PHOSPHORUS RUNOFF FROM TURFGRASS

RESEARCH UPDATE

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Introduction

Even though statewide restrictions on applying phosphorus (P) fertilizer to turfgrass went into effect in 2005, there is still interest over the impact that this legislation has on water quality and turfgrass health. In order to determine the horticultural and environmental effects of restricting P in turfgrass fertilizer, a dedicated research facility was established at the Turfgrass Research, Outreach and Education (TROE) Center on the St. Paul Campus at the University of Minnesota during the 2004 growing season. An ongoing study is evaluating the effects of P fertilization and clipping management on P runoff from turfgrass. This report summarizes results of the first three years of this study. The objectives of this research are to:

(1) Determine the extent of P runoff following fertilization of turfgrass;

(2) Evaluate the effects of clipping management on P runoff;

(3) Assess the effects of various management practices on turf health;

(4) Identify best management practices to minimize potential movement of P from turfgrass.

Materials and Methods

Plots for this study were constructed in 2003 and treatments were initiated in fall 2004 following sodding of the TROE site with Kentucky bluegrass. Eight treatments are being evaluated: four fertilizer treatments with and without clippings removed. Fertilizer treatments include: control (no fertilizer), N + K, N + K + low P, and N + K + high P. Fertilizer is applied in the spring, early fall and mid-fall in three equal applications. Nitrogen is applied at 3 lb N/1000 sq. ft./yr. and K is applied at 1.4 lb K2O/1000 sq. ft./yr. From fall 2004 to summer 2005, low P was 1 lb P2O5/1000 sq. ft./yr. and high P was 3 lb P2O5/1000 sq. ft./yr. In fall 2005, the P application rates were reduced to one-third of the first year rates to reflect recommendations for an established lawn.

The 8'x24' plots are equipped with a stainless steel gutter at the lower end, which collects runoff and delivers it to a 35-gallon bucket with a 5-gallon insert. Runoff volume in the 5-gallon bucket is measured by weighing; larger flows are pumped to the 35-gallon bucket via a metered pump. This allows complete collection of runoff. This study is unique in that runoff has been collected throughout the year, including during winter snowmelt events. Sample collection started in the fall of 2004 and will continue for several more years. Total P and soluble P in runoff have been quantified using standard laboratory procedures. Turfgrass quality has been determined through visual evaluation on a 1-9 scale (1 = dead, 6 = minimally acceptable, and 9 = ideal) and relative growth has been measured by the dry weight of clippings produced under each treatment.

Results and Discussion

Phosphorus Runoff. The amount of both total P and soluble P lost in runoff from turfgrass in 2005 increased significantly as the P fertilizer rate increased, especially at the highest P application rate (Table 1). This effect was similar under both frozen and non-frozen soil conditions. Phosphorus runoff losses in 2005 were equivalent to 2.3% of the total amount of P applied from Sept. 2004 to Aug. 2005 at the high P rate and 3.2% of the amount applied at the low P rate. In 2006, after P rates were reduced to amounts recommended for established turfgrass, losses of P in runoff were generally highest for the control treatment where no fertilizer was applied (Table 2). Under non-frozen soil conditions, both total and soluble P runoff were twice as high with no fertilizer than for the three fertilizer treatments. When the soil was frozen, P loss was lowest for the N + K with no P treatment and similar for no fertilizer, low P and high P. Phosphorus

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	Phosphorus runoff - 2005					
	Total P			Soluble P		
Treatment effects	Frozen	Non-Frozen	Total	Frozen	Non-Frozen	Total
	lb./A					
Fertilizer						
No fertilizer	0.34	0.10	0.44	0.24	0.04	0.29
No P	0.39	0.07	0.46	0.25	0.03	0.28
Low P	0.52	0.09	0.61	0.39	0.04	0.44
High P	1.17	0.14	1.31	0.94	0.09	1.03
Clippings						
Removed	0.60	0.09	0.69	0.46	0.04	0.50
Returned	0.61	0.12	0.72	0.46	0.06	0.52

Table 1. Phosphorus runoff under frozen and non-frozen soil conditions in 2005.

