Effects of Nitrogen Fertilization on Phosphorus Removal in Bermudagrass Hay

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Story in Brief

During 2000, three harvests of common bermudagrass [*Cynodon dactylon* (L.) Pers.] were made at two high soil-test phosphorus (P) sites (Latta and Stephens) in northwest Arkansas to assess the effects of N fertilization on P removal in bermudagrass hay. Ammonium nitrate was applied in split applications totaling 0, 50, 100, 150, 200, 250, or 300 lb N/acre for the year. On the third (final) harvest date, concentrations of P in the forage declined linearly with N fertilization rate at both sites ($P < 0.0001$), and ranged from 0.26 to 0.39% at the Latta site and 0.29 to 0.53% at the Stephens site. A quadratic effect ($P = 0.015$) was also observed at the Latta site. Generally, changes in concentrations of P on the first two harvest dates varied only marginally with N fertilization. Total yields of forage DM ranged from 9,692 to 12,532 lb/acre at the Latta site and from 4,533 to 8,688 lb/acre at the Stephens site. Cumulative P removal over three harvests increased linearly ($P = 0.013$) from 37.1 to 45.8 lb/acre at the highly fertile Latta site and linearly ($P = 0.0004$) from 17.9 to 26.7 lb/acre at the Stephens site. Droughty conditions late in the summer prevented a fourth harvest and reduced total P removal.

Introduction

Many soils in northwest Arkansas have excessively high levels of phosphorus (P) because of repeated applications of poultry and other animal wastes. One long-term technique that can be used to lower these high levels of soil-test P is removing all forage as hay or silage (mining). Unlike grazing situations, hay or silage produced on these sites can be removed to other locations for feeding, thereby preventing the livestock from recycling the P back onto the same site. Bermudagrass has been described for more than a century as one of the most important grasses grown in the Southeastern US. This highly productive, warm-season grass is used widely by beef and dairy producers for both grazing and hay production. Bermudagrass also is highly responsive to fertilization with N and is an important and valuable cash crop in northwest Arkansas. These traits make it an attractive forage choice for mining P from sites that are already excessively high in P. Our goal was to evaluate the relationships between concentrations of P or P removal and N fertilization rate for common bermudagrass grown on two sites in northwest Arkansas.

Experimental Procedures

Generation of Sample Sets. Twenty-eight 10-ft x 20-ft plots were established on two producer farms (Latta and Stephens) located near Lincoln, AR in the early spring of 2000. Both sites had past histories of poultry waste application. Manure from a caged layer operation was applied during the previous year (1999) at the Latta site only. Concentrations of soil-test P were 305 and 571 lb/acre at the Stephens and Latta sites, respectively. These sites are representative of many in northwestern Arkansas that have histories of intermittent or annual applications of poultry waste. Nitrogen was applied as ammonium nitrate (34-0-0) in split applications of 0, 50, 100, and 150 lb N/acre on April 28 and July 19. For the year, N fertilizer was applied at cumulative rates of 0, 50, 100, 150, 200, 250, and 300 lb N/acre as shown in Table 1. Plots at each site were arranged in a randomized complete block design with four replications. Plots were clipped to a 2-in stubble height on May 30, July 7, and August 18 with a sicklebar mower. Fresh weights were obtained from each plot in the field and representative subsamples were retained for determination of percentage of DM and subsequent laboratory analysis. The extremely dry conditions in Arkansas during the late summer of 2000 prevented a final (fourth) harvest in early fall. On April 28 and November 4, 2000 and April 25, 2001, soil samples (eight 6-in cores per plot) were obtained and subsequently submitted to the University of Arkansas Agricultural Diagnostic Laboratory for determination of soil-test P by Mehlich III extraction.

Forage Preparation and Analysis. All forage samples were dried to a constant weight under forced air at 122°F. Dry forage samples were ground through a Wiley mill (Arthur H. Thomas, Philadelphia, PA) equipped with a 1-mm screen before analysis. Total plant P was determined by inductively coupled plasma spectroscopy following a digestion on a heating block in nitric acid and hydrogen peroxide.

Statistical Analysis. For each individual harvest at each site, orthogonal contrasts (PROC GLM; SAS Inst., Inc., Cary, NC) were used to test each response variable for linear, quadratic, and cubic responses to N fertilization. For each individual plot, fertilization rate (0, 50, 100, or 150 lb N/acre) was not necessarily the same on both application dates; therefore, for the first and second harvest, contrast statements were constructed based on the initial (April 28) application of ammonium nitrate. For the third harvest, contrast statements were based on the second application of fertilizer N on July 19. A combined analysis of all data from all three harvests at each site was conducted by similar methods. This analysis included seven N fertilization rates (0, 50, 100, 150, 200, 250, and 300 lb N/acre), and a test for quartic effects was included in the model.

