Technical Completion Report

Wellhead Protection from Nitrate Contamination through Minimum Fertilization of Turf

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The activities on which this report is based were financed in part by the Department of the Interior, U.S. Geological Survey, through the Rhode Island Water Resources Center. The content of this publication does not necessarily reflect the views and policies of the Department of the Interior, nor does mention of trade names or commercial products constitute their endorsement by the United States Government.

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ABSTRACT

In an effort to protect ground water resources in shallow aquifers, research was continued to investigate the potential for minimum fertilizer use in turf maintenance. Since the soils in much of southern New England overlaying shallow aquifers are highly suited for turfgrass culture, either as recreational facilities or commercial sod production, it is critical that the use of fertilizers and pesticides that might leach beneath the root zone be used at minimum rates. Based on research conducted over the past ten years, it seems reasonable that fertilizer-N rates used on turf could be reduced to 1 lb/1000 sq-ft (<50 lbs/acre). This is possible if fertilizers are used so as to supplement nitrogen released in the soil through natural mineralization of organic matter.

Three nitrogen sources were applied to experimental plots of Kentucky bluegrass sod established during the spring of 1994. Fertilizers were applied at two or three times in early spring and early and late summer such that the total amount used was 1 lb N/1000 sq-ft. A 3 lb N/1000 sq-ft and an unfertilized control were included among the seven fertility treatments. Suction lysimeters installed at a two-foot depth extended below the root zone and were used to monitor the nitrate content of soil water throughout the year. Soil water nitrate concentrations together with net water percolation rates were used to estimate nitrate leaching from turf. During the 1995 growing season, grass clippings were sampled on eleven dates and analyzed for total nitrogen. These analyses indicated that the turf generally was obtaining sufficient nitrogen to maintain good growth and quality. While the high nitrogen plots produced more clippings of higher nitrogen content in the spring, no significant differences in nitrogen content were observed during summer and fall. Turf quality was maintained at acceptable levels in all treatments except during August when high temperature and disease caused a quality decline in all plots. By early fall, all plots contained turf of good quality. Nitrate leaching reflected the fertility treatments with the high nitrogen plots leaching more than those receiving 1 lb N/1000 sq-ft. EarthGro Lawn Food (reinforced compost) leached somewhat more nitrate than Coron (methylene urea) mostly because of the sodium nitrate present in the former material. These preliminary results suggest that quality turf can be grown with nitrogen rates of 1/3 to 1/4 those normally recommended. This research is being continued through 1995-96.

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INTRODUCTION

The use of land in southern New England is of such intensity that most areas are or soon will be subjected to some level of development. Shallow aquifers, especially those representing sole-source water supplies, need special protection but the land overlying them is often highly valued for residential or commercial development. It is important to identify those land uses which constitute the least threat to these sensitive water resources. Turf culture (residential, commercial, institutional and recreational) has come under much media criticism as an environmentally risky land use wherever ground water protection is important (Jenkins 1994). This has influenced land use planning policy in spite of an ever growing body of research which shows turf to be a relatively effective ground cover for minimizing both nitrate and pesticide leaching to ground water (Cohen et al. 1990; Petrovic 1990; Kenna 1995).

If turf is an environmentally sound ground cover over high value aquifer systems, it is important that managers of turf and those responsible for protecting ground water resources understand the best cultural practices for minimizing nutrient release from turf areas. Such knowledge will maximize the protective functions of turf and permit policy makers to assure the public that effective safeguards for wellhead protection and preservation of water quality are being implemented. Most research has concentrated on quantifying the discharge of pollutants into ground water. This study helps define fertilizer management strategies for turf culture which are most protective of ground water quality.

This research was developed from the substantial base of data on nitrate recovery and discharge in turf which we have generated over the past decade. While our studies have emphasized worse case situations in order to determine the potential for nitrate leaching, we have learned much about the seasonal patterns of soil water nitrate flucuations and the annual cycle of nitrogen demand by turfgrasses. Based on such information, we are convinced that a turf fertilization program can be devised which will utilize about 25% of the nitrogen commonly applied to turf with little or no decline in turf quality.

