AN INDEPENDENT NEWSLETTER FOR TURF MANAGERS

Turf Grass TRENDS

[Vol 4] Volume 5, Issue 2

February 1995

Problem or myth?

Nitrate leaching from turf

by Dr. Richard Hull

For a little more than a decade, there has been a nagging concern in the minds of many turfgrass scientists over the environmental soundness of turf management as it is practiced now. This uncertainty has found expression in technical reports, grant proposals and even in articles written for the practical turf manager.

The popular press, both print and electronic, has picked up on these expressions of concern and exploded them into full-blown environmental crises. Consequently many people, both in and out of the green industry, are convinced that turf culture is an environmentally risky enterprise which probably is not sustainable in ecologically sensitive areas.

This figure depicts the sequence of nitrogen enrichment in N-15 as N-14 is lost during metabolic transformations of nitrogen

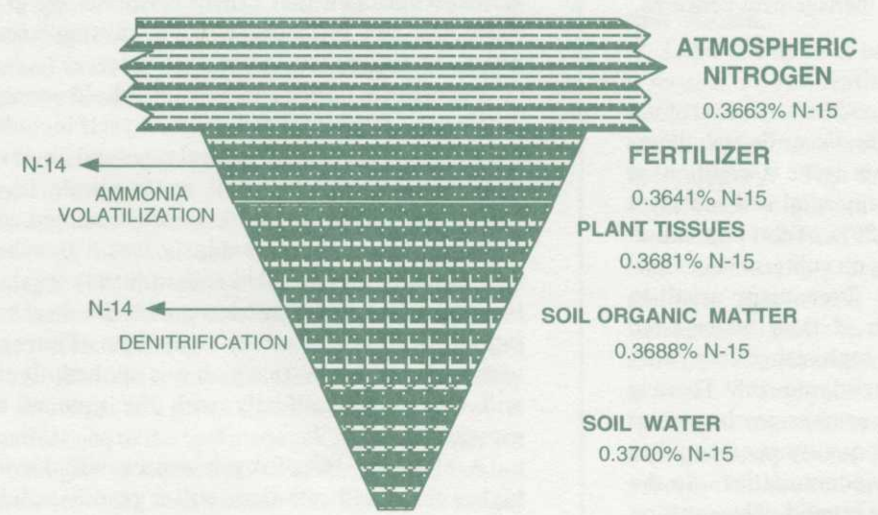


Figure by Dr. Richard Hull

When atmospheric nitrogen is chemically fixed as fertilizer, there is a discrimination against the heavy 15N which results in fertilizer depleted in 15N. After fertilizer is applied to the soil, it is absorbed by plant roots and microorganisms and undergoes several metabolic transformations. At every step, where gaseous nitrogen is lost as NH3, N2O or N2 there is a preference for 14N which leaves the remaining soil and plant nitrogen enriched in 15N. Thus soil water NO3-N normally contains more 15N than did fertilizer-N but not as much 15N as would be found in animal tissues or their waste products. While the differences in 15N% are very small, they can be detected in sensitive mass spectrometers and used to estimate the source of N in an environmental sample.

The principal environmental concerns over turf culture fall into two general categories. First, and of greatest concern, is the introduction of toxic chemicals into the domestic landscape through the use of synthetic fertilizers and pesticides. These are viewed as a threat to the health of people through direct contact at time of application and indirectly as contaminants of ground and surface waters which are often used as domestic water supplies. The second is a concern over the wisdom of using scarce resources, e.g. water, energy and plant nutrients, for the growing of turf when they could be used for more critical purposes. When such resources become truly limiting, it is argued, turf and landscape maintenance must be assigned a lower priority than agricultural, industrial or critical domestic uses. Thus turf and landscape maintenance with its heavy reliance on water, chemicals and energy is not sustainable in a resource limited society.

Are these concerns legitimate? Is it inevitable that turfgrass management must change dramatically in the years ahead? Does turfgrass science have anything to say about these questions?

As with most environmental questions, it is difficult to respond with a definitive yes or no. It might be better to analyze the nature of the concern and determine what issues are supported by science and what are not. The questions outlined above are too large and complex to be treated in a single issue of *Turf Grass Trends*, so I will concentrate on a single concern in the belief that it is fairly typical of the turfgrass environmental controversy. Nitrate leaching from turf and its role in water pollution is representative of turf management concerns.

The alarm is sounded

Is there any basis for concern over nitrate washing out of turf and contaminating domestic wells and underground water resources or is this issue a creation of environmental extremists? In many rural and suburban areas of our country more than 50% of the population depends on private wells drawing on subterranean aquifers as its sole water supply. Even many small-to medium-sized cities draw much of their water from underground supplies which are replenished in part by rainfall percolating through the overlying soil. There is no question that ground water resources are important and that the maintenance of their quality is essential to the stability and growth of many communities. So the concern over ground water quality is valid. The question is: how much of a threat to water quality is the growing of turf on soils overlying ground water reserves?

