0.36***	-0.33***		0.39***	-0.31***
DMY	0.28***	0.06	-0.60***	0.65***		-0.73***	0.73***

*,**,*** Significant at the 0.05, 0.01 and 0.001 levels, respectively.
† Soil Mg not applicable in 1987.

TABLE 4. MEAN MARSHALL RYEGRASS TISSUE MINERAL CONCENTRATIONS AS AFFECTED BY APPLIED LIMESTONE IN 1984, 1986 AND 1987

Limestone Rate (tons/ac)	Tissue Mineral Parameter			
	P†	K	Ca	Mg
		1984		
0	0.167	2.16	0.398	0.093
0.3	0.180	2.02	0.553	0.125
1.7	0.181	2.04	0.687	0.134
		1986		
0	0.326	3.28	0.230	0.087
0.3	0.325	3.28	0.263	0.092
1.7	0.381	3.21	0.477	0.133
		1987		
0	0.181	2.63	0.138	0.058
0.3	0.178	2.58	0.152	0.057
1.7	0.195	2.40	0.402	0.096

†Plant parameters represent mean values from 2, 3, and 2 clippings in 1984, 1986, and 1987, respectively.

TABLE 5. MEAN MARSHALL RYEGRASS TISSUE MINERAL CONCENTRATIONS AS AFFECTED BY APPLIED P IN 1984, 1986 AND 1987

P_2O_5 Rate (tons/ac)	Tissue Mineral Parameter			
	P†	K	Ca	Mg
0	0.108	2.20	0.468	0.108
30	0.120	2.09	0.521	0.112
61	0.144	2.03	0.546	0.118
92	0.167	2.15	0.554	0.119
123	0.200	2.21	0.571	0.120
245	0.210	1.92	0.545	0.115
491	0.285	1.91	0.616	0.132
		1986		
0	0.295	3.36	0.290	0.096
61	0.297	3.30	0.308	0.099
123	0.318	3.26	0.310	0.101
184	0.327	3.22	0.326	0.104
245	0.338	3.24	0.329	0.106
491	0.383	3.19	0.337	0.107
982	0.451	3.21	0.361	0.114
		1987		
0	0.149	2.45	0.202	0.063
61	0.154	2.50	0.224	0.066
123	0.164	2.55	0.213	0.067
184	0.174	2.51	0.230	0.070
245	0.177	2.52	0.237	0.071
491	0.203	2.57	0.246	0.075
982	0.271	2.64	0.265	0.080

†Plant parameters represent mean values from 2, 3, and 3 clippings in 1984, 1986, and 1987, respectively.

