Nutrient and Pesticide Losses from Bermudagrass Fairway Turf

Study shows amounts of runoff after major storm events.

BY GREGORY E. BELL AND KYUNGJOON KOH

The Oklahoma State University runoff research site. Researchers at Oklahoma State University conducted a five-year study to measure the loss of nitrogen (N) and phosphorus (P) caused by natural rainfall from a common bermudagrass fairway managed with typical fertilization and irrigation practices. Among their findings, in a worst-case scenario during a season of near record rainfall, they estimated that a fairway they studied would lose around 1.3% of the N and 7.7% of the P applied as fertilizer.

Dense grass stands have unique characteristics that encourage water to infiltrate soil as well as impede and filter runoff (11, 14). However, research has demonstrated that the runoff-reduction characteristics that naturally occur in a dense turfgrass stand are not sufficient to prevent substantial runoff caused by major storm events (3).

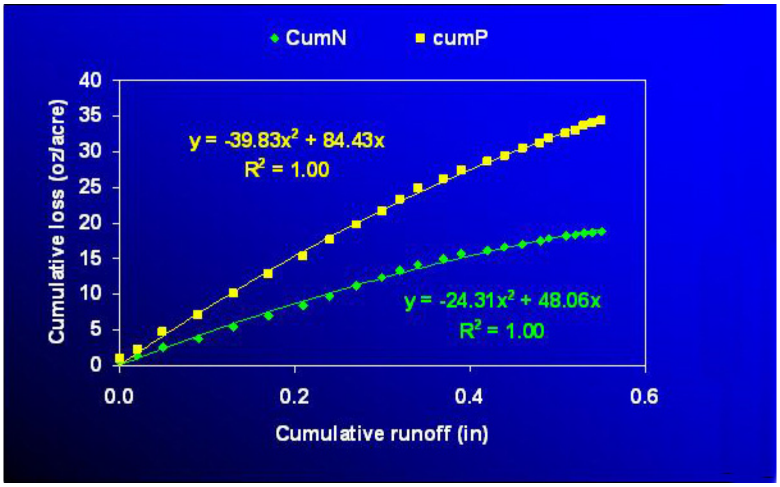
Applications of fertilizers and pesticides, followed by major storm events, can result in unsatisfactory nutrient and pesticide transport to surface waters. Although nationwide surveys of golf course water quality indicate that widespread water quality impacts by golf courses did not occur at the sites studied (7, 8), there is a danger that some nutrient or pesticide applications may combine with surface water runoff and flow into adjacent water features.

NUTRIENT AND PESTICIDE RUNOFF

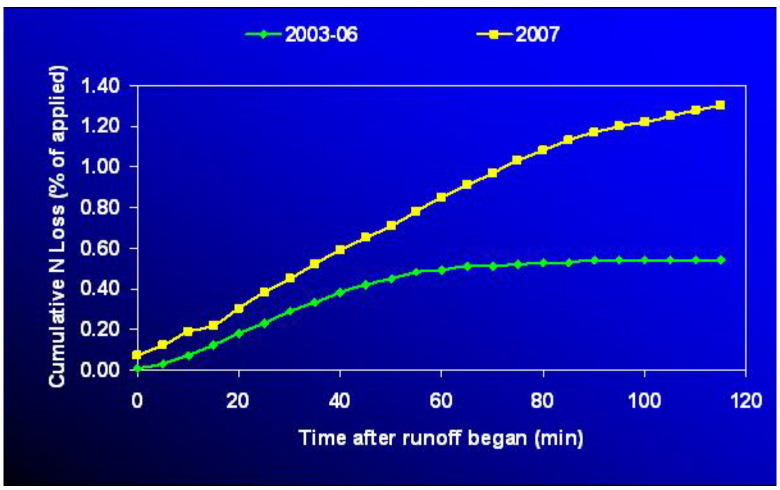
An important environmental hazard caused by nutrient runoff is eutrophication (10). Low levels of nitrogen (primarily as NO_3^-) and dissolved reactive phosphorus (primarily as $H_2PO_4^-$, HPO_4^{2-}, and PO_4^{3-}) can cause algal blooms, resulting in a loss of oxygen in surface water. Because about 99% of the phosphorus (P) in soils is unavailable for plant growth (4), fertilizers are an important source of plant-available P.