The first serious questions over the environmental soundness of turf management were raised by suburban communities on Long Island, New York. During the 1950s and early 60s, an alarming increase in the nitrate content of water from many domestic and small municipal wells was observed. The U.S. Public Health Service had determined that nitrate-nitrogen levels greater than 10 parts per million (ppm or mg/L) posed a health risk especially to newborn babies. Nitrate can bind to the hemoglobin of the blood reducing its capacity to carry oxygen. This can cause a kind of asphyxiation called methemoglobinemia. Small children and babies are most susceptible to this poisoning where it is known as the "blue baby" syndrome. Thus when wells began to approach or even exceed the 10 ppm nitrate-nitrogen limit, people became justifiably concerned. The open question was not over the presence of nitrate in well water but over its source.

Because children's health was at stake, rational discussion did not always prevail. It soon became

Arguments against threshold nitrogen applications

by Dr. Richard Hull

In many discussions of nitrate leaching from turf, the concept of threshold application rate is introduced. As I understand it, a threshold rate of nitrogen fertilizer is the largest amount which when applied will not cause an increase in soil water nitrate and, therefore, will not promote nitrate leaching. It is stated that so long as the threshold rate is not exceeded, nitrate leaching will not occur and ground water quality is not endangered. Apparently it represents the amount of fertilizer nitrogen that can be absorbed by grass roots and soil microbes without causing excess nitrate to accumulate in the soil water.

Personally, I do not like the threshold concept. To be sure, several investigators, myself included, have applied nitrogen at several rates and observed that at a specific rate, soil water nitrate levels increased. Below that rate, nitrate remained constant and low. There obviously was a threshold rate which when exceeded caused nitrate levels to increase. The problem I have with the threshold rate is that it is different for every form of nitrogen used and every grass to which it is applied. It also will change dramatically with the time of the growing season.

A slow release nitrogen source will have a higher threshold rate than will a readily soluble material and its threshold rate will be greater than recognized that there were three likely sources for the increased nitrate: agricultural fertilizers, leach field releases from domestic septic systems and fertilizers used on home lawns, golf courses, etc. Because these communities had been largely agricultural for many years, it was initially concluded that leaching from potato and vegetable farms was not a likely source of the nitrate in wells. On the other hand, residential and commercial development had increased dramatically in eastern and central Long Island so that seemed a more likely source of the problem. In response, many communities installed municipal sewage systems to eliminate their reliance on individual septic tanks. However, this often did not result in a significant lowering of the nitrate content in well water. Attention was then turned to lawn fertilizers as the only remaining source of nitrate contamination. The Long Island problem was of course experienced by other communities but more importantly the alarm had been sounded.

Many suburban residents became convinced that they would eventually have similar nitrate problems and that lawn maintenance was the cause. This has resulted in local ordinances restricting lawn size or the amount of fertilizer that can be used to maintain turf. Golf courses and sod farms are specifically excluded from the list of acceptable land uses in many ground water sensitive areas of the Northeast and elsewhere.

Evidence revisited

The evidence which implicated turf fertilizer use as the cause of well contamination by nitrate can now be viewed with a bit more objectivity than was possible during the 1960s. Much research has been reported and the science of environmental monitoring and cause-and-effect assessment has become much more sophisticated. One problem with many of the early reports on nitrate contamination of domestic wells was a lack of valid controls. Before one can suggest the source of contamination, one must know what the background level of the contaminant is and from that calculate the amount of increase attributable to a specific land use. Such background readings should be of water upstream from the site under study. To determine upstream for subterranean aquifers, detailed ground water maps are needed; a tool not always available when well contamination was first studied.

Land use in most urban/rural interface areas is such a mosaic of residential, commercial, agricultural and unused or forested lands that it is all but impossible to ascribe contaminants found in a well to any specific land use category. That is surely true of nitrate which is contributed to ground water in some quantity by every land use. This was demonstrated in studies of nitrate contamination in ground water using the relative abundance of the natural heavy isotope of nitrogen: ^{15}N. Nitrogen-15 exists in nature as 0.366% of atmospheric nitrogen; the remaining 99.634% being the lighter ^{14}N isotope. When synthetic fertilizers are made from atmospheric nitrogen, they contain 0.366% or less ^{15}N. As nitrogen compounds react with biological and chemical processes in the soil or within organisms, the lighter ^{14}N is often preferentially lost in various gaseous forms (N_2, N_2O, NH_3) and the remaining nitrogen becomes enriched in the heavier ^{15}N. (See figure on page 1.) Thus nitrogen from animals present in manure normally contains between 0.370 and 0.375% ^{15}N. These small differences in the ^{15}N content of different nitrogen sources was used as a means of identifying the origin of nitrate present in well water. Preliminary studies using clearly defined watersheds in agricultural areas suggested that nitrate