This research is an evaluation of several approaches to achieving this marked reduction in nitrogen use and hopfully one or more strategies will emerge as successful and can be recommended to turf managers.

RESEARCH OBJECTIVES

The research reported here is from the first post-establishment year of a study which has the following three objectives.

1. To minimize nitrogen fertilizer use on turf by applying it only when soil nitrogen supplies are not adequate to maintain turf quality. Emphasis is being placed on spring and early summer applications with less use in the fall.

2. To compare fertilizer sources for their ability to deliver nitrogen in the amount and at a rate required by turfgrasses. Readily available and slow release organic nitrogen sources are being compared.

3. To determine if good quality Kentucky bluegrass turf can be maintained with annual nitrogen applications of not more than 1 lb N/1000 sq-ft (less than 50 lbs. N per acre).

METHODOLOGY

Experimental Design: The plot area utilized for this research is located on the Turfgrass Research Farm of the Rhode Island Agricultural Experiment Station at Kingston, RI. The soil type is an Enfield silt loam (Coarse loamy over sandy skeletal, mixed, mesic, Typic Dystrochrept). The site had been in turf for the past 25 years but not utilized for experimentation since 1989. In early April, 1994, the existing sod was killed by a topical application of glyphosate [*N*-(phosphonomethyl)glycine] and the dead turf removed with a sod cutter. The site was limed and prepared for sodding. Commercially grown Kentucky bluegrass (*Poa pratensis* L.) sod was installed on April 26, 1994. The sod was grown within 500 yards of the plot site using a commercial blend (Lofts Seed Inc.) consisting of 25% by weight 'Suffolk', 25% 'Sydsport', 25% 'Baron', 15% 'P-104' Kentucky bluegrasses and 10% 'Jamestown II' Chewings fescue. Past experimentation has shown Kentucky bluegrass to be least efficient in recovering nitrate from solution (Liu et al. 1993) and the most demanding of fertilizer nitrogen. If Kentucky bluegrass turf can be maintained at 1 lb N/1000 sq-ft/year, the same can be done with any cool-season turfgrass.

Seven nitrogen fertility treatments were initiated on June 20, 1994 and maintained to the present. These are summarized below:

N source	Rate	Time & amount applied (lbs.)
	lbs N/1000 ft^2/yr	
Urea	3	June - 1.0; Nov. - 2.0
Urea	1	April - 0.5; June - 0.25; Sept. - 0.25
CORON	1	April - 0.5; Sept. - 0.5
CORON	1	April - 0.5; June - 0.25; Sept. - 0.25
Compost	1	April - 0.5; June - 0.5
Compost	1	April - 0.5; June - 0.25; Sept. - 0.25
Control	0	

The 3 lb urea-N treatment simulated conventional fertility management for a home lawn. Urea is a water soluble, readily available, and inexpensive nitrogen source commonly included in commercial turf fertilizers. CORON is a liquid methylene diurea product, 28% N by weight of which about 30% is urea and 70% is controlled release polymerized material. In our research, it has supported good quality turf, provided little leachable nitrate, and is the sort of nitrogen formulation popular with lawn maintenance companies. The compost used was Earthgro Lawn Food with an analysis of 8-2-4. It consists mostly of composted leaves and poultry manure fortified with $NaNO_3$. Its 8% nitrogen is about 50% water soluble and 50% insoluble. It is typical of commercially available 'organic' lawn fertilizers and in our research, has supported good quality turf but tends to permit some nitrate leaching. These nitrogen sources represent the spectrum of materials currently used in lawn fertilizers and were intended to provide a realistic assessment of minimum fertility turf management.

In this study, most fertilizer was applied in the spring when soil nitrate concentrations are lowest and absorption by grass roots is greatest (Hull et al. 1993). Low applications in September are intended to enable grass to recover more quickly from summer injury to the root system caused by drought, high temperatures, insect predation and human activity. An unfertilized control plot was included in each of the four replications to monitor natural seasonal changes in soil mineralization of organic nitrogen and normal fluctuations in soil water nitrate levels.