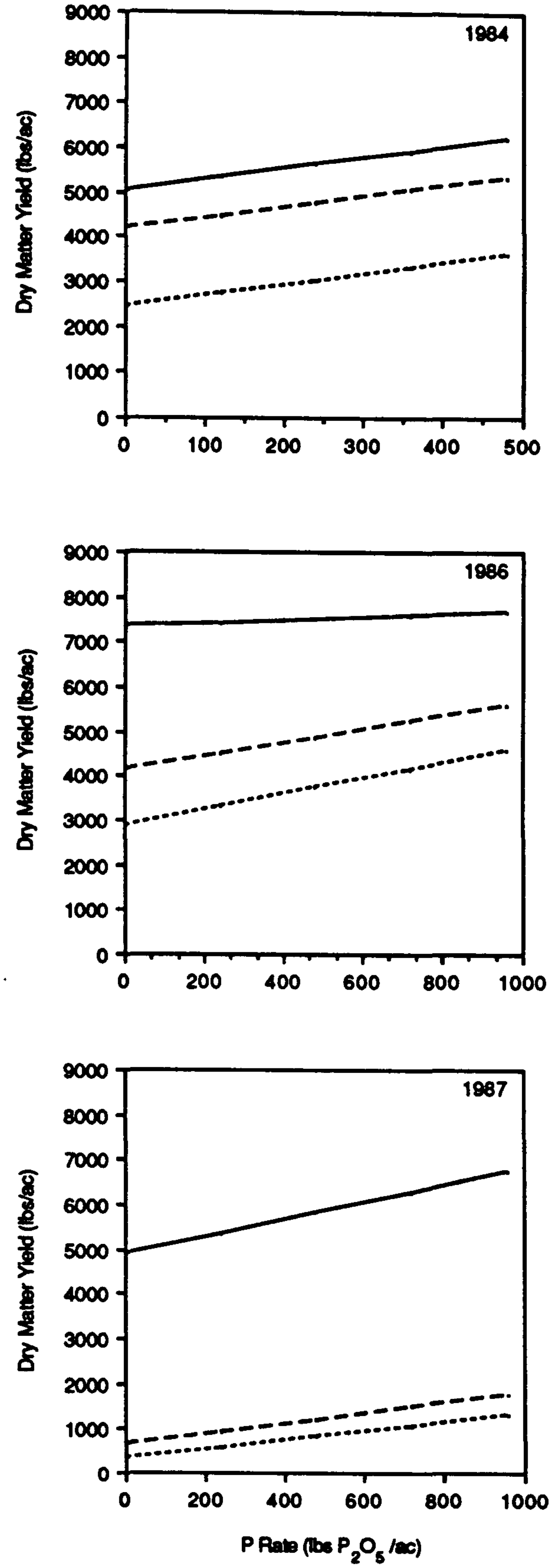
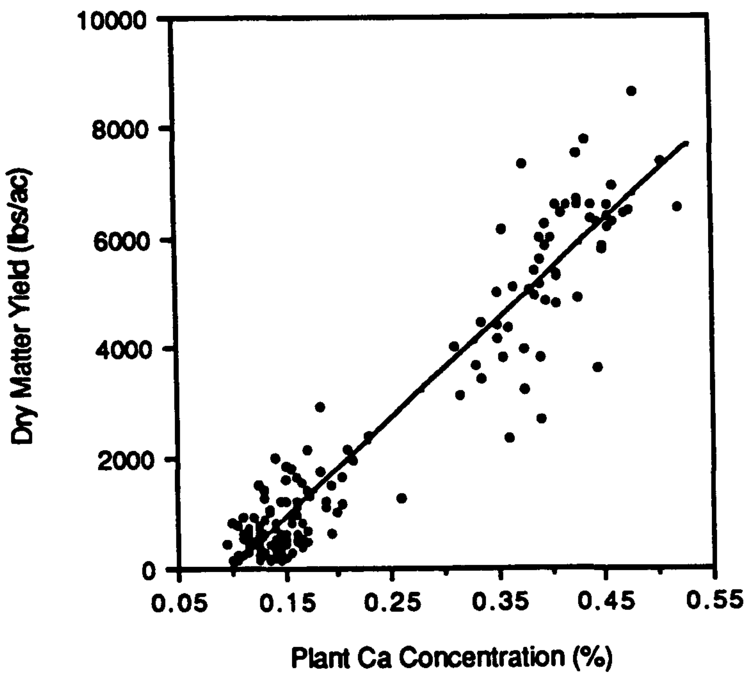


Figure 1. Marshall ryegrass yield response to P fertilization as affected by limestone rate (0 ton lime/ac = · · · · ; 0.3 ton/ac = - - - - ; 1.7 ton/ac = ——) in 1984, 1986, and 1987.



