POTENTIAL LEACHING AND RUNOFF OF NUTRIENTS FROM GOLF GREENS AND FAIRWAYS

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Abstract. Research was conducted to determine the transport of N and P by runoff of surface water from golf fairways and by leaching through greens. Step-wise increases in runoff P concentrations were found for 5 and 11 kg P ha^{-1} fertilizer application rates for the first runoff event from bermudagrass plots with a 5 % slope. The total mass of P transported for four events was 10.6 and 11.5 % of that added for the 5 and 11 kg ha^{-1} rates, respectively. Leaching of nitrate-N and P was monitored for two working putting greens at an Atlanta country club. Nitrate concentrations in the leachate did not exceed the 10 mg L^{-1} drinking water standard for the first three years of monitoring. Leachate P concentrations were highest the first year and decreased thereafter due to changes in amounts of applied P fertilizer.

INTRODUCTION

Water pollution from inorganic ions often comes in the form of nitrates and phosphates that enter from various anthropogenic sources which include, but certainly are not limited to, fertilizers applied to cropland as well as to urban areas. An area of concern has been the intensively managed golf courses that are becoming more numerous, where turf is maintained with many applications of fertilizer throughout the year and where irrigation is used to a great extent. The porosity of the sand-peat greens coupled with high inputs of fertilizer and irrigation can lead to leaching, not only of the extremely soluble nitrogen sources, but also of less soluble phosphate fertilizer. Fairways in the Southeastern Piedmont may have impervious soils causing high rates of runoff during heavy rainfalls, especially on sloped areas. Similarly, homeowner and commercial lawns are another large source of fertilizer elements being lost to surface waters.

Nitrogen and P added to turfgrasses transported in runoff and subsurface flow eventually find their way to potable water supplies. Added nutrients, especially P, causes eutrophication of surface water leading to problems with its use for fisheries, recreation, industry, or drinking water due to increases in growth of undesirable algae and aquatic weeds. Phosphorus is usually the single most limiting element for algae growth, since many blue-green algae are able to utilize atmospheric N_2. Most of the P lost from grassed areas is in the soluble, not particulate form, that is immediately available for algae growth. Thus, limiting both N and P losses from turfgrass areas is an important environmental issue.

EXPERIMENTAL DESIGN

The objective of this investigation was to evaluate the potential movement of N and P following application to golf courses with the future goal of developing best management practices to reduce potential transport to potable water systems where eutrophication may lead to reduced water quality. Two research venues were used with different methods and objectives. The first was to study N and P runoff from plots simulating golf fairways. The null hypothesis was that N and P concentrations in runoff water would not be above drinking water standards for N or above eutrophic concentrations for P. To reject this hypothesis the N would be above 10 mg L^{-1} and P would be above 1.0 mg L^{-1}. The second was to record the N and P concentrations in percolate water from lysimeters in working golf greens over a period of three years. The null hypothesis and the criteria for rejecting it were the same as for the runoff water, but applied to percolates. The runoff experiment included several rates of N and P in a well designed, replicated experiment. However, the second was a monitoring study where the nutrient rates and sources and irrigation rates were according to normal practice at a golf course.

METHODS

Twelve individual plots (3.7 x 7.4 m), separated by landscape timbers, were developed on a Cecil soil in a grid with a 5% slope from the back to the front. The subsoil was a clay loam and the top soil was a sandy loam. A ditch was dug at the front of the plots to install a trough for collecting the runoff water in a tipping-bucket sample collection apparatus. The plots were planted to 'Tifway 419' *Cynodon dactylon* (L.) Pers. x *C. transvaalensis* Burtt-Davy on May 17, 1993 and the plots were completely covered with sod by August 1, 1993. Off-center rotary action sprinkler heads were mounted 7.4 m apart and 3.1 m above the sod surface. When operated at 138 kPa, the system produced an even distribution of simulated rainfall at an intensity of 3.3 cm/hr.

At the Cherokee Town and Country Club in Atlanta two bentgrass putting greens are each equipped with three lysimeters. The stainless steel lysimeters are 38 cm X 53 cm X 15 cm deep (kitchen sinks) and placed 18 cm beneath the green surface. Stainless steel lines run from the drain in each to the edge of the green where percolate is collected.