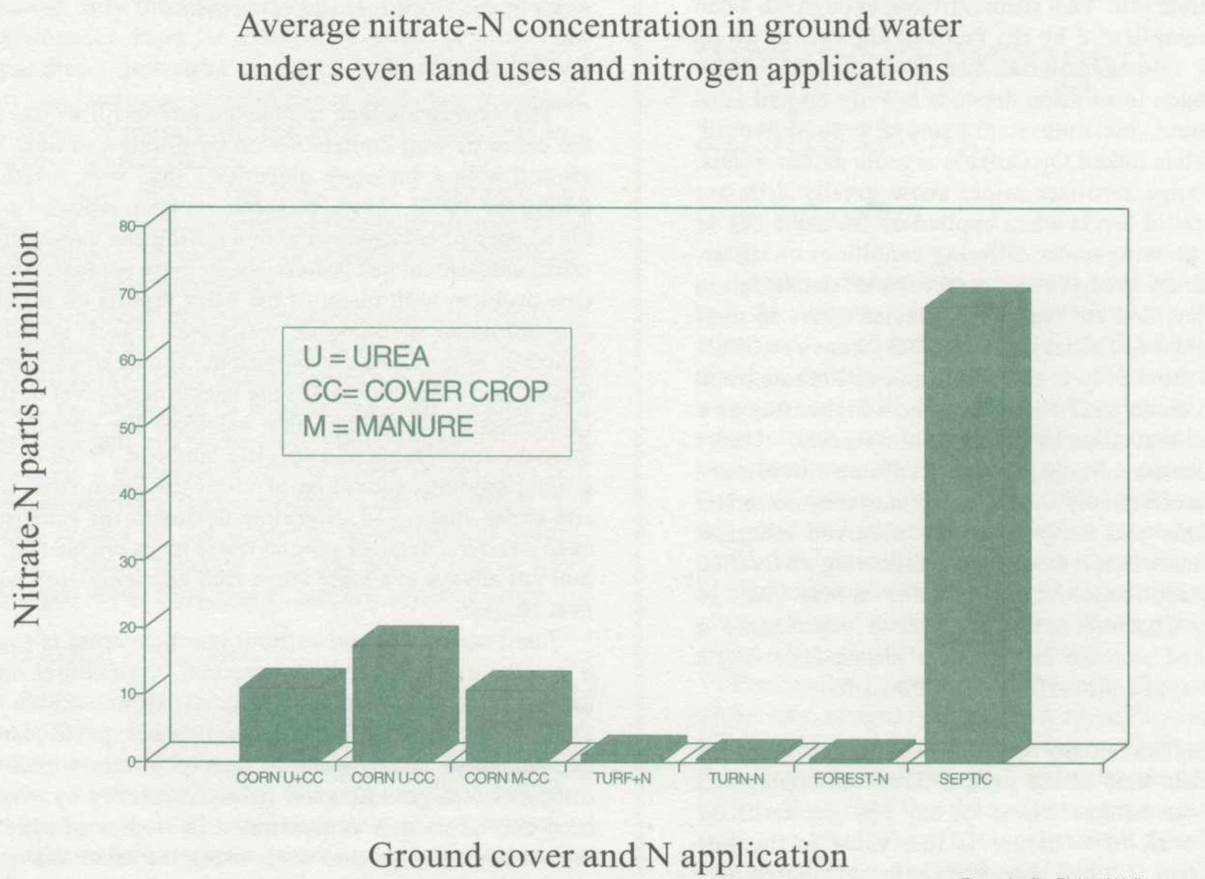
a nitrate salt. That seems obvious enough but it can be complicated by the fact that the rate at which slow release materials are oxidized and release nitrogen to solution depends heavily on soil temperature, moisture status, and microbial activity which is linked to available organic matter. Thus, the same fertilizer might show greatly different threshold levels when applied on the same day to turf growing under differing conditions on different soils. We have also demonstrated that turfgrass species and cultivars of a species differ in their efficiency of nitrate uptake. That means a fertilizer will show a lower threshold application rate when used on an inefficient grass and a higher rate on a grass that absorbs nitrate more readily. Under northern conditions, turfgrasses absorb nitrate much more effectively in the spring than they do in late summer and early fall. We observed marginal increases in soil water nitrate following a 5 lb/1000 sq-ft application of urea-N made on May 15th. In early September, the same plots experienced a marked increase in soil water nitrate following a urea application of 1 lb N/1000 sq-ft.

So, under any given set of conditions at a specific time of the year, a threshold application rate can be determined for any nitrogen fertilizer However, of what use is this value to the turf manager if it can change by several hundred percent under different conditions and at a different time? Consequently I see little value in reporting threshold rates for nitrogen fertilizers because they are so unique to a given set of conditions and of no practical use to the turf manager. It is far better for a manager to understand the principles behind nitrate leaching than to base fertilization practices on a notion of threshold application rates. ■

derived from synthetic fertilizers and animal wastes could be distinguished in ground water samples based on their ^{15}N percentage. When this approach was attempted in the more urbanized Northeast, results were much more ambiguous.

In a Long Island study, fertilizers used on a golf course averaged less than 0.3641% ^{15}N (less ^{15}N than in atmospheric nitrogen). Well water samples taken from fertilized fairways averaged 0.3687% ^{15}N while up-stream wells averaged 0.3679% ^{15}N. The concentration of nitrate-nitrogen in water from the golf course wells and up-stream wells averaged 10.3 and 3.9 ppm, respectively. While fertilizer apparently caused some increase in well water nitrate concentrations on the golf course, the amount of ^{15}N enrichment did not indicate that the increase was entirely from fertilizer sources. Nitrate found in domestic wells on Long Island contained more than 0.3667% ^{15}N and the level increased from east to west (toward greater urbanization). This suggested that nitrogen from animal sources was mixing with soil derived nitrogen. Even the up-gradient well samples contained comparatively high concentrations of nitrate indicating off-site sources of contamination.

