CORNELL UNIVERSITY TURFGRASS TIMES

CUTT

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Management of Annual Grassy Weeds

Annual grasses have been and continue to be among the most serious of all weed management issues in landscape, golf course and athletic field turfs. The most common of the warm season or summer annuals include large and smooth crabgrass (*Digitaria* spp.); green, yellow or giant foxtail (*Setaria* spp.); barnyardgrass (*Echinochloa crusgalli*); and goosegrass (*Eleusine indica*). Understanding more about the ecology and biology of these weeds will help one to develop a plan for effective management over time.

Crabgrass

Several species of crabgrass exist in the US, and two main species exist in the Northeast: large crabgrass (*Digitaria sanguinalis*) and smooth crabgrass (*Digitaria ischaemum*). Crabgrass is seemingly ubiquitous in the landscape and is often unsightly due to its coarse leaves, becoming light green or brown as the season progresses. It generally dies in early autumn following the first killing frost. Although crabgrass thrives in areas of high fertility and soil moisture, it also tolerates a wide range of soil conditions, and is associated with areas where soil and maintenance practices are poor. As you may recall, crabgrass reproduces from seed which germinates from mid-spring to late summer, depending on soil temperatures.

Researchers at the University of Maryland and Cornell University have found that the density of turf stand will impact soil temperatures below the turf stand and thus influence crabgrass germination as well. In a dense stand of turf receiving medium maintenance, soil temperatures greater than 73° were generally required for significant emergence. It has also been reported that minimum temperatures of 55–58° at daybreak in the upper inch of soil for 4-5 days will encourage the initiation of crabgrass germination. Other research has shown that mean soil temperatures of 62–65° are required for germination. Research also suggests that under average turf density, crabgrass emergence can continue for up to 12 weeks during a typical growing season in the Northeast. We have seen that application of a preemergence herbicide too early in the season, before soil temperatures warm adequately, may result in the need for additional crabgrass control measures later in the season.

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This Times

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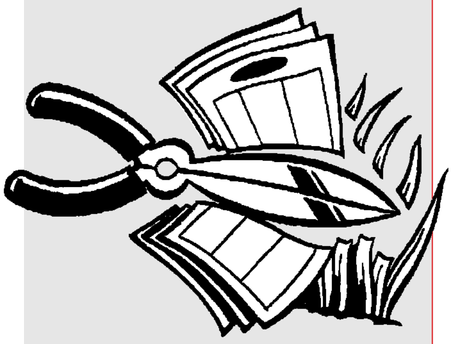
Clippings

Colonial Acres Golf Course in Glenmont, NY, was one of 39 places nationwide to earn this year's EPA Performance Track award. Of the 344 members of the Performance Track program, Colonial Acres is the first golf course to be recognized and is the first entity in New York to earn the honor. Course superintendent Pat Blum earned the title "Superman of the Environment."



The "Green" Track

Colonial Acres First Golf Course to be Given EPA Award

The Environmental Protection Agency is honoring an unlikely place.

It isn't a factory trying to improve its emissions standards nor a park trying to save wildlife. It is Colonial Acres Golf Course in Glenmont, NY, one of 39 places nationwide to earn this year's EPA Performance Track award. Of the 344 members of the Performance Track program, Colonial Acres is the first golf course to be recognized. It also is the first entity in New York to earn the honor. Course superintendent Pat Blum earned the title "Superman of the Environment" for his work at the nine-hole, executive (par-3) layout.

"Golf courses are not the type of facilities that EPA has typically recognized," said Dan Fiorino, director for the Performance Track program, "but it is designed so that any sort of operation can qualify. It was very nice to have a golf course look at the program, and they met our criteria. We're hoping that this will generate some other interest in that area."

Colonial Acres uses 100 percent runoff water, contained in two holding ponds on the course, according to Blum. It also uses environmentally friendly fertilizer and pest control.

The Performance Track award recognizes "top environmental performance among participating U.S. facilities of all types, sizes and complexity, public and private." No golf course had attempted the process before, Blum said.

"To get accepted into the program, you have a three-year period where you are asked to set goals," he said. "One of the goals we'll have to meet is trying to reduce the amount of electricity our golf course uses. How long is your equipment actually running and putting out air emissions from the machines? We're trying to reduce that. We're trying to increase wildlife habitat and reduce the amount of environmental impact by pesticide use."

Blum, a 36-year-old father of two from Niskayuna, has earned other environmental awards in his 11 years at the course. He was the 2002 winner of the Environmental Leaders in Golf award. Colonial Acres became a certified Audubon Cooperative Sanctuary in 1998.

The EPA recognition, Blum said, was "the ultimate goal." The process started last summer, when an Audubon representative told Blum that an EPA officer wanted to see the course. "You hear 'EPA' in the golf industry, and you're scared to death," Blum said. "He saw the course, and I explained the whole environmental thing that we do, and he suggested that I get into this program of the EPA Performance Track."

New Performance Track members will be honored next month in Baltimore.

A Correction

The Summer 2003 issue of *CUTT* contained errors in the broadleaf weed control article by Dr. Leslie Weston in reference to Speed Zone and Power Zone herbicides. Dr. Weston wishes to correct these errors and have our readership make note of them for future reference.

Speed Zone and Power Zone herbicides are marketed by PBI Gordon, not Riverdale Corporation. Speed Zone contains carfentrazone-ethyl, 2,4 D, MCPP and dicamba. Power Zone contains the herbicides carfentrazone-ethyl, MCPA, MCPP and dicamba.