Treatments for runoff experiments

There were 12 identical plots in the simulated fairway area. In most cases only eight plots were used and all were treated similarly as replications with treatments differing in time rather than in space. The nutrient experiment involved rates of 10-10-10 at 0, 12, and 49 kg ha^{-1} and P rates of 0, 5, and 11 kg ha^{-1}. Irrigation schedules were 4 (5.0 cm), 24 (5.0 cm), 72 (2.5 cm), and 168 (2.5 cm) hr after treatment (HAT) with collections of runoff at each irrigation.

Measurements and analytical procedures

Nitrate and P were analyzed colorimetrically using a LACHAT flow analyzer for both runoff and percolate samples. Nitrate analysis was by a sulfanilamide method after reduction to nitrite on a Cd column. Phosphorus analysis was by a molybdate blue-ascorbic acid method.

RESULTS AND DISCUSSION

Runoff experiments

Runoff concentrations of P were highest for the first runoff event at 4 hours after treatment (HAT) and decreased significantly for subsequent events (Fig. 1). This result came despite the fact that the runoff volume

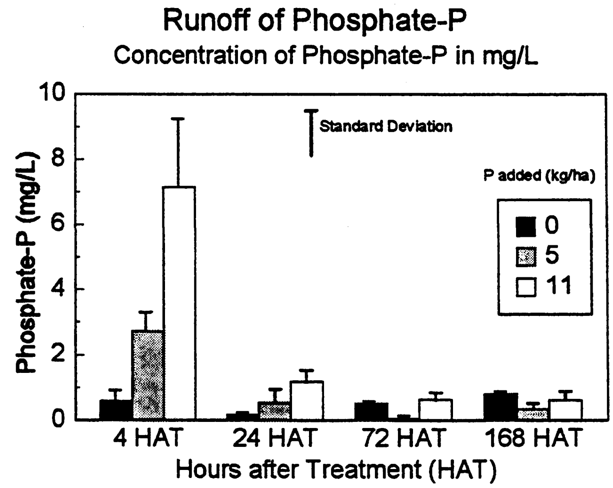

Figure 1. Concentrations of P for 3 P rates and 4 simulated rainfall events.

was highest during the second runoff event at 24 HAT (data not shown). Thus, recently applied P was mostly transported during the first simulated rainfall and was found in the soluble form, since the runoff water was filtered through a 0.45 μm filter before analysis. It would seem from this result that the most vulnerable time for runoff of P is at the first rainfall after application, especially if the fertilizer has had little time to react with the soil colloidal surfaces. The result also shows that P when first applied from commonly-used agricultural fertilizers is quite water soluble.

There were step-wise increases in P concentrations for the first runoff event for the two P rates of added (Fig. 1). Although there appears to be a step-wise increase at the second rainfall event, the standard deviations indicate that the 5 and 11 kg ha^{-1} rates caused no significant differences in P concentrations. The P concentrations resulting from added P for the last two rainfall events were the same as for the control. Percent added P recovered in the runoff was 10.6 and 11.5 % for the 5 and 11 kg ha^{-1} rates, respectively. Thus, the mass recovered was fairly consistent for the two rates added. The hypothesis that P is not transported in amounts high enough to cause eutrophication must be rejected, since concentrations as high as 9 mg L^{-1} were found in the runoff water.

The concentrations of nitrate in the runoff water were relatively low for the first three runoff events (below about 3 mg L^{-1}) and increased for the runoff event at 168 hours to as high as 9 mg L^{-1} for individual plots (data not shown). The reason for this delay is most likely because the ammonium form of nitrogen was added and it took some time before the conversion to nitrate. However, the

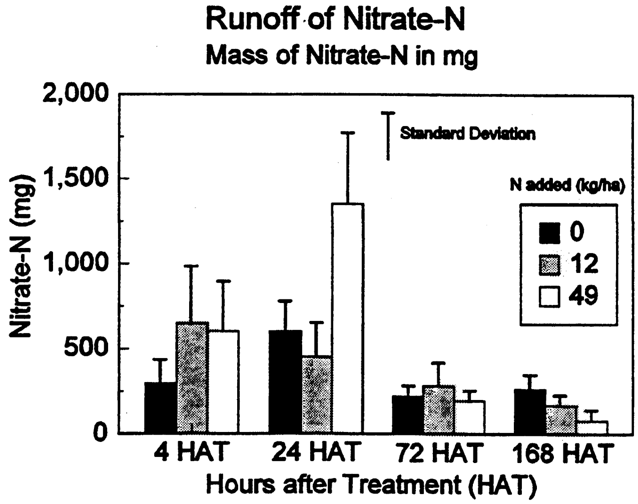

Figure 2. Mass of nitrate-N for 3 N rates and 4 simulated rainfall events.

