Research *You Can Use*

Phosphorus Leaching from Sand-Based Putting Greens

Auburn University investigates sub-surface applied phosphorus to minimize leaching.

BY BETH GUERTAL

Even though phosphorus (P) is the nutrient needed in the third greatest amount for turfgrass growth and production, the amount of research that has been done on P fertilization of turf is rather limited. This is especially true when the larger amounts of potassium (K) and nitrogen (N) required for turfgrass growth and development are used as a reference point.

Lack of research about P nutrition for turfgrasses may be for several reasons. First, although P is needed in larger quantities than micronutrients (such as iron, manganese, copper, and zinc), the amount typically required is much smaller than amounts of N and K, so it is easy to develop a mindset that P is less important. Second, years of field-crop research have shown that P is less mobile than N, so it has been thought that P is less likely to be lost from the rootzone via leaching. Leaching of N from sand-based putting green mixes has been widely studied in turfgrass systems, but there is less evaluation of P leaching because it has not been thought to be a loss pathway of much environmental consequence. Loss of P via runoff, with subsequent possible pollution of surrounding surface water, has received far more study in turfgrass systems.

A third reason for limited P research in turf is that P fertilizer recommendations are made as a result of years of soil-test calibration and are not based on crop-response calibration curves.

The lysimeter research facility at the Auburn University Turfgrass Unit consists of four sets of 16 lysimeters each. Each lysimeter drains completely into a collection vessel. The collection vessels are housed under the valve boxes shown in the photo foreground, and the lysimeter is built above it.

Soil testing and fertilizer recommendation methods for P have long been evaluated for field and pasture crops. Because it tends to be a regional issue and related to factors such as crop, soil type, and soil extractant, there are only a few studies that have evaluated turf growth and response related to extractable soil P, especially in high-sand greens.

Turfgrass putting greens are unique because they use constructed rootzones, typically high in sand, and thus have very low cation exchange capacities. There is evidence that P will leach in sandy soils. In one recent turfgrass study, P leaching losses from a St. Augustinegrass residential landscape in a sandy Florida soil were measurable, and they were highest during lawn establishment and immediately after heavy rain (3). Phosphorus leaching is especially likely when P accumulates in excess of that capable of being held by the soil. This accumulation at the soil surface can occur as a long-term effect of P application in no-till crop production systems.

Because a putting green cannot be inverted or tilled, in some respects a green can be viewed as in a no-till soil. Thus, many of the research findings from agronomic no-till research might be a starting point for P research in putting greens. For example, research in no-till corn has shown that band placement of P (in a narrow strip alongside the seed) can increase early growth of corn, compared to when that P was broadcast (2). This is because banded P is less prone to rapid fixation by soil clays because less P comes into contact with the soil. When broadcast applied, P may accumulate at the soil surface, resulting in stratification of P within the soil profile.

Phosphorus placement research has not yet been completed in putting greens, so we do not know if P will stratify (or move) in a sand-based putting green. We also do not know if banded P would be more available to a growing turfgrass plant than if the same P was broadcast applied. In turf production, "banded" P would actually be a vertical band, as P would be applied as a part of core aeration, with P fertilizer swept into holes left by the aeration procedure. Thus, for this research project, one objective of the research was to determine if deep placement of P in aeration holes (banded, or sub-surface applied) increased P uptake by turf. A second objective was to determine if P placement (sub-surface or broadcast) or P rate affected P leaching in a high-sand USGA-type putting green.

An example of the first-generation lysimeters that were built prior to the switch to plastic cattle waterers. This top view shows four individual lysimeters, each of which drains into a collection vessel.