Results and Discussion

Concentrations of Phosphorus in Forages. At the Stephens site, fertilization with N had no effect ($P > 0.05$) on concentrations of P in bermudagrass forage on the May 30 harvest date (Table 2). On the

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July 7 harvest date, a linear response (P = 0.056) was observed; however, the range of concentrations was small (0.31 to 0.35%) and is probably of little biological significance. Similarly, linear (P = 0.042) and cubic (P = 0.046) responses to N fertilization were observed at the Latta site on the May 30 and July 7 harvest dates, but these responses also were quite limited (overall ranges = 0.41 to 0.44% and 0.35 to 0.39%, respectively). In contrast, substantial reductions in concentrations of P with increasing levels of N fertilization were observed at both sites on the final (August 18) harvest date. These effects were linear (P < 0.0001) at the Stephens site, and quadratic (P = 0.015) at the Latta site. Concentrations of P in forages fertilized with 150 lb N/acre in July fell to 55 and 67% of those in unfertilized plots at the Stephens and Latta sites, respectively.

DM Yield. Yields for individual harvests ranged from 1,433 to 3,404 lb/acre at the Stephens site and 2,269 to 4,922 lb/acre at the Latta site. The effects of N fertilization on yields of DM were predictable (Table 3); DM yields increased linearly (P < 0.01) on May 30 and July 7 at the Stephens site and on May 30 at the Latta site. Quadratic effects (P < 0.052) were observed on the August 18 harvest date at both sites, and a cubic (P = 0.022) response was observed on the July 7 harvest date at the Latta site.

P Removal. Removal of P (Table 4) increased linearly (P < 0.005) on the May 30 harvest date at both sites, but the maximum removal at the Latta site was much greater (17.8 lb P/acre) than at the Stephens site (7.6 lb P/acre). This was largely the result of differences in DM yield, but concentrations of P also averaged about 0.10% higher at the Latta site on this date. A linear increase (P = 0.001) was observed at the Stephens site on the July 7 harvest date for carryover effects of the initial application of N; this was not observed at the Latta site (P > 0.05). Removal of P on the final harvest date was complicated by competing factors; DM yield increased with N fertilization at both sites, but concentrations of P in the forage declined substantially. Therefore, differences in P removal between the forages fertilized with 150 lb N/acre and unfertilized controls were very small (< 1.1 lb P/acre).

Cumulative Responses to N Fertilization. During 2000, the cumulative effects of N fertilization (Tables 5 and 6) were to increase DM yield linearly (P < 0.0001), but to reduce concentrations of P in the forage at both sites. These reductions were primarily linear (P < 0.0001), and were driven by the large changes in concentrations of P observed for the final harvest date. Removal of P increased linearly (P = 0.013) at the Latta site; a quadratic trend (P = 0.061) was observed at the Stephens site. The maximum removal of P was about 46 lb/acre on the highly fertile Latta site. Removal of P could have been higher at both sites, but a severe late-summer drought prevented a meaningful final (fourth) harvest.

Effects on Soil-Test Phosphorus. Between April 2000 and April 2001, soil-test P fell by 78 lb/acre (Table 7) at the Latta site; however, there was no response to N fertilization on any individual evaluation date.

Implications

Based on these limited results, a maximum of about 50 lb P/acre can be mined from a site with the bermudagrass harvested as hay. Increasing DM yield with heavy applications of fertilizer N may not necessarily result in proportional increases in P removal.

Table 1. Application scheme for fertilization of bermudagrass with ammonium nitrate (34-0-0) at the Stephens and Latta sites during 2000

Total N Applied[a]	1st Application[b]	2nd Application[c]
	------------- lb N/acre -------------	
0	0	0
50	50	0
100	50	50
150	100	50
200	100	100
250	150	100
300	150	150

[a] Total application for the entire growing season.
[b] April 28, 2000.
[c] July 19, 2000.