Most inorganic P fertilizers are highly soluble, and, if not properly applied, increase the risk of P loss to surface runoff (12). Phosphorus can contribute to eutrophication at concentrations as low as 25 µg L^{-1} (5). Sufficient phosphorus concentration is typically the limiting factor for eutrophication of surface water (16). As a result, at least one state, Minnesota, has passed legislation that restricts the application of phosphorus fertilizer to turfgrass (15).

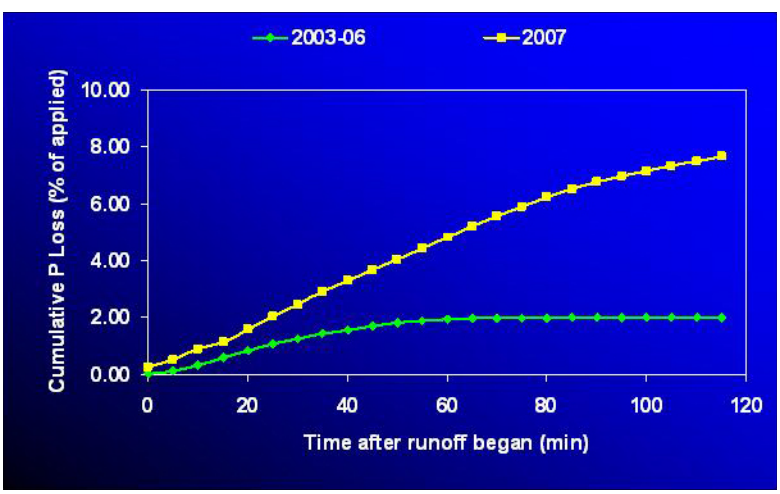
Pesticide loss from turf depends on factors such as pesticide chemical properties, soil type, turf species,



The relationship between cumulative runoff volume and cumulative nutrient losses for nitrogen and phosphorus applied to bermudagrass fairway turf at Oklahoma State University.



The amount of nitrogen (N) lost in natural rainfall runoff from the study site in 2003-06 and in 2007. Runoff losses are measured as a percentage of N applied.



The amount of phosphorus (P) lost in natural rainfall runoff from the study site in 2003-06 and in 2007. Runoff losses are measured as a percentage of P applied.

thatch, application timing, and weather conditions (11, 15). Research has shown that the greatest mass and concentration of pesticides in runoff from a turf area occurs during the first significant runoff event after pesticide application (9, 13, 19) and that the amount of pesticide loss is primarily related to its solubility (18).

RESEARCH AT OKLAHOMA STATE UNIVERSITY

The Oklahoma State University Turfgrass Runoff Research Site, Stillwater, Okla., has a silt loam soil with an infiltration rate of less than 0.5 inch per hour. One particular study measured the loss of N and P in natural rainfall runoff from bermudagrass maintained under fairway conditions. Runoff samples were collected and tested for NO_3^-, NH_4^+, and dissolved reactive phosphorus (DRP) during natural rainfall events that produced runoff in 2003 through 2007.

Thirty rainfall events produced runoff over the five-year period. Sixteen rainfall events produced runoff during the growing seasons from 2003 through 2006, and 14 events have produced runoff since 2007. That year (2007) nearly constituted the highest annual rainfall recorded in Stillwater, Okla. On average, runoff events in 2003 through 2006 resulted in losses of 0.5% of the N and 2.0% of the P applied as fertilizer. The 2007 research indicated that in a season of near record rainfall, bermudagrass fairways would lose about 1.3% of the N and 7.7% of the P applied as fertilizer (4).

Other experiments compared nutrient and pesticide runoff losses from bermudagrass fairways by using a simulated rainfall system versus sprinkler irrigation. Simulated rainfall and irrigation caused runoff 24 hours after application of fertilizer and pesticides and 48 hours after irrigating the site to saturation. During those studies, runoff continued for 90 minutes after it began. Nitrogen (urea), phosphorus (triple super phosphate), 2,4-D plus mecoprop and dicamba (Trimec Classic), chlorpyrifos (Dursban), and flutolanil (Prostar) were applied prior to each event.