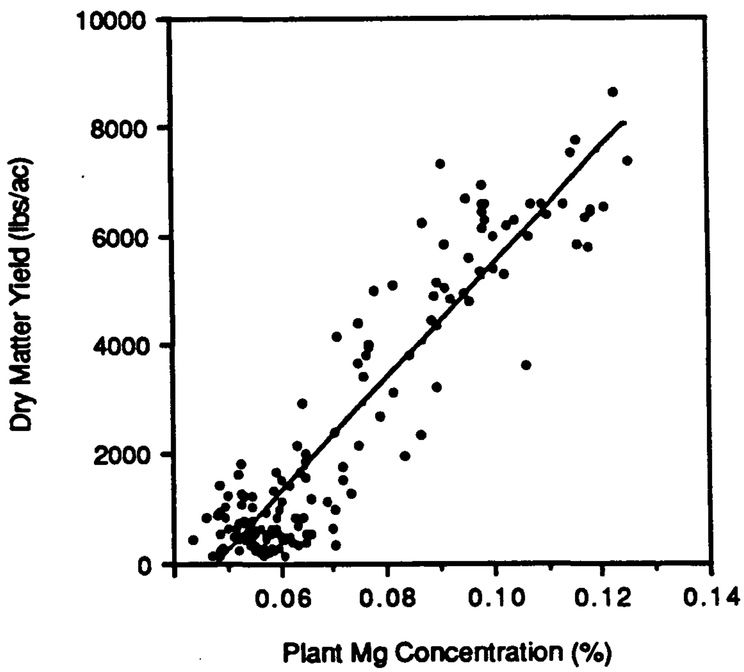


Figure 2. The relationships between Marshall ryegrass yield and tissue Ca and Mg concentrations in 1987.

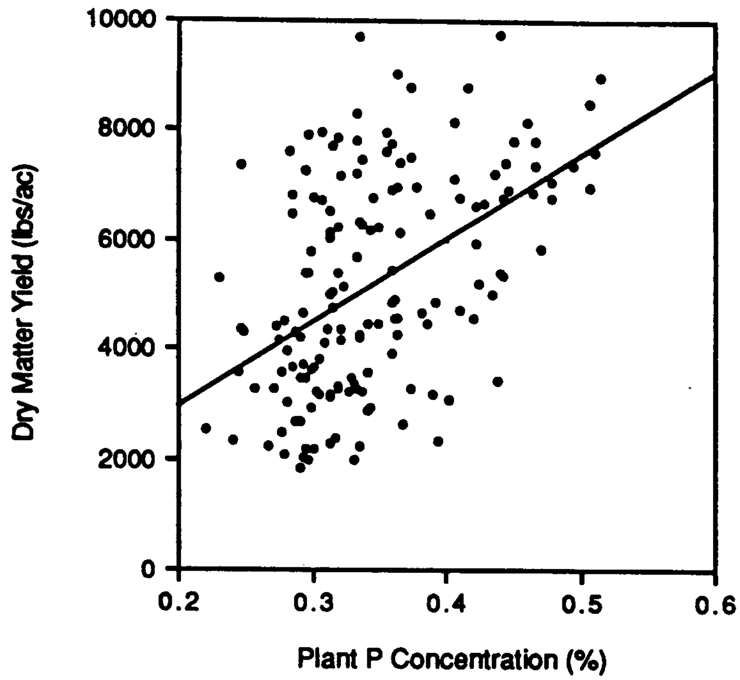


Figure 3. The relationship between Marshall ryegrass yield and tissue P concentrations in 1986.

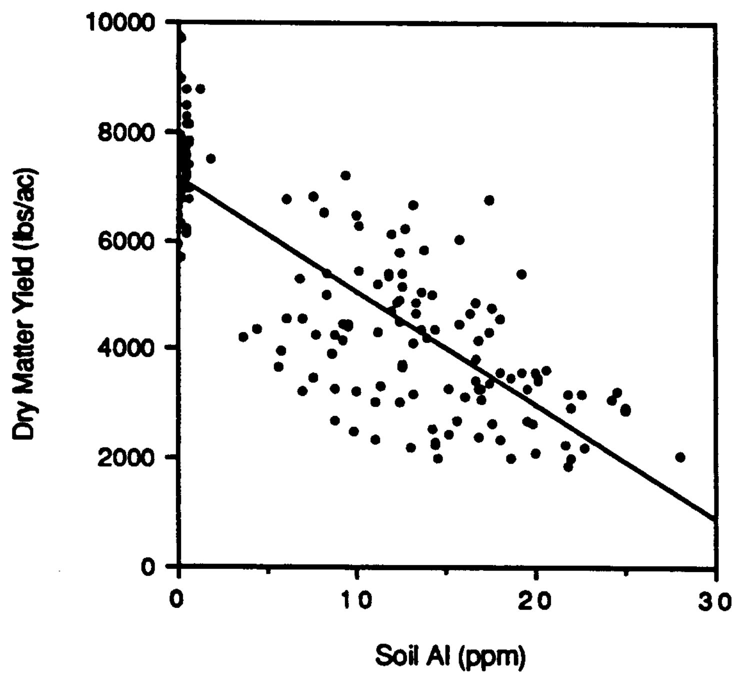


Figure 4. The relationship between Marshall ryegrass yield and soil test Al levels in 1986.