mass of nitrate-N in the runoff was higher for the first two simulated rainfall events and were highest at the second event for the 49 kg ha^{-1} rate (Fig. 2). The mass of nitrate-N in the runoff water followed the pattern for the runoff volume (data not shown) which is quite different from that for P. The mass of P in the runoff followed the exact same pattern as the concentration (Fig. 1). Thus, the runoff of nitrate-N appears to be associated more with runoff volume than that of P. The percent of added N recovered as nitrate in the runoff was 5.2 and 1.0 % for the 12 and 49 kg ha^{-1} rates, respectively. Therefore, the percent recovery of N was not consistent between the two rates tested. The runoff volume was 29.3% of the total added simulated rainfall averaged over all the experiments. The null hypothesis that nitrate in the runoff water does not reach the level of the drinking water standard of 10 mg L^{-1} can be accepted, since no sample exceeded that level.

Lysimeters on two working putting greens

Phosphorus concentrations in percolate from each of the two putting greens followed the same pattern, but P concentrations for green 2 were higher that for green 1 for the 1997 data (Fig. 3). The peaks in P concentration were related both to rainfall intensities and additions of P to the greens as fertilizers. The peaks in P concentrations came at about 30 to 50 days following P application. The immediate peak came from earlier applications. Due to the nature of the layout of the lysimeters on the greens and to other variables, it was not possible to calculate percent recoveries of the fertilizer P. However, the hypothesis that P concentrations would not reach a level where eutrophication can be a problem can be rejected based on the concentrations of 1 to 3 mg L^{-1} for the year of 1997. Unfertilized percolates are usually <1 mg L^{-1}.

The concentrations of nitrate-N in the percolate from the two putting greens followed basically the same pattern as the P concentrations for 1997 (Fig. 4). However, unlike the P concentration data, the two greens had very similar concentrations of nitrate-N. Here peaks in N concentration came about 20 to 30 days following application, so the nitrate-N seemed to move through the greens at a faster rate than P. The data for cumulative mass of nitrate-N in the percolate show increases in

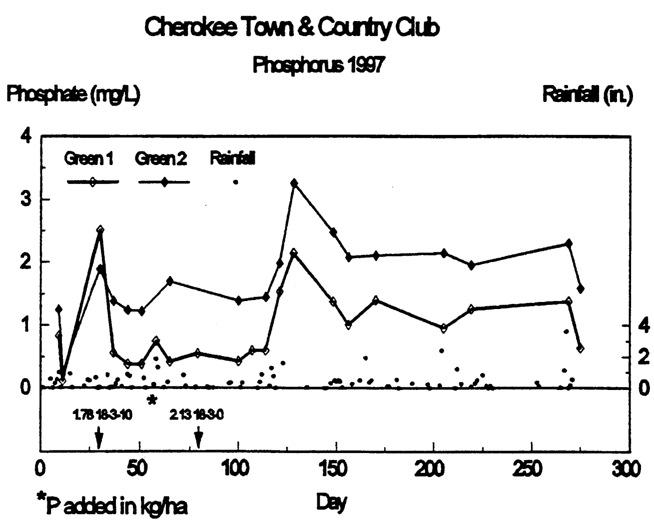

Figure 3. Phosphate concentrations for 1997 for 2 working putting greens.