Protecting the quality of golf course water features is an important role for superintendents. Research continues to indicate that phosphorus is the nutrient of most concern. Superintendents need to be judicious in their use of phosphorus fertilizers, and care should be taken to minimize runoff to surface waters.

Analyses of runoff (after correcting for N and P contained in the irrigation water) indicated that the simulated rainfall system and sprinkler irrigation did not differ in their influence on the amount of nutrients and pesticides lost in runoff from bermudagrass turf (3). Approximately 2.5% of the N applied, as much as 20.3% of the P applied, and up to 15.9% of the pesticides applied were lost in runoff. Nitrogen and phosphorus losses in the natural rainfall runoff were not as severe as the simulated rainfall or sprinkler irrigation. However, the simulation study does demonstrate the potential for nutrient and pesticide losses for product applications made 24 hours after soil saturation and when a severe storm causes runoff 24 hours after the application.

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CONNECTING THE DOTS

JEFF NUS, Ph.D. *(manager, Green Section Research) speaks with* DR. GREG BELL *regarding nutrient and pesticide runoff.*

Q. *To what extent did the simulated rainfall rate that you used in your studies compare with rainfall rates during storms in Oklahoma?*

A. We have an Oklahoma Mesonet weather station less than 500 yards from our runoff site and turfgrass research center. The Mesonet is heralded as possibly the best state data collection system in the country. Obviously, with our propensity for tornadoes, we host a lot of storm-related research and we need to have excellent data collection systems. As part of our studies, we have collected the data generated by that station from its inception through 2008 (13 years). During that period, the station recorded an average of 33 inches of rainfall per year. Only about 13% of that rainfall occurred in the winter, when our warm-season grasses were dormant and our cool-season grasses were growing very slowly. Spring rainfall accounts for about 33%, summer for 27%, and fall for 28%. During the last study, both our irrigation system and rainfall simulator were set to apply 1.5 inches of rainfall per hour to a surface with an infiltration rate of 0.5 inch per hour. Obviously we generated a lot of runoff — a lot more runoff than normal. In fact, such an event, even with the severe weather that Oklahoma suffers during tornado season, is extremely rare.

We collected natural rainfall runoff from most of the storms that occurred from 2003 through 2007. During that period we had four slightly lower-than-normal rainfall years (2003-2006) and one record rainfall year (2007). During those five years, the largest rainfall event that we experienced in any 24-hour period was 5.3 inches, and we had severe flooding because of it. However, the most rain that fell during that event in any single hour was 1.4 inches, and in any 90-minute period was 1.9 inches. Although this event was the most severe that we experienced in five years (including a record rainfall year), it did not result in as high a precipitation rate as we used in our simulations, even during its most severe periods. For that reason, I think that the rainfall rates we use here and in other studies across the country overestimate chemical losses to runoff that actually occur in nature. We are always simulating worst-case scenarios.

Simulated rainfall, regardless of how it is applied, cannot mimic natural rainfall. Natural rainfall changes in droplet size, angle of descent, intensity and other factors constantly. Rainfall simulations are too consistent to truly compare with natural rainfall. Even if we built a complicated machine that constantly varied all of the factors that occur in natural rainfall, it would still have to follow a pattern and differ from natural rainfall.

We have always collected runoff at our site, both natural and simulated, with 12 automatic samplers. We probably will not be doing any more simulations unless we need consistent rainfall to properly assess some particular parameter. From now on I expect to collect runoff from natural rainfall almost exclusively.

Q. *From the results of your study, what are your recommendations to superintendents about their use of fertilizers and pesticides on golf courses?*

A. Our work and the work of others have consistently indicated that little of the fertilizers or pesticides applied to turf are lost in runoff. Although we usually force a huge amount of runoff from exceedingly high-simulated precipitation and usually force these events to occur shortly (within 24 hours or less) after pesticide or fertilizer application, only small amounts of the chemicals applied are lost in runoff. However, these small amounts are sometimes enough to be dangerous to us or to our environment. Nitrogen concentrations that exceed one part per million and phosphorus concentrations that exceed 50 parts per billion can cause algal blooms, resulting in eutrophication, a situation that causes surface water to lose oxygen and no longer support fish or plants. Some pesticides are more dangerous than others, but, in general, it can take only a very small amount of pesticide in surface water to kill fish or cause other problems. These overdose situations, however, are easy to prevent by using common sense and by following a few basic application practices.