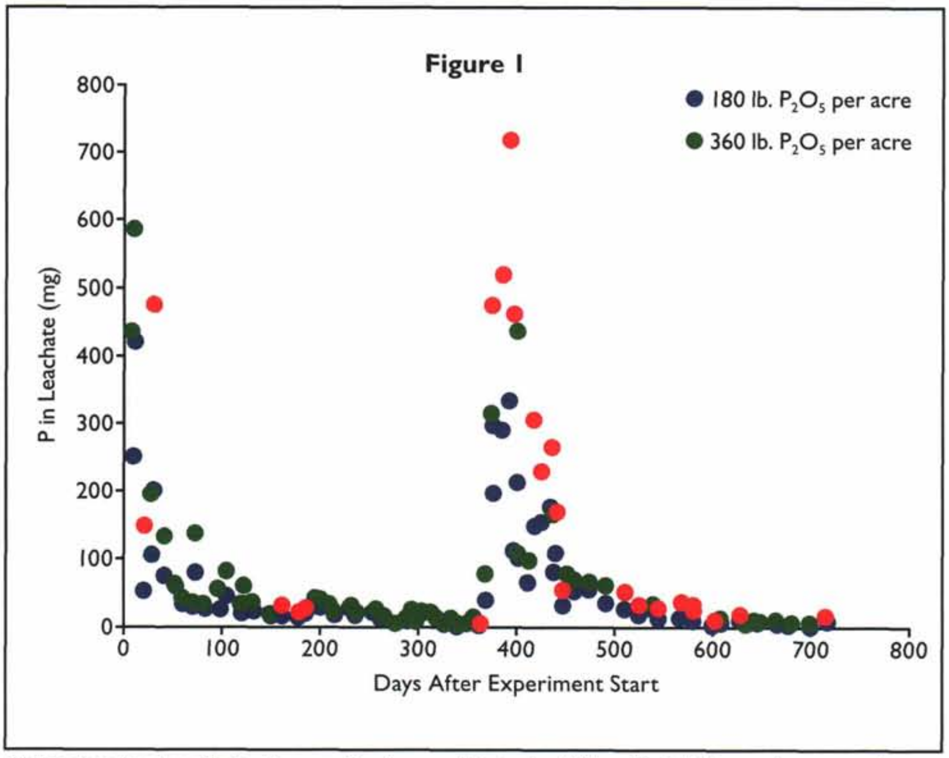
MATERIALS AND METHODS

The two-year study was started in 2002 using 16 small individual putting greens at the Auburn University Turfgrass Research Unit, located in Auburn, Ala. Built in 2001, the putting greens consisted of 70-gallon plastic cattle watering tanks buried in the ground, with the edge of the tank even with the soil surface. Each green drained to a 5-gallon collection chamber, enabling leachate to be collected and measured. The greens were filled with an 80/20 (sand/peat) USGA-type greensmix, and in March 2002 each green was sprigged with Tifdwarf hybrid bermudagrass. One month after sprigging, P fertilizer treatments were initiated when each putting green was at 50% establishment.

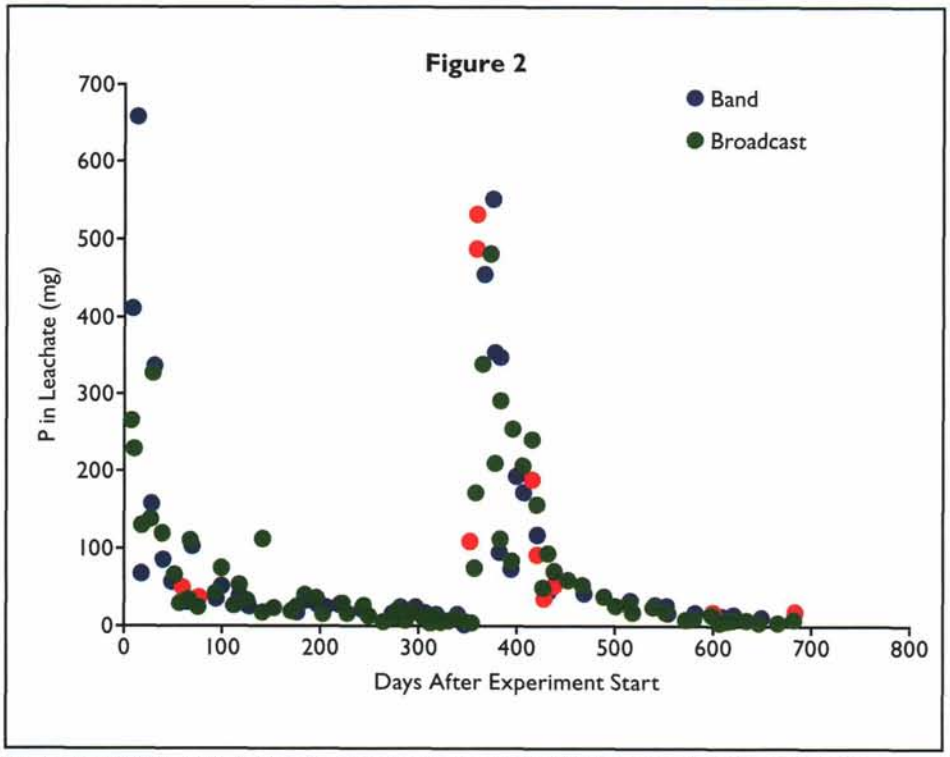
Phosphorous fertilizer treatments consisted of two rates of P fertilization (180 lb. P_2O_5 per acre and 360 lb. P_2O_5 per acre) and two types of P placement (band and broadcast). The P rates were based on the Alabama recommended rate (180 lb. P_2O_5 per acre) of fertilizer P for a bermudagrass putting green with an initial "very low" P soil test (average P soil test was 2 lbs. P_2O_5 per acre). The higher P rate was twice the recommended rate and was selected to represent a worse case scenario — a high rate of P applied to the soil surface.