While the authors of these reports tended to implicate fertilizer nitrogen as a contributor to well contamination, they could not exclude significant contributions from other, probably animal based (sewage), sources. It is now generally concluded that isotopic nitrogen ratios of well samples from areas of highly diversified land uses are difficult to interpret and certainly do not show that fertilizers used on turf are direct contributors to elevated ground water nitrate levels. It is also interesting to note that in the same study, wells in a potato field averaged more than 20 ppm nitrate-nitrogen containing 0.3686% ^{15}N. Potato fertilizer contained 0.3664% ^{15}N which suggests that some animal derived nitrogen was also contributing to well water nitrate under crop fields.



Nitrate-N concentrations of soil water under seven ground covers fertilized at about 200 lbs N/acre/year (+N) or unfertilized (-N). Average of two years. Based on Gold et al., 1990, J. Soil & Water Conservation 45:305-310.

Evidence from turf research

Since these early studies, there has been much research on the contributions of turf fertilizers to nitrate present in ground water. This work was thoroughly reviewed in 1990 by A. Martin Petrovic at Cornell University and will not be repeated here. I will only comment that some preliminary studies on golf course greens which received relatively high rates of soluble nitrogen fertilizers and were extensively irrigated were found to leach substantial amounts of nitrate.

These were mostly sand-based greens which had little capacity to retain nitrogen and generally represented the worst case situation for nitrate leaching. A more realistic study was reported by Stuart Cohen and his colleagues in 1990. They studied four established golf courses on Cape Cod, Massachusetts, placing ground water monitoring wells up-gradient and on greens, tees and fairways. These were sampled monthly for nitrate over an 18-month period and generally failed to find nitrate-nitrogen concentrations in excess of 10 ppm. On one course, where nitrate-nitrogen was in the 10-30 ppm range, relatively high rates of nitrate containing fertilizers had been used. When these rates were reduced to 2-3 lbs N/1000 sq-ft (down from 5.5 lbs N), ground water nitrate-nitrogen levels decreased to less than 5 ppm.

In this study, the ground water was less impacted by other land uses so that in three of the four sites, up-gradient wells produced water which contained only 0.1-0.2 ppm nitrate-nitrogen. The authors of this report concluded that, while golf course fertilizers could elevate the nitrate content in well water, they rarely caused an increase greater than 10 ppm nitrate-nitrogen and this could be reduced by simple modifications in fertilizer management.

It should be noted that Cape Cod was selected for this study because it has extremely sandy soils of low organic matter content which overlay shallow aquifers. In other words, if ground water contamination from turf fertilization did not occur on Cape Cod, it probably would not occur anywhere. Research has pretty well confirmed this conclusion with the sole exception of some Southeastern locations where soils are equally sandy, there is even less soil organic matter and the annual precipitation is greater. Combine this with soils that rarely freeze and warm-season turfgrasses which are dormant during the winter, and significant nitrate leaching is commonly observed. In the northern and central states where cool-season grasses predominant and soils are heavier, significant nitrate leaching from reasonably managed turf is highly unlikely.

Field Tips

How to minimize nitrate leaching

by Dr. Richard Hull

While much is known about conditions which favor nitrate leaching from established turf, there is also a good deal that is not well understood. However, enough is known to formulate a few reasonably sound recommendations for minimizing nitrate leaching from turf. These practices are especially important if your turf is on a site over a shallow aquifer and preserving ground water quality is a concern.

Even without concerns over ground water quality, these suggestions are valid because they promote efficient nitrogen use by turf and that means less must be applied and money may be saved.

· Many small applications (0.25 to 0.5 lbs N/1000 sq-ft) will promote less nitrate accumulation in the soil and therefore, less leaching. This practice will also provide a more uniform fertility level and promote better and more consistent turf growth. This approach to fertilization also will allow you to use less expensive inorganic materials and urea. While more labor for application is required, it may be partially offset by less costly materials and an over-all reduction in amount used.

· New seedings and freshly sodded turf are especially prone to nitrate leaching until a root system becomes established. It is better to let the turf become somewhat hungry for nitrogen than applying much fertilizer during the first two to three months. If fertilizer is clearly needed (seeding on a poorly prepared low quality soil), apply the principle in small

Turf nitrate losses in perspective

The comparative size of nitrate losses from turf was probably placed in the most realistic perspective in a study conducted in southern Rhode Island by Drs. Art Gold and Mike Sullivan and their associates. In this unique investigation, the quantity of nitrate leaching from soil devoted to four distinctly different land uses was compared within a small geographic area; a 3.7 mile radius of Kingston, RI. The soil type was similar at all sites and of course climatic conditions were virtually identical. Using suction lysimeters placed at the topsoil/subsoil interface, they measured nitrate leaching from soils planted to variously managed silage corn, a fertilized and unfertilized home lawn, a native mixed oak-pine forest and from a conventional septic system for a three-person home. Nitrate leaching from these sites was monitored following every rainfall event for two years.