There is little evidence to support dangerous levels of pesticides or nitrogen in surface water caused by runoff following applications to turfgrass. However, it is becoming clear that phosphorus is a major problem, and at least some of it is coming from urban areas, including golf courses. Advisors no longer encourage applications of phosphorus to turfgrass. In fact, they discourage phosphorus applications unless the turf or soil is clearly deficient.

It may sound silly, especially to a group of highly regarded pesticide applicators like golf course superintendents, but do not apply products to frozen or saturated soil. I only mention that because I have had more than one professional call and ask if their pre-emergent herbicide would still be effective if they applied it to frozen soil. I even had one ask about applications to snow.

Grass buffer strips are recommended to reduce the amount of runoff that occurs from agricultural fields to surface water. Golf course rough works the same way, and the more mowing heights that you have perpendicular to a slope, the better. Every time runoff encounters a higher height of cut, it slows. Fairway runoff slows when it encounters rough, but slows even more if it encounters two higher heights of cut, a first cut of rough and then a primary rough.

Recommended fertilizers and pesticides should be watered in immediately after application to improve efficacy and help prevent runoff losses. Applicators should always be aware of the weather as well — not just the current weather, but the forecast. A light rain can be helpful to move fertilizers or soil-applied pesticides into the soil profile, but light rain can turn into heavy rain and force runoff. The longer a pesticide or fertilizer is in contact with plants and soil before a runoff event, the less likely it is to be lost in runoff. Obviously, the more fertilizer that is applied, the more fertilizer that is likely to be lost in runoff. As far as granular versus spray applications, it does not seem to make much, if any, difference how products are applied. It is the amount and duration of runoff that determines how much product is lost. An application of slow-release, rather than quick-release, fertilizer may limit the amount of fertilizer lost to the first runoff event after application, but it could also increase the losses from subsequent events. We really do not know. However, we do know that we are not just trying to save our environment with this advice, we are also trying to save money and time. The more pesticide or nutrient lost to runoff, the more replacement applications that will be required.

Q. *To what extent do best management practices (BMPs) limit nutrient runoff from irrigated turf if superintendents are using effluent water to irrigate their golf courses?*

A. I know little about irrigating with effluent water, but I can offer some very basic suggestions. Effluent water is often high in nutrients, especially phosphorus, and phosphorus is our most common problem in surface water. Testing water for nitrogen and phosphorus usually costs about the same as a soil test and can usually be done through a county extension office. However, unlike soil tests, water tests are most accurate if the water is fresh, so a superintendent may want to take samples directly to a laboratory or freeze them if they are going to be exposed to room temperature for more than 24 hours. Soluble phosphorus in water, usually called dissolved reactive phosphorus, is just like fertilizer. It is immediately plant available and can be considered part of a fertilizer program. Effluent water is often high in salts and requires a leaching fraction. A leaching fraction is simply an amount of water, in addition to the water required to irrigate the turf, applied for the expressed reason of leaching salts. In other words, if you apply enough salt water to irrigate your turf, evapotranspiration removes the water from the soil but leaves most of the salt. Consequently, you have to apply more salt water than is needed for your plants so that some of the salt-water application will be available to leach some of the soil-resident salts away. A leaching fraction (calculated by equation) sometimes requires a substantial amount of excess irrigation. Therefore, superintendents who apply excess irrigation have to be careful not to force runoff. Sometimes the amount of irrigation required has to be divided into more than one period to allow infiltration between events.

Q. *Besides Minnesota, do you know of other states (or municipalities) or discussions within the U.S. Environmental Protection Agency that have restrictions on the use of phosphorus to fertilize turf?*

A. There is a lot of talk about phosphorus. There are other states besides Minnesota, Maryland for one, that have serious restrictions or are contemplating serious restrictions to phosphorus fertilization on turf. Since turfgrass is not a food crop, we will probably always be the first to suffer restrictions in resources, including fertilizer. Some fertilizer companies have been touting no-phosphorus fertilizer for years, but nearly all of them are now restricting the amount of phosphorus they put in their formulations.