Sub-surface treatments were applied by core aerating the green (⅜-inch diameter cores, 4 inches deep, 4-inch spacing), removing the cores, and sweeping the P fertilizer (triple superphosphate, 0-45-0) into the aeration holes, followed by sand topdressing. Broadcast P fertilizer treatments were applied by aerating the plots, removing the cores, sweeping topdressing sand into the aeration holes, and spreading P fertilizer across the entire plot surface. Phosphorus treatments were applied on April 18, 2002, and reapplied on April 16, 2003.

The research area received irrigation as needed to provide a total of one inch of rainfall/irrigation per week. Plots were mowed with a walk-behind greens mower to maintain a mowing height of 5/32 inch. In 2002, percent establishment was visually evaluated in each plot until 95% establishment was recorded. Each week, the total volume of leachate from each green was



P in leachate (mg) as affected by sampling time and P rate in a Tifdwarf hybrid bermudagrass putting green. Significant differences in leachate P are indicated when the data point for the 360 lb. P_2O_5 rate is colored red, indicating a significant difference at that sampling date compared to the 180 lb. P_2O_5 per acre fertilization rate.



P in leachate (mg) as affected by sampling time and method of P placement in a Tifdwarf hybrid bermudagrass putting green. Significant differences in leachate P are indicated when the data point for the sub-surface applied treatment is colored red, indicating a significant difference at that sampling date compared to the broadcast P fertilization method.

measured, and a subsample was taken for solution P analysis. At 3, 6, 9 (2003 only), and 12 weeks after P fertilization, soil samples were collected from each plot. Samples were taken at 2-inch increments to a depth of 10 inches, and P was extracted with Mehlich III for phosphorus determination. Each month clipping yield was measured and P content of the clippings was determined.

RESULTS

Figures 1 and 2 illustrate the results from two years of leachate collection. Results are shown as mg of collected P, determined by multiplying the volume of collected leachate (mL) and the concentration of P (micrograms/mL) in the collected subsample. Over the two years the study was conducted, there was rarely a significant P rate × P method interaction (6 times out of 79 leachate collections), indicating that differences in leached P were largely due to P rate or the method of applying the P, but not the combination of the two.

Over the 715 days that the study was conducted, leachate was collected and analyzed 79 times. Out of those collections, the rate of P fertilization significantly affected leachate P 26 times (33%), with the P in leachate always higher from plots that received the higher rate of P (Figure 1). The method of P application (sub-surface or broadcast) significantly affected leachate P 11 times (14%) (Figure 2). Most of these significant results occurred in the second year of the study, and they are partly reflected as a delay in P leaching from broadcast treatments, as compared to sub-surface. For example, in 2003, at 7, 13, and 14 days after the P fertilization (DAF) was applied, leachate P from plots in which the P fertilizer was swept into the aeration holes was greater than from plots in which the fertilizer had been broadcast. By 71, 75, 84, and 89 DAF, leachate P was greater from plots in which P was broadcast applied.