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runoff losses were equivalent to 0.7% of the total annual amount of P applied at the high P rate and 2.3% of the amount applied at the low P rate. Laboratory results for total P runoff from non-frozen soil in 2007 are incomplete, but both total and soluble P losses from frozen soil increased as P rate increased (Table 3). The rate effect was not as strong as in 2005 and the no fertilizer control was not significantly different from the no P and low P fertilizer treatments. Phosphorus rate had no effect on soluble P runoff from non-frozen soil. Soluble P comprised about 70% of the total P in runoff in both 2005 and 2006, which is consistent with the low erosion rates from turfgrass and reduced losses of P attached to soil particles. Phosphorus runoff in winter and early spring while the ground was still frozen accounted for 85% of total P runoff in 2005, 54% of total P runoff in 2006 and 75% of soluble P runoff in 2007 even though there was only one runoff event from frozen soil in 2007. Measurements of P losses from lawns or other managed turf areas while the soil is frozen have not previously been reported, but these data show that winter snowmelt events and spring rainfall on frozen ground are an important part of annual nutrient export from turfgrass in northern climates.

Clipping management had inconsistent effects on P runoff (Tables 1-3). Removing grass clippings reduced P runoff from non-frozen soil in 2005, but had no effect when the ground was frozen. The reverse was true in 2007, when returning clippings increased P runoff from frozen soil, while in 2006 total annual P runoff decreased when clippings were returned. Differences between years may have been due to differences in the amount and timing of precipitation, but results do indicate that under some conditions the P in recycled clippings can be a source of P for runoff.

Runoff Volumes and Phosphorus Concentrations. Differences in P runoff amounts were affected by differences in both runoff volume and P concentration (Tables 4 and 5). Runoff volumes in 2005 were 3 to 4 times higher than in 2006 and 2007, which was consistent with the much higher P runoff losses in 2005. In 2005 and 2007, 75 to 80% of the runoff volume was from frozen soil, which also paralleled the fact that 75 to 85% of the P runoff occurred while the soil was frozen. Runoff volume was about twice as high from the no fertilizer control as from any of the other treatments in 2006 and this was consistent with the 50 to 100% increases in runoff P for the no fertilizer control compared with the other treatments.

Flow-weighted P concentrations increased with P application rate in all three years. Concentration differences were generally consistent with P runoff amounts, although in 2006 the large runoff volumes from the no fertilizer control overrode concentration differences. Concentrations were higher in frozen soil runoff in 2005 and 2006, but in 2007 soluble P concentrations in runoff from frozen and non-frozen soils were equivalent.

Turf Quality and Growth. Turf quality and growth were significantly lower for the no fertilizer control than any of the fertilizer treatments receiving N and K in

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Treatment effects	Runoff volume - 2005			Runoff volume - 2006			Runoff volume - 2007		
	Frozen	Non-Frozen	Total	Frozen	Non-Frozen	Total	Frozen	Non-Frozen	Total
	inches			inches			inches		
Fertilizer									
No fertilizer	0.87	0.42	1.28	0.19	0.56	0.74	0.28	0.13	0.41
No P	1.14	0.32	1.45	0.09	0.28	0.37	0.25	0.04	0.29
Low P	0.92	0.33	1.24	0.18	0.28	0.45	0.28	0.04	0.33
High P	1.00	0.32	1.31	0.15	0.17	0.32	0.23	0.02	0.26
Clippings									
Removed	1.01	0.32	1.33	0.17	0.25	0.57	0.24	0.07	0.31
Returned	0.94	0.37	1.31	0.13	0.25	0.37	0.28	0.05	0.32

Table 4. Runoff volumes from frozen and non-frozen soils from 2005 to 2007.

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all three years (Table 6). The quality rating for no fertilizer dropped 50% from 2005 to 2007 and was only about 1/3 of the fertilizer treatments. Quality ratings increased slightly or remained relatively stable throughout the study for the fertilized treatments. Relative growth as measured by clipping dry weights was similarly affected. Growth of the no fertilizer control was only 11 to 36% of the fertilized treatments. Phosphorus application rate had no effect on turf quality or growth, supporting the recommendation that there is no benefit to applying P fertilizer to established turf when soil P is in the adequate soil test range.

Treatment effects	Phosphorus runoff - 2006					
	Total P			Soluble P		
	Frozen	Non-Frozen	Total	Frozen	Non-Frozen	Total
	lb./A					
Fertilizer						
No fertilizer	0.09	0.11	0.20	0.05	0.10	0.15
No P	0.04	0.05	0.09	0.02	0.04	0.05
Low P	0.09	0.05	0.14	0.05	0.04	0.09
High P	0.09	0.04	0.13	0.06	0.04	0.10
Clippings						
Removed	0.09	0.08	0.17	0.05	0.06	0.12
Returned	0.06	0.05	0.11	0.04	0.04	0.07

Table 2. Phosphorus runoff under frozen and non-frozen soil conditions in 2006.