The early spring applications of 0.5 lbs. N/1000 sq-ft were made on April 13, 1995. All mid-June nitrogen applications were made on June 15, 1995 which included all treatments except the Coron early spring/late summer and the unfertilized controls. The late summer applications were made on September 1 and the late fall application of 2 lbs. urea- N/1000 sq-ft to the high nitrogen plots was made on November 24, 1995. Plots were hand irrigated with about 0.25 inches of water within one to two hours of the time fertilizer was applied. In 1996, the early spring applications were made on April 1 and the late spring treatments on June 14.

Nitrate Leaching, Nitrogen Recovery in Clippings and Turf Quality: Suction cup lysimeters were installed in each plot at a depth of two feet on June 1, 1994. Lysimeters consisted of a ceramic cup 0.88 inch OD by 2.75 inches long mounted on a 21 inch long PVC pipe 0.8 inch OD. The ceramic cups were obtained from Soilmoisture Equipment Corp., Santa Barbara, CA and rated for standard flow rate. During installation, cups were set in a slurry of silica flour to insure good contact with the soil matrix. When the lysimeters were evacuated to -0.8 bars, 10 to 50 mL of soil water were drawn into the cup over a two hour period.

During 1995, soil water samples were collected on 15 dates which encompassed the entire year. These were analyzed for nitrate-N by passing a water sample through a cadmium/copper reduction column and analyzing the resulting nitrite spectrophotometrically (Keeney and Nelson 1982). The results were used to estimate nitrate leaching by multiplying the soil water nitrate concentration by leachate volumes calculated for each precipitation event identified from soil and meteorological data using the hydrologic component of the CREAMS model (Smith and Williams 1980). Soil water sampling and analysis are continuing throughout 1996.

Clippings were harvested on 11 dates during the 1995 growing season from a 10.3 sq-ft area of each plot. Clippings were oven dried, ground to pass a 30-mesh screen and analyzed for total Kjeldahl nitrogen according to Easton (1978). Nitrogen recovered in clippings is a nondestructive means of estimating nitrogen absorption by roots and transport to shoots and for monitoring the nutritional status of turf. Clippings are being harvested at biweekly intervals throughout the 1996 season.

All plots were scored for visual quality on eight dates during the 1995 growing season. Quality scores constituted a subjective integration of turf color, texture, uniformity and freedom from weeds, disease and other injury. Perfect turf was assigned a score of 9 while dead turf would be scored at 1. A score of 6 or higher indicates acceptable turf quality. Plots are being scored throughout the 1996 growing season.

RESULTS AND DISCUSSION

This project is continuing through the 1996-97 year with funding from the RIWRRC under a different title. Consequently what is presented here can only be viewed as a progress report for the year 1995. The results from the year of establishment (1994) were reported in an earlier completion report (Hull 1995). This research realistically will require three to four years to test adequately the minimum fertilizer hypothesis on which this project is based.

Turf quality:

Turf quality scores were taken on eight dates in 1995 (Table 1.). While the late spring presented near normal temperatures and slightly below normal rain fall the summer was warmer than normal and dry (3.5 inches below normal). This resulted in a sharp decline in turf quality during August. However, the return to more normal conditions in September along with a nitrogen application to three plots, resulted in a marked increase in quality.

Table 1. Quality scores of Kentucky bluegrass turf fertilized with three nitrogen sources at three rates.

Nitrogen source	Yearly rate	Months applied	Quality scores*					
			May	June	July	Aug.	Sept.	Average
	lb/1000 sq-ft	mo.						
Urea	3	6 & 11	8.0	7.8	8.2	4.5	7.8	7.3
Urea	1	4, 6 & 9	8.0	7.0	7.2	5.1	8.0	7.1
Coron	1	4 & 9	7.6	6.2	6.1	5.4	7.5	6.6
Coron	1	4, 6 & 9	7.2	6.5	6.2	4.6	7.2	6.3
Compost	1	4 & 6	7.1	6.5	5.8	4.2	7.2	6.2
Compost	1	4, 6 & 9	7.6	7.0	7.6	5.1	7.8	7.0
Control	0	-	6.9	6.0	5.6	5.2	7.5	6.2

* Quality scores: 9=perfect turf, 1=dead turf; based on 8 scorings averaged by month.