In this study, two years of leachate data indicates that, when applied at an agronomically recommended rate, P leaching was greatest in the first month after fertilizer application. The single application of P fertilizer (at a high rate of P) to a sandy putting green soil created a risk of P leaching. Others have shown similar results, with P leaching losses greatest in immature landscapes and when rainfall amounts were greatest (1).

When P fertilizer was applied at a recommended and 2× rate, the rate of bermudagrass establishment (Year 1) never increased by the addition of the extra phosphorus (2× rate). However, establishment was faster when the P was broadcast applied, rather than banded. For example, on June 20, plots receiving broadcast P were 88% established, while those receiving sub-surface applied P were 79% established, a significant difference. All plots had reached 95% establishment by July 12, after which clipping yield and P uptake data were collected.

There was never an agronomic benefit to applying P above the recommended rate of 180 lb. P_2O_5 per acre. Soil-test calibration is a continually evolving issue, as new extractants, methods of calibration, and soil-test devices are developed. Although outside of the objectives of this research, other work at Auburn is beginning to show that current Auburn soil-test recommendations for bermudagrass putting greens may need adjustment, as bermudagrass response may be maximized at a soil-test critical level below the current 180 lb. P_2O_5 per acre recommendation. Reevaluations of soil-test procedures are a constant research need and are always underway with different crops and nutrients.

In 2002, July, August, and September clipping yields were never affected by P rate. When P was broadcast applied, the July and August clipping yields were greater than when P was sub-surface applied. In 2003, clippings were collected in May (twice), June, and July. As in 2002, P rate did not affect clipping yield. The sub-surface application of P only increased clipping yield in the first May clipping harvest, with no significant difference in clipping yield due to method of P fertilization thereafter.

Upon closer inspection, the collection vessel is simply a 5-gallon gas can built into a wood-framed box. The plastic tube that drains into each gas can is attached to the drainage hole of each 70-gallon cattle waterer, which is buried to ground level. Each collection vessel is emptied once per week, unless sufficient rainfall occurs to require additional collection.

Over the two years of clipping harvests, P rate did not affect P uptake by the bermudagrass, but method of P fertilization did. In 7 of the 8 clipping harvests, P uptake was greater in bermudagrass from plots receiving broadcast P than in sub-surface applied plots. Tissue P content ranged from 1.1% to 6.6%. End of experiment (2004) shoot density was not affected by either P rate or method of P placement.

In summary, leaching of P may occur in sand-based putting greens. There were no agronomic or environmental benefits to band application of P fertilizer. Uptake of P and clipping yield were better when P was broadcast applied than when the P was band applied. Applying a 2× rate of P fertilizer never improved grass establishment, clipping yield, shoot yield, or P retention in the rootzone. Application of P at a 2× recommended rate makes no agronomic or environmental sense. When applying P fertilizer to a sand-based putting green, use smaller amounts applied at a more frequent interval, using your soil-test recommendations as a point of reference.

LITERATURE CITED

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EDITOR'S NOTE: An expanded version of this paper can be found online at *USGA Turfgrass and Environmental Research Online* (http://usgatero.msu.edu/v06/n16.pdf).

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CONNECTING THE DOTS

A Q&A with Dr. Beth Guertal, *Auburn University, about phosphorus management for golf courses.*

Q: *Ecologically, phosphorus is sometimes referred to as the "linchpin" nutrient regarding eutrophication of surface water. Please explain.*

A: Long-term application of phosphorus (P) to the soil surface can lead to accumulation of P at the surface. This P is prone to movement with surface runoff, either as P attached to soil particles or P dissolved in the runoff water. Once P leaves with runoff water, it ends up wherever the water does — in streams, rivers, or lakes. When bodies of water receive excess P, it helps create an environment that is favorable to algae growth (eutrophication), or "algae blooms." This flush in algae growth reduces water oxygen content and can lead to fish kills. Phosphorus is not the only factor in eutrophication, but it is involved, and there has been a great deal of research that focuses on non-point P pollution effects on water quality.