I do not see phosphorus restrictions as a problem for most of us. However, like the superintendent who has a rare turfgrass disease, some courses could be devastated by phosphorus restrictions, whereas the great majority of the profession is not affected by them at all. I would be in favor of phosphorus restrictions if those who are managing sites that are deficient were allowed to apply the minimum requirement based on a soil test or a qualified expert opinion. That would require a law based on logic and science, however, and those who encourage environmental restrictions sometimes do not take logic and science into consideration.

Q. *Your discussion of research concerning turf's capacity to limit runoff seems convincing. However, proposed restrictions on the use of turf on sloped sites contained in the U.S. EPA's Water Sense Program seem counterintuitive. Please comment.*

A. I have to admit that the Water Sense recommendations may in fact make water sense in a desert community. However, some of our most populated areas, Phoenix, Las Vegas, and southern California, for instance, are in near-desert areas. Does the EPA intend to tell all of those people that they cannot have lawns for their children to play on and that they cannot play golf? Is that realistic? As for the rest of the country, what is the alternative to turfgrass and why does the EPA think that turfgrass should not be irrigated? Where a turfgrass is adapted, it is one of the most drought-resistant species in the area. If there is a better alternative to reduce erosion, prevent dust storms, cool the air around a house, provide a child's playing surface, and do all those things well at one time, show me.

Q. *Your work, and recently published work by Dr. Stuart Cohen, suggest that phosphorus is the nutrient of most concern in respect to runoff. In your experience, are superintendents getting that message and restricting their use of phosphorus because of these and other studies?*

A. Yes, I believe that superintendents are getting the message. Stuart and I are not the only scientists spreading the word about phosphorus runoff. In addition, the USGA Green Section and the GCSAA have not been silent on this issue. The USGA, in fact, has not only funded my work and Stuart's work, but has funded professors and USDA scientists in Connecticut, Maryland, Minnesota, Ohio, Mississippi, Wisconsin, Kansas, Texas, Georgia, Florida and others. The superintendents who read the *Green Section Record*, *Golf Course Management*, *Turf and Environmental Research Online*, and other professional publications know what eutrophication is and know what causes it. They also know how to apply pesticides and fertilize. Superintendents are well educated, if they want to be.

Q. *How do warm-season turfgrasses, like bermudagrass and zoysiagrass, compare with cool-season turfgrasses, like perennial ryegrass, Kentucky bluegrass, creeping bentgrass, and fescues, in their capacity to reduce runoff?*

A. Research suggests that even turfgrasses growing at less than full cover significantly reduce runoff. It is widely believed, and research in Pennsylvania has suggested, that the more dense the turf, the more it will reduce runoff. The more tortuous the route that runoff has to follow, the more slowly it proceeds. The slower the runoff moves down a slope, the more time it takes; consequently, the more likely it is to infiltrate the soil. Having said that, I also have to mention that there is an exception to that statement. We all know that mowing turfgrass lower, without violating its adaptability to mowing height, causes it to grow more dense. Consequently, the stepped buffer effect that I mentioned earlier, achieved by mowing grass at increasing mowing heights perpendicular to a slope, does not agree with the statement that I just made.

If water is running down a slope on a fairway mowed at one-half inch, and suddenly it encounters rough of the same species mowed at two inches, the water will slow and actually begin to puddle. The more dense the fairway, the more slowly the runoff will move across it, and the more dense the rough, the more slowly the water will move into it and through it. However, the rough is not as dense as the fairway, and yet the water does not enter it easily. My theory for this effect, and it is only a theory, is that the water running through the fairway turf is not restricted as it enters the rough. However, there is also water running across the leaves of the fairway turf, and that water on top of the turf is restricted when it encounters the rough. It is easy to see that some water flows on top of the grass during runoff because all of the leaf blades, especially on a cool-season grass, are facing down slope after a heavy rainfall. Since water binds to water tighter than water binds to almost anything else, the restricted upper water causes the runoff to slow. As for warm- or cool-season grasses being more effective for reducing runoff, I don't have a clue.

Q. *What is the most important finding from your work, and what message does this carry to superintendents?*

A. Use your pesticide and fertilizer, especially phosphorus, wisely. Otherwise, you may lose it to runoff or to legislation.