PUBLICATIONS
1987

Forage Research In Texas, 1987

Forage Response to Residual Soil Phosphorus and pH. I. Marshall Ryegrass

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Summary

Marshall ryegrass yield response relative to residual soil phosphorus (P) and to soil pH change due to limestone treatments applied in 1983 was evaluated. Ryegrass harvested in 1986 was strongly influencd by the level of lime applied in 1983. Dry matter production for plots receiving no lime was 3,423 lbs/A, whereas yields for plots treated with 0.3 and 1.7 tons of limestone/A were 4,576 and 7,417 lbs/A, respectively. Increasing residual soil phosphorus produced higher dry matter yields, with the magnitude of the effect being mitigated by the level of limestone applied or soil pH. At the highest limestone rate, or above pH 6, increasing residual soil P had a much smaller impact on ryegrass yield than observed in the absence of or at the low limestone rate. Increased soil pH produced by limestone application had a much greater effect on ryegrass yields than did residual soil P. Optimum yields were estimated to occur above pH 6, implying that exchangeable aluminum played a significant role in limiting yields at lower soil pH.

Introduction

East Texas soils are becoming increasingly acidic. A summary of soil test results evaluated in the late 1960's revealed that 2 percent of these soils were testing below pH 5.2. A similar evaluation in the early 1980's indicated that 12 percent of these soils were testing below pH 5.0. As soil acidity increases, plant utilization of nutrients becomes less efficient. This study was designed to evaluate the effect of limestone and phosphorus application on forage production in a strongly acidic soil.

KEYWORDS: Liming / phosphorus / soil acidity / annual ryegrass.

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 treatments of 0, 0.3, and 1.7 tons/A were applied as main plots in a split plot design. The sub plot treatments were P_2O_5 rates of 0, 30, 61, 92, 123, 245, and 491 lbs/A roto-tilled incorporated into the soil along with the limestone. The same P_2O_5 rates were re-applied to the individual plots in 1984. Each of these treatment combinations was replicated eight times. Phosphorus was supplied as triple superphosphate. Limestone was applied as 100 percent minus 7-mesh and 27 percent minus 100-mesh agricultural grade limestone, consisting predominantly of $CaCO_3$ with a minute amount of $MgCO_3$. Individual plots were 9 × 15 ft.

Soil samples were collected from the surface 6-inch soil depth in summer 1985. Marshall ryegrass was seeded into the plots in October after the final Coastal bermudagrass harvest. Urea was applied to the experiment at the rate of 60 lbs N/A in mid-December, in early February, and following each of the first two cuttings. The site was adequately fertilized with potassium and sulfur. Three harvests were made in 1986. Approximately 64 ft^2 of each plot was cut, weighed, and sampled for moisture content. Yields were calculated from these data. Coastal bermudagrass was sorted from the ryegrass in the moisture samples from the second and third harvests. Yields were adjusted according to the weight percent ryegrass each plot contained. Yield data were analyzed statistically using SAS.

Results and Discussion

The effects of applied limestone and phosphorus on annual ryegrass production are presented in the analysis of variance (Table 1). Limestone and phosphorus rates had a significant impact on dry matter yields, as did the lime × P interaction.

Ryegrass yield was strongly influenced by limestone, especially at the highest rate of lime (Table 2). Dry matter yields, as a function of limestone rates averaged across all P treatments, showed an 1,153 lbs/A increase in yield for the 0.3 ton per acre rate compared to the 0 lime check. The 1.7 ton/A lime treatment increased yields 3,994 lbs/A over the 0 lime check and 2,841 lbs/A above the 0.3 ton/A lime rate.

Ryegrass dry matter yield increased with increasing residual soil P (Table 3). The results shown in Table 3 represent the effects of residual P on ryegrass yields when averaged across all limestone treatments. These data indicated ryegrass yield had increased as residual soil P increased. The data provide more meaningful information when the effects of lime and phosphorus are viewed at the same time by examining the lime × P interaction. The analysis of variance indicated the interaction was significant ($p<0.05$) for harvests 1 and 2, and the combined annual total yield. The interactive effects are shown below in Table 4.

The interaction data (Table 4) indicated ryegrass yield at the high lime rate was increased to a much lesser extent by increasing residual soil P than occurred at the 0 and 0.3 ton lime/A rates. Soil testing in 1985 showed a significant lime × P treatment interaction on soil P availability (Table 5). The interactive effect of lime on soil P did not explain the interactive effect on ryegrass yield. However, exchangeable Al was reduced as soil acidity declined from the application of limestone, making P uptake more efficient in the absence of exchangeable Al. Therefore, limed soil may show less effect of residual soil P on ryegrass yield as P uptake may have been more efficient when soil acidity declined due to limestone treatment.