Q: *As environmental stewards, superintendents have to be cautious to minimize nutrient runoff and leaching from golf courses. Has phosphorus gotten the attention it deserves from the scientific community regarding its potential effect on surface water and groundwater quality?*

A: Next only to nitrogen, P has garnered its share of attention from the scientific community. A lot of focus has been placed on P runoff in cropping systems where there has been long-term application of animal wastes (especially poultry litter). Basically, animal waste contains P (usually more P than N), and that waste has to go somewhere. Usually, that "somewhere" is a pasture or production field, and long-term surface application of manure results. This often results in accumulated P, and that P may move in runoff to water.

The other area where we've seen a lot of research is in no-till crop production. Placement of P is an issue there, because in a no- or minimum-till system there is little disturbance of the soil, and P may be largely surface applied. If the field is continually no-tilled, the fertilizer P may accumulate and move to water with runoff. This research has some application to turfgrass, as the systems are similar in that there is no inversion tillage, and fertilizers are typically surface applied without incorporation.

Q: *Was applying sub-surface phosphorus (e.g., sweeping the applied phosphorus fertilizer into aeration holes) a way to minimize phosphorus runoff losses? Do you have data that support this rationale?*

A: The idea behind "band" application of P wasn't to reduce runoff losses, but rather to increase the availability of P for plant uptake. The idea was taken from row-crop production, where P is often applied in a horizontal band two inches from the planting row and two inches deep. This zone of concentrated P reduces soil:fertilizer contact, slowing the conversion of P into less-soluble forms (such as calcium phosphates or iron phosphates). These less-soluble forms of P are not immediately available for plant uptake and must be solubilized over time into plant-available P. A band of P slows that conversion, and roots from new seedlings can reach the P in the band, increasing uptake. Our idea was to take that banding concept and turn it vertically, placing the P in a concentrated zone at the bottom of a core aeration hole.

Q: *Why do you think P uptake and clipping yield were better when P was broadcast applied compared to sub-surface?*

A: In these newly establishing research plots, the surface-applied P was available for the new bermudagrass growth, which was largely on the surface through stolons and shallow rhizomes.

Q: *Do you think the results of your study on sand-based putting greens are applicable to potential P losses from other turfgrass sites such as sports fields and home lawns?*

A: The results represent an absolute worse-case scenario: sandy soils, turf initially in the establishment phase, and, in one treatment, an excessive rate of P application. It is important to remember that well-maintained and uniform turf is one of nature's best filters, and when P is correctly applied, runoff and leaching are often minimal. This is especially true in heavier soils that have higher silt and clay contents than used in our sand-based study — where P is far less prone to movement via leaching, for example.

The key is to avoid excessive application that results in a buildup of P at the surface. When I look at the soil tests that come through Auburn's laboratory, you can see the home lawns that have had long-term overapplication of materials such as 10-10-10 or 13-13-13. These tests often have P in the "very high" or "extremely high" category, and no additional P fertilizer is needed, probably for quite a while.

Q: *Phosphorus fertilizer is agronomically important for rapid turfgrass establishment. Is this when phosphorus is especially prone to leaching losses? What's the best advice for superintendents to minimize such P losses during establishment?*

A: There is actually very little published research that examines P leaching in turfgrass systems. A few runoff studies have shown a greater risk for P movement during the establishment phase (research on cool-season grasses), basically because there is more bare soil, which is prone to erosion. When the soil erodes, the P goes with it.

My best advice would be to: 1) apply P according to soil-test recommendations, and 2) do not overapply P in order to "build up" your soil P. Additionally, take soil tests frequently during grow-in. In some other P research we conducted on a loamy soil, additional P fertilizer was needed at approximately 3-month intervals, when the P was applied at the recommended rate.

Q: *Did you find your research results surprising, and do those results point to other needed research regarding P losses from sand-based rootzones?*

A: I thought that we would see positive results from the application of banded P, especially as the greens matured. We did not see that, and broadcast P was our best treatment. In some of our other research, on five-year-old TifEagle greens, we showed an increase in P uptake when the P was band applied compared to surface broadcast.

Also, P leaching, even from plots that had a 2× application rate, was less than anticipated, and dropped off quickly after each year's application. The next research would be to see how that changes when there is long-term application of P, and how the leaching of P might change in older, established greens.

Jeff Nus, Ph.D., *manager, Green Section Research.*