Differences among fertilizer materials and times of application were generally significant but not consistent throughout the season. Urea generally produced the highest quality turf but the one-pound rate was often equal to or better than the three-pound rate. Earthgro Lawn Food (compost) treated turf benefited from the early September application made in 1994 and that advantage persisted throughout the season. Coron treated plots exhibited a similar pattern with the 0.5 lb application in September producing a slight advantage over the 0.25 lb treatment. By mid- to late-fall, all plots exhibited good quality turf (data not shown) indicating that soil water nitrogen was more than adequate to meet grass needs. The unfertilized plots showed the capacity for mineralized soil organic nitrogen to meet their nutritional needs. Only in the spring did these plots rank poorest. Later in the season, unfertilized plots were of higher quality than some receiving nitrogen fertilizer.

These results are from the first full post-establishment season and must be regarded as preliminary.

Soil water nitrate and nitrate leaching:

Soil water samples were collected on 15 dates in 1995 and the nitrate-nitrogen concentrations are summarized in Table 2. Because

Table 2 Soil water nitrate-N concentrations from Kentucky bluegrass turf plots fertilized with three N sources on three dates.

Nitrogen source	Rate	Nitrate-nitrogen**								
		Feb.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.
	lbs/1000 sq-ft	mg NO_3-N L^{-1}								
Urea-L*	3	3.8	0.5	0.5	1.3	16.4	11.8	6.2	6.2	6.9
Urea-E	1	0.2	-	0.8	0.8	0.8	2.7	1.9	2.4	4.8
Coron-L	1	0.1	0.4	0.9	1.1	0.1	4.2	3.2	2.4	3.0
Coron-E	1	0.3	0.4	0.6	0.9	0.6	2.0	1.1	1.5	1.1
Compost-L	1	0.7	0.4	0.7	1.4	2.7	2.6	1.8	3.8	7.0
Compost-E	1	0.3	0.4	0.8	0.6	1.0	6.9	3.3	3.1	2.7
Control	0	0.6	0.5	0.9	0.5	0.6	1.9	1.0	1.4	1.2

* L = Some fall application; E = Mostly spring applied nitrogen.
** Bases on 15 sampling dates averaged by month.

of warmer than normal conditions throughout the summer, soil mineralization of organic nitrogen probably contributed to elevated soil water nitrate levels. Even the unfertilized plots contained soil water nitrate-nitrogen in excess of 1.0 mg NO_3-N/L (ppm) during late summer and fall. During the spring, nitrate-nitrogen levels were consistently less than 1.5 ppm. The higher urea-nitrogen treatment was evident by its elevated soil water nitrate levels. The 1.0 lb N/1000 sq-ft application in mid-June resulted in a nitrate-nitrogen concentration in soil water of 16 ppm during July.

All 1.0 lb N/1000 sq-ft application rates failed to produce soil water nitrate-nitrogen levels in excess of 10 ppm NO_3-N set by the US Public Health Service as the maximim allowed in drinking water. Because of low rainfall during the summer months, nitrate leaching to the 2-ft. depth of the suction lysimeters may have been delayed or not detected even if nitrate levels in the surface soil horizons were relatively high. This may explain why the Earthgro compost plots which received 0.5 lb. N in mid-June did not exhibit elevated soil water nitrate until August. The relatively high nitrate concentrations in soil water of Earthgro Compost treated plots probably is a result of the readily soluble sodium nitrate added to increase the analysis of that product. Even so, the nitrate-N level from those plots rarely exceeded 5.0 ppm.

Nitrate Leaching:

Nitrate leaching was estimated based on soil water nitrate concentrations and net percolation estimated from the CREAMS model (Table 3). Almost half of the annual precipitation and

Table 3 Estimated seasonal nitrate-N leached from Kentucky bluegrass turf plots fertilized with three N sources on two dates.