Table 2. Effects of N fertilization on concentrations of P in bermudagrass harvested at two sites near Lincoln, AR

Fertilization	Stephens site			Latta site		
rate	May 30	July 7	August 18	May 30	July 7	August 18
lb N/acre	% of DM					
0	0.30	0.35	0.53	0.41	0.36	0.39
50	0.33	0.34	0.45	0.42	0.39	0.32
100	0.33	0.33	0.36	0.42	0.36	0.28
150	0.32	0.31	0.29	0.44	0.35	0.26
SEM[a]	0.011	0.015	0.013	0.007	0.010	0.009
Effect[b]	NS	L = 0.056	L < 0.0001	L = 0.042	C = 0.046	L < 0.0001
						Q = 0.015

[a] Standard error of the mean.
[b] NS, not significant (P > 0.05); L, linear effect; Q, quadratic effect; C, cubic effect.

Table 3. Effects of N fertilization on DM yield of bermudagrass harvested at two sites near Lincoln, AR

	Stephens site			Latta site		
Fertilization rate	May 30	July 7	August 18	May 30	July 7	August 18
lb N/acre	lb DM/acre					
0	1,514	1,433	1,712	3,070	4,487	2,269
50	1,718	1,735	2,866	3,714	4,256	3,114
100	1,811	1,943	3,225	3,722	4,922	3,676
150	2,350	2,480	3,404	4,113	4,782	3,756
SEM[a]	128	114	103	193	150	166
Effect[b]	L = 0.001	L < 0.0001	L < 0.0001	L = 0.007	L = 0.069	L < 0.0001
			Q = 0.0004		C = 0.022	Q = 0.052

[a] Standard error of the mean.
[b] L, linear effect; Q, quadratic effect; C, cubic effect.

Table 4. Effects of N fertilization on P removal from bermudagrass harvested at two sites near Lincoln, AR

	Stephens site			Latta site		
Fertilization rate	May 30	July 7	August 18	May 30	July 7	August 18
lb N/acre	lb/acre					
0	4.5	5.1	9.0	12.7	16.0	8.7
50	5.6	5.9	12.9	15.7	16.6	9.9
100	5.9	6.4	11.7	15.7	17.6	10.2
150	7.6	7.6	9.7	17.8	17.0	9.8
SEM[a]	0.45	0.36	0.62	0.98	0.62	0.54
Effect[b]	L = 0.001	L = 0.001	Q = 0.0002	L = 0.005	NS	NS

[a] Standard error of the mean.
[b] NS, not significant (P > 0.05); L, linear effect; Q, quadratic effect.

Table 5. Cumulative effects of N fertilization on DM yield, concentrations of P, and total removal of P in bermudagrass harvested at the Stephens site near Lincoln, AR during 2000

Fertilization rate	Yield	P	P Removal
lb N/acre	lb/acre	% of DM	lb/acre
0	4,533	0.39	17.9
50	5,197	0.41	21.0
100	6,495	0.36	24.3
150	6,399	0.38	24.9
200	7,064	0.33	23.6
250	7,648	0.34	26.7
300	8,688	0.29	25.4
SEM[a]	344	0.01	1.4
Effect[b]	L < 0.0001	L < 0.0001	L = 0.0004
			Q = 0.061

[a] Standard error of the mean.
[b] L, linear effect; Q, quadratic.

Table 6. Cumulative effects of N fertilization on DM yield, concentrations of P, and total removal of P in bermudagrass harvested at the Latta site near Lincoln, AR during 2000

Fertilization rate	Yield	P	P Removal
lb N/acre	lb/acre	% of DM	lb/acre
0	9,692	0.39	37.1
50	10,310	0.40	41.3
100	11,198	0.37	42.3
150	11,684	0.37	43.6
200	12,467	0.35	43.5
250	12,564	0.36	45.8
300	12,532	0.34	43.5
SEM[a]	492	0.01	2.1
Effect[b]	L < 0.0001	L < 0.0001	L = 0.013
		Qu = 0.072	

[a] Standard error of the mean.
[b] L, linear effect; Qu, quartic.

Table 7. Soil-test P for bermudagrass plots at the Stephens and Latta sites in April 2000, November 2000, and April 2001 as determined by Mehlich III extraction. Nitrogen fertilization rate demonstrated no effect (P > 0.05) on soil-test P at either site on any date; therefore, only overall means are presented

Sampling date	Stephens	Stephens SEM	Latta	Latta SEM
	-------------------	------------------- lb/acre	-------------------	-------------------
April 2000	306	6	572	10
November 2000	276	8	568	10
April 2001	NA[a]	- -	494	8

[a] Not available. Site lost after November 2000.