The nitrate content of percolation water varied greatly among the different land uses. (See figure on page 4.) Leachate from silage corn fertilized at 180 lbs N/acre with urea or manure contained about 15 ppm nitrate-nitrogen. Leachate from the domestic septic system averaged 68 ppm nitrate-nitrogen. Water percolating through an unfertilized lawn contained 0.2 ppm nitrate-nitrogen while that from a lawn receiving over 200 lbs N/acre/year contained 0.9 ppm. The unfertilized forest leached water containing 0.2 ppm nitrate-nitrogen which was equal to that from the unfertilized lawn. The most telling comparisons were of total annual nitrate-nitrogen leaching to ground water from the different land covers. (See figure above.) While silage corn fields released on average 66 lbs NO_3-N/acre and two septic systems on half-acre lots released 42 lbs NO_3-N/acre, the unfertilized lawn and forest leached only 1.2 lbs N while a fertilized lawn released a little more at 5 lbs NO_3-N/acre/year. It is obvious that the land uses most protective of ground water quality are unfertilized forests and lawns and even heavily fertilized turf leaches much less nitrate than does land devoted to field crops or residential development with on-site sewage disposal systems.

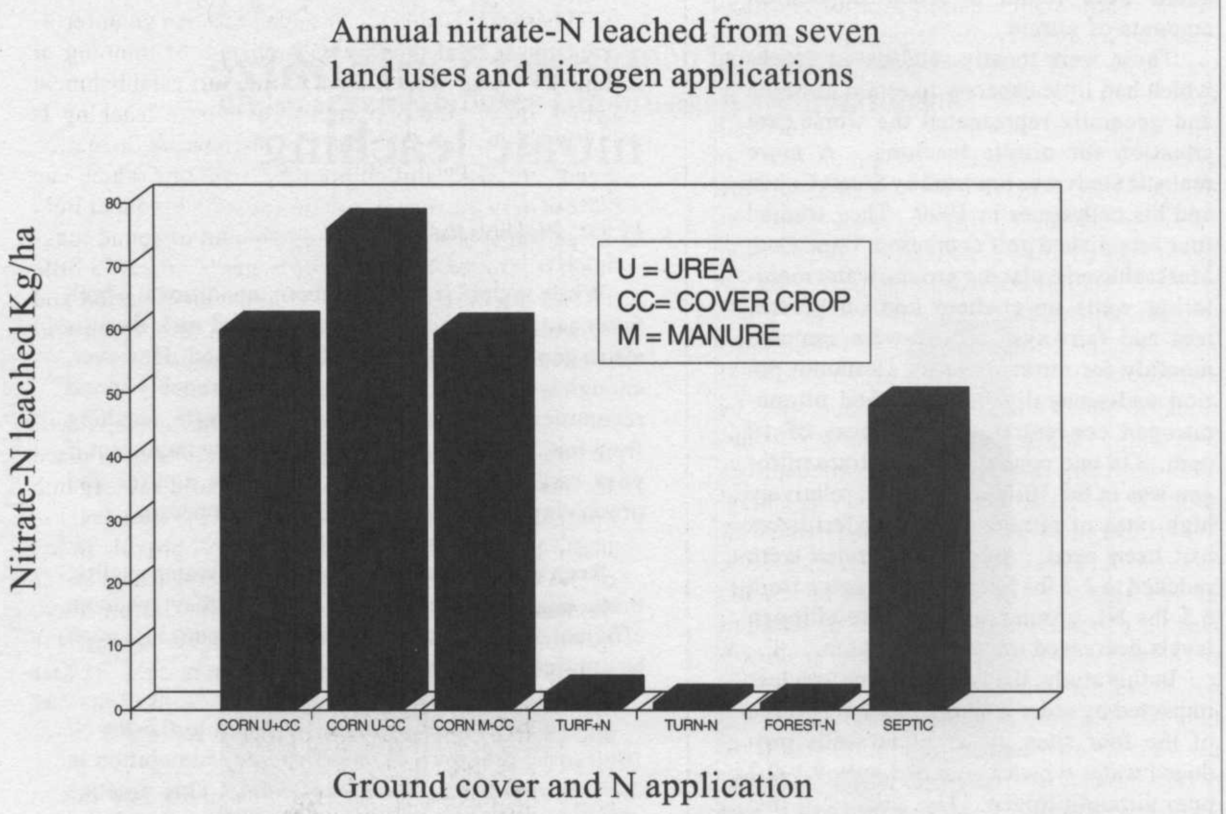


Figure by Dr. Richard Hull

Annual nitrate-N leached from seven ground covers fertilized with 200 lbs N/acre/year (+N) or unfertilized (-N). Average of two years. Based on Gold et al., 1990, J. Soil & Water Conservation 45:305-310.

Minimizing nitrate leaching from turf

Even though turf, fertilized or not, is among the land covers most protective of ground water quality, it still can be managed so as to reduce its nitrate release to the lowest levels possible. In the September 1994 issue of *Turf Grass Trends*, I discussed some of the conditions which contribute to nitrate leaching and listed some steps turf managers can take to reduce these losses. Those suggestions were made with a view toward maintaining turf with minimum use of nitrogenous fertilizers. The idea was to utilize nitrogen mineralized from soil organic matter as much as possible. Obviously if little nitrogen in used, little is likely to be leached from the turf-soil system. This approach, the practicality of which remains to be demonstrated, is only valid for established turf where large soil organic pools have accumulated. What about new turf established on a site devoid of organic matter and most plant nutrients? Can a minimum fertilizer nitrogen strategy work there? Probably not, and annual nitrogen applications of 3 to 4 lbs/1000 sq-ft likely will be necessary. When that much nitrogen is applied to young turf, some special precautions should be taken to minimize nitrate leaching.