Nitrogen source	Rate	Nitrate-N leached					
		1-3	4-6	7-9	10-12	Total	% of applied
	lbs N/1000 sq-ft			mg NO_3-N m^{-2}			
Urea-L*	3	659	34	1768	1856	4317	28.8
Urea-E	1	40	26	296	1116	1478	29.6
Coron-L	1	21	32	419	770	1242	24.8
Coron-E	1	40	26	205	344	615	12.3
Compost-L	1	45	34	368	1657	2104	42.1
Compost-E	1	114	23	659	786	1582	31.6
Control	0	110	23	198	357	688	-
Percolation inches		6.8	1.6	5.9	10.9	25.2	49.0

* L = Some fall application; E = Mostly spring applied nitrogen.

irrigation was estimated to have percolated through the soil during 1995. This carried with it nitrate-nitrogen ranging from 4.3 g/m^2 for the high rate of urea to 0.6 g/m^2 for the Coron treatment in which most was applied in the spring. This represented quantities equivalent to 29% and 12% of the nitrogen applied, respectively.

Because nitrate concentrations in the soil water were so low in the spring, relatively little nitrate leached during that season. Also, precipitation was low resulting in only 1.6 inches of percolation. The greatest percolation occurred in the fall when soil water nitrate levels were highest. This resulted in nitrate leaching in excess of 1.5 g N/m^2 from the Earthgro Lawn Food when half had been applied in early September. The least leachable nitrogen source was Coron which lost less than 25% of that applied.

The leaching levels observed in this study were greater than those noted in other experiments conducted as part of this investigation (Hull et al. 1993). In part, this was due to the low nitrogen rates applied. When expressed as a percent of that applied, even low leaching levels may appear large. In this study, those plots receiving 3-lbs of urea-N leached nitrate equivalent to 29% of the nitrogen applied but that represented only 37 lbs nitrogen per acre. The EarthGro Lawn Food treatment that received 1 lb N/1000 sq-ft and leached the equivalent of 42% of that nitrogen, actually lost only 18 lbs. nitrogen per acre.

Also, the high temperatures and dry conditions which characterized the 1995 growing season, probably contributed to rapid and extensive root decline while encouraging mineralization of soil organic nitrogen. This lack of roots reduced nitrate uptake by the turf leaving soil nitrogen vulnerable to leaching. Because these plots were sodded in 1994, root growth may not have been as extensive or deep as it would in seeded turf (Geron et al. 1993). The 1996 season having more normal precipitation and cooler than normal temperatures should promote greater root retention and activity with less nitrate leaching. This appears to be occurring.

CONCLUSIONS

During this first post-establishment year, treatment effects were evident and the turf began responding more like an established sod. This permits us to make the following tentative conclusions.

1. Nitrogen applied at 1 lb/1000 sq-ft can support good quality turf if one-half or three-fourths of it is applied during spring and early summer with the remainder applied in late summer.

2. A late fall application of nitrogen will provide earlier green-up in the spring but otherwise offers no advantage and can promote nitrate leaching.

3. Controlled release nitrogen sources support good turf quality and offer less potential for nitrate leaching.

4. Nitrate leaching occurs mostly during late summer and fall when living turf roots are least abundant. A total suppression of leaching will require managing turf so as to maintain active roots and maximize their growth.

5. Unfertilized turf leached about 6 lbs of nitrate-nitrogen per acre during 1995. This is equivalent to 0.14 lbs N/1000 sq-ft. One fertilizer treatment in this study leached less nitrate than the unfertilized turf.

ACKNOWLEDGMENTS

In addition to the support provided by the Rhode Island Water Resources Research Center, which is gratefully acknowledged, funding was also provided by Earthgro Inc., Coron Corp, and the Rhode Island Agricultural Experiment Station. Fertilizer materials were contributed by Coron Corp. and Earthgro Inc. The technical assistance of three undergraduate students, Paul Santer, Antoinette Snyman and Philip Thibaudeau for sample collection and analysis during the summer of 1995 is also gratefully appreciated. We thank Carl Sawyer for providing soil percolation data based on the CREAMS model. Greg Fales and his staff at the Turf Research Station is acknowledged for their efforts in maintaining the turf plot area.

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