The data were fitted to a regression equation by regressing ryegrass yield against applied limestone and residual soil P. The best fit equation for the data was found to be $Y = 2791.1 + 2.25(\text{Lime}) + 39.8(P) - 0.0094(\text{Lime} \times P) - 0.00027(\text{Lime}^2)$, where Y equals ryegrass dry matter yield. With all parameters significant, this equation implies ryegrass responded to applied limestone in a curvilinear fashion that was influenced by the level of residual soil P and applied lime. Predicted ryegrass dry matter yields as a function of residual soil P at the three levels of limestone are shown in Figure 1.

The yield potential of Marshall ryegrass in this strongly acidic soil was greatly enhanced by raising soil pH. The yield increases were most likely occurring as a result of increased plant nutrient availability along with the amelioration of phytotoxicity induced by significant levels of exchangeable Al and Mn present in acid soils. Increasing residual soil P did lead to higher dry matter yields, but to a lesser extent than achieved when using limestone.

TABLE 1. ANALYSIS OF VARIANCE RESULTS FOR LIME AND PHOSPHORUS TREATMENT EFFECTS ON RYEGRASS DRY MATTER YIELDS

	Significance of Effect[1]			
Source	Harvest 1	Harvest 2	Harvest 3	Total
Lime	**	**	**	**
Phosphorus	NS	**	**	**
Lime*Phosphorus	*	*	NS	**

[1]*-significant at $p<0.05$. ** - significant at $p<0.01$. NS - non significant.

TABLE 2. RYEGRASS RESPONSE TO LIMESTONE RATES

Limestone Rate	Soil pH	Dry Matter Yield Harvest 1	Harvest 2	Harvest 3	Total
Tons/A		Pounds/Acre			
0	4.50	387	1,215	1,821	3,423
0.3	4.65	432	1,769	2,375	4,576
1.7	6.20	721	3,284	3,412	7,417

TABLE 3. RYEGRASS RESPONSE TO RESIDUAL SOIL P

Residual Soil P	Dry Matter Yield Harvest 1	Harvest 2	Harvest 3	Total
(ppm)	Pounds/Acre			
3.4	494	1,920	2,292	4,706
4.7	478	1,981	2,492	4,951
7.6	510	2,022	2,335	4,867
11.5	474	2,001	2,577	5,052
13.9	515	2,039	2,583	5,137
23.6	536	2,207	2,584	5,327
44.4	585	2,460	2,890	5,935

TABLE 4. INTERACTIVE EFFECTS OF LIMESTONE AND RESIDUAL SOIL PHOSPHORUS ON TOTAL RYEGRASS DRY MATTER YIELDS

	Dry Matter Yield		
P_2O_5 Rate	Limestone Rate, lb/A 0	600	3,400
lbs/A	Pounds/Acre		
0	2,966	4,273	6,853
30	3,393	4,197	7,392
61	3,172	3,816	7,615
92	2,963	4,546	7,649
123	3,209	4,882	7,266
245	3,680	4,709	7,594
491	4,621	5,613	7,569

TABLE 5. INTERACTIVE EFFECTS OF LIMESTONE AND PHOSPHORUS RATES ON SOIL P AVAILABILITY

P_2O_5 Rate	Limestone Rate, lbs/A 0	600	3,400
lbs/A	ppm		
0	4.73	2.80	2.73
30	5.13	4.08	4.83
61	6.98	7.63	8.23
92	10.48	11.25	12.70
123	14.32	11.67	15.55
245	19.50	19.85	31.38
491	37.85	39.97	55.40

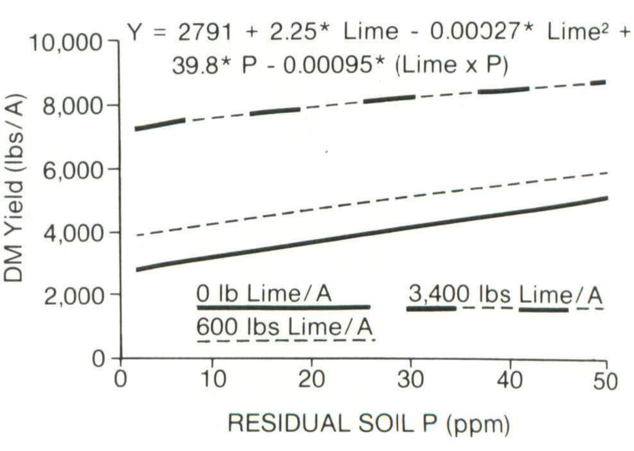

Figure 1. Ryegrass yield in response to applied limestone and residual soil P.