The speed by which an extensive root system will develop is an important consideration in guarding against nitrate leaching. If the number of roots and their depth of penetration in the soil is limited, their capacity to absorb soil water nitrate will be low and the opportunity for leaching will be great. This was demonstrated recently by researchers at Ohio State University who compared nitrate leaching from 'Baron' Kentucky bluegrass turf seeded or sodded on May 1. During the following summer, soil water nitrate and potential for leaching was greater under seeded than under sodded turf. Nitrate concentration under both turfs was often greater than 10 ppm nitrate-nitrogen. In the autumn, soil water nitrate levels remained high (>30 ppm NO_3-N) but no differences between establishment method was evident. During the winter and from then on, soil water nitrate was consistently lower under seeded turf than under sodded turf. (See figure on page 8.) Throughout the second year after establishment, soil water nitrate-nitrogen under seeded turf remained below 4 ppm while that under sodded turf climbed to more than 10 ppm.

Apparently a sodded turf initially establishes roots more quickly than does a seeded turf but after two or three months the seeded grass produces the deeper more extensive root system which is better able to absorb soil nitrate. This difference in root system efficiency probably does not persist indefinitely but may be evident for two or three years. In any event, the method of establishment should be considered when designing a fertilizer program for new turf.

frequent applications. Sod normally is heavily fertilized before it is sold so, a sodded turf can go unfertilized for several months with no risk of thinning or injury. Irrigation is critical during turf establishment which means the opportunity of nitrate leaching is increased. Normal rules for estimating irrigation needs are less valid on poorly rooted turf which can access only the top inch or two of soil. Frequent light irrigation is best but a goodly amount of sound judgment is also useful. It may be better to tolerate a little nitrate leaching during the establishment period and insure a thick, vigorous, well rooted turf which will protect the ground water for many years.

· Young turf, past the establishment stage, will require more nitrogen than turf that has been in place for many years. It takes time to build the organic content of the soil. Once the organic matter level is high, its metabolism and turnover will provide much of the turf's nitrogen needs as was emphasized in the September *Turf Grass Trends* article. Before then, however, a vigorous turf is a veritable sponge for nitrogen and leaching potential is minimal. At that time, it is best to meet the nutritional needs of the turf and be less concerned over nitrate leaching.

· Injured and thin turf, especially late in the summer, is least able to absorb nitrate and thus is prone to nitrate leaching. However, the grass may need nitrogen, so frequent small applications is the approach to take. Treat such a turf much as you would if it were newly seeded. The similarities between a few seeding and a recovering turf are numerous and they should be treated similarly.

· Although fall fertilization has been recommended for many years as the mainstay of turf fertility management, concern over nitrate leaching has prompted greater attention to early spring and early summer applications of nitrogen. If grass is injured during the summer and needs to recover before cold weather sets in, light frequent nitrogen applications

This Ohio study also demonstrated that nitrate levels in soil water increased dramatically in both seeded and sodded plots even when no fertilizer was applied. Nitrate-nitrogen levels in excess of 30 ppm were observed under non-fertilized turf during the late summer and fall following spring establishment. This points out the large contribution to nitrate leaching that can originate from soil organic matter when it is oxidized and its nitrogen released to soil water. This is an unavoidable consequence of soil disturbance and the removal of fall and grass root growth is stimulated by cool temperatures. By the time soil organic matter mineralization occurs again during the following summer, an extensive root system will have become established the opportunity for excessive nitrate leaching will never develop.

This study also demonstrates the possible misinformation that can originate from short-term research. Early field studies on newly established turf that lasted only one or two years produced results that badly exaggerated the potential for nitrate leaching. Nitrate leach-