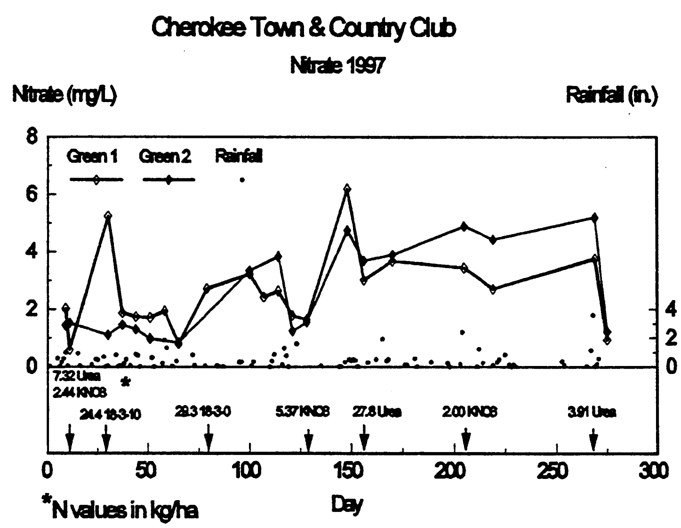

Figure 4. Nitrate-N concentrations for1997 for 2 working putting greens.

response to rainfall events (data not shown). As for the nitrate-N in the runoff water, the nitrate-N in the percolate from the two working putting greens did not exceed the drinking water standard in 1997, thus the null hypothesis can be accepted.

Phosphorus concentrations in the percolate from the two working putting greens were much higher in 1995 than for the other two years monitored (Table 1). The greens were established in the fall of 1994. At that time there were likely high rates of P applied to enhance grow-in. The P levels found the first year were not indicative leachate P for a mature green. Thus, care must be taken during the initial grow-in of a green so as not to add too much P that may end up in the drainage water and pollute streams. Low amounts of P added to mature greens keeps the P in the percolate to environmentally acceptable levels.

A different story was found for the nitrate-N over time. The concentrations of nitrate-N in the percolate from the two putting greens tended to increase with time (Table 1). The concentrations were relatively low for the first two years, but increased for 1997. The mass of nitrate-N leached increased dramatically for 1997 over the previous year (data not shown). Also, the current data for 1998 are showing an even greater increase in percolate nitrate-N. The reasons are not entirely clear at this time. It is possible that the N that stored in the organic layer of the greens was being mineralized to a greater extent during the last two years. This N has not yet reached an equilibrium where the output is a steady proportion of the input. Future data may show a return to a steady state. Whatever the cause, the amounts of nitrate-N in the percolate for individual lysimeters were approaching the drinking water standard in 1997.

Table 1. Leachate P and Nitrate-N Concentration (mg/kg) Averages for Individual Collection Dates for 3 Years for 2 USGA Golf Greens.

	Green 1			Green 2		
	Nitrate N concentration (mg/kg)					
	Mean	Min.	Max.	Mean	Min.	Max.
1995	**2.23**	0.01	13.61	**1.14**	0.01	8.80
1996	**1.73**	0.01	16.09	**1.37**	0.01	13.69
1997	**2.63**	0.01	12.99	**2.60**	0.42	8.67
	Phosphate-P concentration (mg/kg)					
	Mean	Min.	Max.	Mean	Min.	Max.
1995	**3.21**	0.65	6.07	**8.53**	5.55	13.27
1996	**1.14**	0.05	6.79	**1.30**	0.16	6.02
1997	**0.93**	0.05	5.34	**1.72**	0.15	4.11

CONCLUSIONS

Phosphorus transported in runoff water from simulated golf fairways caused P levels high enough to possibly cause eutrophication of surface waters. Most of the P was transported during the first rainfall event. Thus, the research shows that P can be transported in runoff water, particularly if the rainfall event is soon after application and the soil is moist at the time of the rainfall event. The form of the transported P from turfgrass is the soluble form and not a particulate form. Nitrate transport in runoff water was negligible when N was added as an ammonium salt. The P levels in percolate from working putting greens were elevated, especially the first year after establishment of the green. The nitrate-N levels in the percolate were below drinking water standards for the first three years of monitoring, but tended to increase with time.

The next steps to be taken in this ongoing research is to study different sources of fertilizers to determine whether coated or other types of fertilizers may decrease runoff and leaching of P and nitrate-N from golf fairways and greens. Further research will also include management practices such as altering the time between fertilizer application and the first rainfall event and altering the soil moisture at the first rainfall event to determine effects on runoff. Some preliminary experiments showed that low soil moisture at the time of the first rainfall event decreased P transport because the volume of runoff was decreased. For leaching of nitrate-N from greens, the effects of mineralization of sequestered N may be studied to determine if it is the cause of increased nitrate-N leaching with time after establishment of the green.

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