Treatment effects	Phosphorus runoff - 2007					
	Total P*			Soluble P		
	Frozen	Non-Frozen	Total	Frozen	Non-Frozen	Total
	lb./A					
Fertilizer						
No fertilizer	0.06	---	---	0.05	0.04	0.10
No P	0.04	---	---	0.04	0.01	0.04
Low P	0.07	---	---	0.06	0.02	0.08
High P	0.13	---	---	0.09	0.02	0.09
Clippings		---	---			
Removed	0.05	---	---	0.05	0.03	0.07
Returned	0.10	---	---	0.07	0.02	0.08

*Total P sample analysis for non-frozen soil in 2007 is in progress.

Table 3. Phosphorus runoff under frozen and non-frozen soil conditions in 2007.

Greater runoff volumes and greater P losses from the no fertilizer treatment in 2006, and to a lesser extent in 2007, were associated with the significant reductions in turf quality and growth compared with the fertilized treatments. The no fertilizer treatment resulted in reduced turf density, greater weed growth and more area with dead grass tissue than the fertilized treatments.

Summary

The rate of P fertilizer applied can have significant effects on P runoff losses from turfgrass, especially when rates exceed plant requirements. When turf quality and growth are poor due to inadequate N and/or K, the resulting increase in runoff creates high potential for P losses even when no P fertilizer is applied. This may also occur when factors other than nutrition limit turfgrass growth. The majority of the P losses in this study were transported in runoff over frozen soil, so P fertilizer should not be applied to turfgrass in the fall. Grass clippings can be a source of P for runoff, but returning clippings did not consistently increase P losses compared with clipping removal. These results demonstrate that maintenance of a healthy stand of turf is an important factor regulating P losses in runoff from lawns and other turfgrass areas. Poor turf quality can lead to higher amounts of runoff, which can increase P losses even where no P fertilizer has been applied.

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Table 5. Flow-weighted P concentrations in runoff from frozen and non-frozen soils from 2005 to 2007.

Treatment effects	Flow-weighted P concentration - 2005				Flow-weighted P concentration - 2006				Flow-weighted P concentration - 2007			
	Total P		Soluble P		Total P		Soluble P		Total P*		Soluble P	
	Frozen	Non-Frozen	Frozen	Non-Frozen	Frozen	Non-Frozen	Frozen	Non-Frozen	Frozen	Non-Frozen	Frozen	Non-Frozen
	ppm				ppm				ppm			
Fertilizer												
No fertilizer	1.77	1.11	1.28	0.54	2.23	0.98	1.33	0.86	0.95	---	0.85	0.83
No P	1.55	0.92	0.99	0.37	1.67	1.00	0.75	0.60	0.75	---	0.62	0.82
Low P	2.46	1.26	1.87	0.62	2.89	1.17	1.71	0.78	1.16	---	1.01	1.47
High P	4.98	2.03	3.95	1.30	2.46	2.14	1.65	1.32	2.54	---	1.64	1.85
Clippings												
Removed	2.66	1.19	2.02	0.62	2.24	1.06	1.34	0.79	1.09	---	0.93	1.08
Returned	2.72	1.47	2.03	0.80	2.38	1.58	1.38	0.98	1.49	---	1.06	1.40

*Total P sample analysis for non-frozen soil in 2007 is in progress.

Treatment effects	2005		2006		2007	
	Quality	Clipping DW	Quality	Clipping DW	Quality	Clipping DW
	1-9, 9=high	% maximum	1-9, 9=high	% maximum	1-9, 9=high	% maximum
Fertilizer						
No fertilizer	3.7	24.5	2.7	9.2	2.0	31.8
No P	5.6	78.4	6.0	82.8	6.0	92.1
Low P	5.5	73.5	5.6	82.0	5.6	85.3
High P	5.7	78.0	5.9	92.1	6.3	88.5
Clippings						
Removed	5.0	52.3	4.9	59.0	5.1	70.1
Returned	5.3	74.9	5.3	74.1	4.9	78.2

Table 6. Turf quality ratings and relative turf growth based on clipping dry weights from 2005-07

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