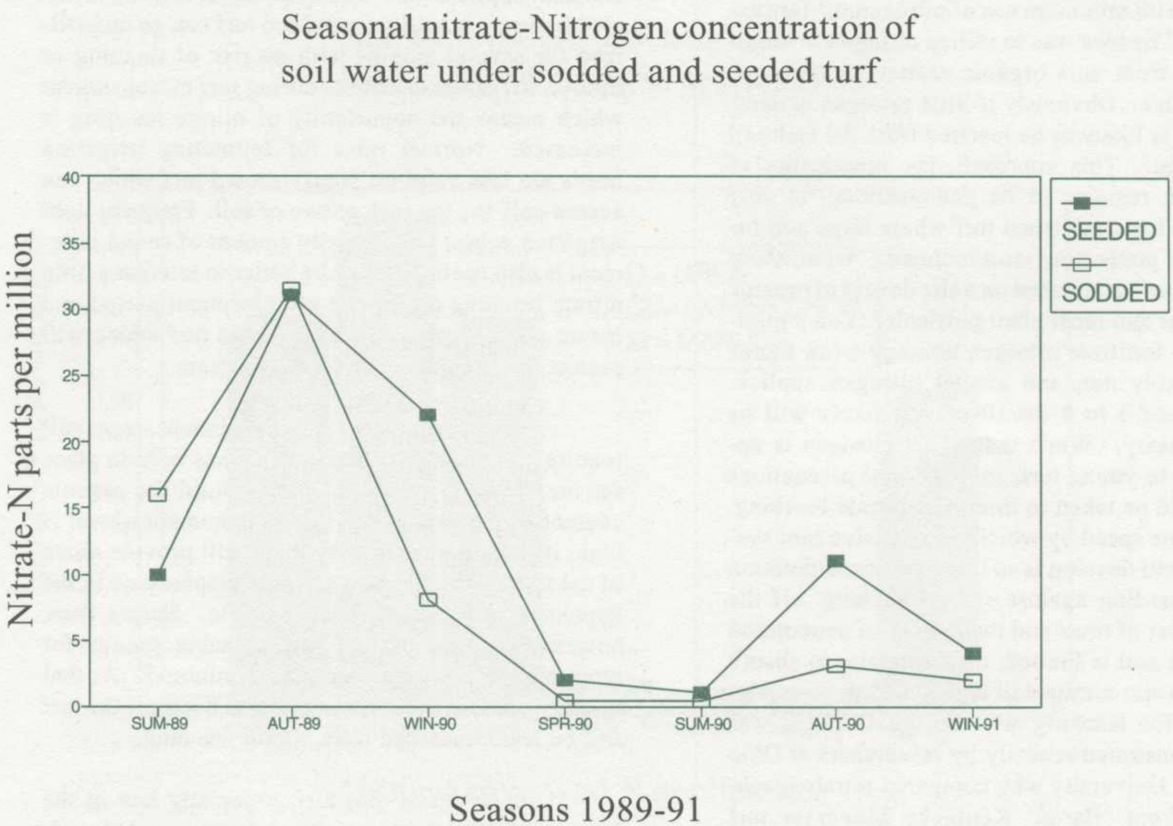


Figure by Dr. Richard Hull

Nitrate-N concentration under seeded and sodded 'Baron' Kentucky bluegrass turf during 1.5 years after establishment. Based on Goron et al., 1993, J. Environ. Qual. 22:119-125.

living plant root systems.

We have demonstrated that large quantities of nitrogen will accumulate in the organic matter deposited under turf as roots, stem bases and underground stems (rhizomes). Normally plant roots and soil microbes absorb most nitrogen released during the decomposition of organic residues but, if the plants have been removed, soil nitrate will accumulate and can leach to ground water. Much of this may be avoided if sod is removed and turf reestablished during the fall. Conditions are less favorable for rapid organic matter decay during the

ing from turf following soil disturbance will always be much greater than leaching from well established turf. Some early studies failed to recognize this and predicted nitrate leaching problems that later research has been unable to confirm. Some present concerns over the environmental soundness of turf culture on ground water sensitive areas, probably originate from reports of early short-term studies.

Irrigation is a critical component to the nitrate leaching story. Unless water passes through the soil, nitrate, even if present in large amounts, will not leach. Because periods of drought are not uncommon throughout most of the country, turf is often irrigated, especially when it is professionally managed. Excess irrigation is wasteful of water but it can also promote nitrate leaching. This was demonstrated clearly by A.J. Gold and W.M. Sullivan in a 1988 report from the University of Rhode Island. Established turf plots were fertilized at 0, 86.6 or 218 lbs N/acre/year using urea and flowable liquid ureaform applied on a schedule similar to that used by lawn care companies. One set of plots was irrigated to avoid drought stress and prevent percolation from the root zone while another set received 1.4 inches of irrigation each week throughout the growing season regardless of rainfall. Soil water leachate was collected by suction plate lysimeters placed at a depth of eight inches in the soil.

While the soil water nitrate-nitrogen concentrations collected over a two-year period never exceeded 5.6 ppm, the amount of nitrate-nitrogen leached from the root zone of overwatered high fertility plots averaged 28.5 lbs/acre. Similar plots irrigated only to correct moisture deficits leached 4.3 lbs NO_3-N/acre/year. This represented an annual loss equivalent to 13 and 2% of the nitrogen applied to over-watered and moderately irrigated turf, respectively. Even the moderately fertilized turf (86.6 lbs N/acre) lost 12 lbs N/acre when over-watered. Thus nitrate leaching can be significant when turf is over-watered even when soil water nitrate concentrations are not particularly high.

Problem or myth?

So what can we conclude from the research reported on nitrate leaching from turf, is there a problem or is it mostly myth? With the exception of some very sandy soils in high rainfall areas of the southeastern states, the probability of significant nitrate contamination of ground water resulting from even intensive turf management is extremely low. Obviously if a heavy nitrogen application (>2 lbs N/1000 sq-ft) is followed immediately by several inches of rain, significant leaching of nitrate will probably occur. However, if the nitrogen fertilizer was a slowly available organic form, even those circumstances would cause little nitrate leaching. For the first few months following turf seeding or sodding, nitrate leaching can occur. High applications of nitrate-containing fertilizers made during late summer or early fall if followed by heavy rain can also promote nitrate leaching. Thus, we cannot guarantee that nitrate will not leach from turf to ground water. However, if even casual precautions are taken to minimize the potential for leaching, turf is still one of the safest land covers available for ground water sensitive areas. ■

are in order. However, a vigorous healthy turf will retain its quality equally well if nitrogen is applied mostly during early and late spring with lesser amounts used in the late summer and fall. Emphasizing spring fertilization will minimize nitrate leaching from turf.

· Avoid nitrate salts. Because it is mined from geologic deposits, sodium nitrate (Chilean nitrate) is viewed by some as organically acceptable and therefore potentially less toxic. It is not very toxic but it is a nitrate source and will leach readily unless plant roots are in their most active phase when it is applied. Using sodium nitrate as an amendment to composts does not reduce its potential for leaching. All nitrate salts of potassium, ammonium and calcium should also be avoided because their nitrogen is already in the nitrate form and is immediately susceptible to leaching. If used, nitrate salts should be applied at less than 0.5 lbs N/1000 sq-ft at a time. Frequent light applications may be acceptable if the turf is actively growing. These salts are very likely to cause leaf burning and they are also most likely to injure turf if applied during hot and dry weather. A good rule in selecting nitrogen sources is to place as much chemistry between the nitrogen you apply and the nitrate which can leach. Organic materials, even urea, undergo several chemical steps before their nitrogen become nitrate. These materials will release nitrogen more slowly and pose less of a nitrate leaching problem.

· Retain clippings on the turf if that is compatible with its use. Grass clippings can contain 5% nitrogen which makes them a good nitrogen source. Research indicates that one-third of the nitrogen used by turfgrasses comes from clippings, if they are not removed. Thus, if clippings are retained on a well established turf, nitrogen applications may be reduced by one-third. Clippings are organic so their nitrogen is basically a slow release nitrogen source which has no nitrate leaching potential. Clippings of cool-season turfgrasses do not contribute to thatch accumulation. ■

Rules set for genetically altered biological pesticides

The Environmental Protection Agency (E.P.A.) has announced a new set of regulations for testing or introduction into the environment of genetically altered microbes.

Long an important issue with the public, the E.P.A's new rules require prior screening of microbial pesticides that are the result of introduced genetic material and that display new activities, characteristics, or whose behavior can be demonstrated to be less predictable than the unaltered base species.

This new screening process acknowledges the unnecessarily highly restrictive nature of previous regulations. It targets only releases of genetically altered microbes, whereas the previous regulations required all microbial pesticides, altered or not, to be subject to testing and screening prior to release into the environment.

TGT's view: *Perhaps this E.P.A. streamlining of the regulatory procedures prior to testing or sale of newly developed biological pesticides will quiet some of the hysterical ravings that have been heard on this subject and help get these new tools into turfgrass managers' hands faster than they would have previously. At the very least E.P.A. officials acknowledge the reality that in the vast majority of cases, research that was being conducted on microbial pesticides was work that was being conducted on species gleaned from nature.* -CS

West Va. University study

Control of Cicada Killer Wasp tunneling possible

Two studies conducted at West Virginia University have found that direct applications of insect controls to wasp burrows are far more successful at controlling the tunneling activities of Cicada Killer Wasps.

In the first study, liquid applications of insecticides were broadcast applied over an entire infested areas of play at a local golf course. During the first eight days after treatment there was substantial suppression, but by the 13th day heavy tunneling activity returned to all test areas.

The results of the second study found that when liquid applications were made directly into the burrow entrance or when an application was made to the area of excavated soil immediately outside the entrance to the burrow that 100% control was evidenced at 3 days after application. Both methods of application were effective at suppressing tunneling activity, with direct application into and around burrow entrances found to be the most effective.

E.P.A. sets review of Triazine-based herbicides

Based on the possible link between the exposure to Triazine-based pesticides and the accelerating incidence of human breast cancers, the Environmental Protection Agency (E.P.A.) has initiated a special review of the three chemically similar pesticides: Atrizine, Cyanazine and Simazine. Recent studies of animals exposed to these three Triazine based compounds indicate an increased level of incidence of breast tumors in certain strains of rats. This coupled with recently published human epidemiological studies pointing to a possible link between increased rates of breast cancer in American women and exposures to environmental toxins, such as pesticides led the E.P.A. to under taken this review.

Several ground water and surface water studies have identified Triazine based herbicide residues in drinking water supplies, particularly in Midwest agriculture production regions during the spring and summer seasons.

These three herbicides are some of the most widely used pesticides in the country with about 100 million pounds applied annually. They are used predominately on agricultural crops, but they are also used as preemergent herbicides on warm-season turfgrass stands.

TGT's view: *The E.P.A. drinking water survey of several years ago clearly identified the Triazine herbicides or their intermediate break-down products as pollutants in drinking water supplies. This led to the implementation of restrictions on their use in 1990. Any positive correlation that is demonstrated during the course of this Special Review between human exposure and increased levels of breast cancer will appropriately lead to the cancellation of all uses of these products.* -CS

1994 Subject Index

Editor's Note: As a service to our readers, Turf Grass Trends *is including this cumulative subject index for 1994.*

1994 Subject Index

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1994 Subject Index

The 1994 subject index will be continued in the March 1995 issue. ■

Coming attractions

March Issue

The turfgrass canopy and its environment

by Loren J. Giesler

and

Dr. Gary Y. Yuen

both of the University of Nebraska-Lincoln

How to profit from the past

Turf Grass Trends Back Issues

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Fax: (202) 483-5797
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