As previously described, these herbicides are available for use on established turf for postemergence broadleaf weed control. They have several advantages, including providing rapid results with visible injury in several hours or the same day, and they are effective in cool weather conditions (above 45° F). Speed Zone is rainfast in as little as 3 hours. Both herbicides provide effective control of such difficult weeds as white clover, dandelion, plantains, spurge, and also provide good control of ground ivy as well. Studies performed by Cornell University and Cornell Cooperative Extension have demonstrated these results.

Carfentrazone-ethyl is new chemistry now available to the turf industry; it is currently marketed alone as Quicksilver herbicide by FMC Corporation. This product can also be applied in combination with other postemergent broadleaf herbicides for fast-acting control. Carfentrazone is a protox inhibitor of plant growth, resulting in inhibition of chlorophyll biosynthesis and membrane disruption of plant cells, leading to rapid necrosis and death. Having new chemistry with these beneficial traits leads to more choices for turf producers and managers for environmentally-sound herbicide application with limited soil persistence and superior toxicological properties.

Scanning the Journals

Does Fertilizer Source Affect Nutrient Loss?

Research has shown that a healthy stand of turfgrass can substantially reduce the loss of nutrients into ground and surface water. However, water quality and contamination from turf-applied fertilizers is increasingly in the forefront when it comes to turf management practices.

Researchers at Cornell University conducted a two-year field study to determine the effect of nutrient source on turfgrass runoff and leachate. Experimental plots were established (80:20 blend of Kentucky bluegrass and perennial ryegrass) on sloped sandy loam soil. Three natural organic (dairy and swine compost and a biosolid) and two synthetic organic nutrient sources (readily available urea and controlled release sulfur-coated urea) were applied periodically at rates of 1.0 and 2.0 lbs. N/1,000 square feet, for a total of 4 lbs. N per year. Runoff and leachate were analyzed for nitrate, phosphate and ammonium.

Results indicate that the greatest losses in both leachate and runoff, regardless of fertilizer source, occurred during establishment. Greater N loss was observed in the plots receiving synthetic organic fertilizers, while greater P loss occurred in the plots with natural organic fertilizers. Once the turf became established, the amount of ammonium and nitrate decreased significantly.

As the grass matured, less water contamination was observed in the fertilized plots due to increased shoot density and infiltration, as well as reduced runoff. The unfertilized control had the lowest shoot density, clipping dry matter production, infiltration rate, and in many cases had equal of higher concentrations of N and P in leachate and runoff.

This study supports previous work that found less risk of water contamination in established turfgrass receiving fertilizer applications. More long-term studies will help quantify the advantages of fertilization against the disadvantages of nutrient losses during establishment.

From: Easton, Z.M. and A.M. Petrovic. 2004. Fertilizer source effect on ground and surface water quality in drainage from turfgrass. J. Environ. Qual. 33:645-655.

Using Manganese to Control Take-All Patch

Take-all patch, caused by the fungus *Gaeumannomyces graminis* var. *avenae*, is a destructive disease of creeping bentgrass. As such, it is a particular concern on the golf course. Infection typically occurs in cool, wet weather, but symptoms are most apparent in warm, dry weather. Maintaining soil pH at about 6.0, as well as balanced nitrogen fertility, can help control the disease. The relationship between fertilization practices and the onset of certain diseases is well documented. Is there such a relationship when it comes to take-all patch?

Researchers at Rutgers University conducted a three-year study to evaluate the suppressive effect of manganese fertilizer applied to fairway turf as a liquid spray. The results showed that manganese fertilization reduced disease severity by about 70 percent. They found that an annual application rate of 2 lbs. of manganese per acre was usually as effective at suppressing the disease as the 8 lb. rate. However, the higher application rates may be required where soil manganese levels are very low. Whether the application was made in the spring or fall did not have a significant effect on the results.

Long-term residual effects were limited. Generally, the beneficial effect of manganese applications lasted for 12 to 18 months. This is because microorganisms eventually convert manganese to forms that are unavailable to plants. Clipping removal further reduces the soil manganese level. Researchers also note that pH adjustment and the use of acidifying nitrogen fertilizers can be used to enhance manganese availability.

For superintendents dealing with take-all patch, including manganese in a fertilizer program can reduce or perhaps even eliminate fungicide applications that are often used to control the disease.

From: Heckman, J.R., B.B. Clarke, and J.A. Murphy. 2003. Optimizing manganese fertilization for the suppression of take-all patch disease on creeping bentgrass. Crop Sci. 43:1395-1398.

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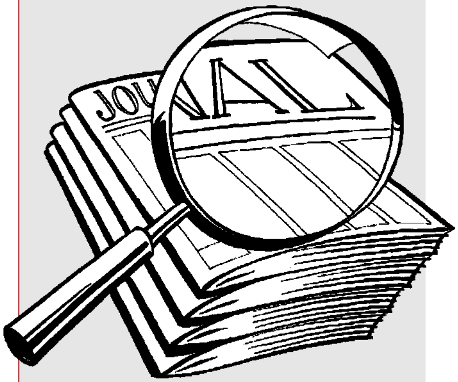

Annual Grassy Weeds

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Crabgrass can set seed at exceptionally low mowing heights, and in optimal conditions can produce several hundred seeds per plant.

If seed production is prevented, one can significantly reduce seed present in the weed seed bank over a longer period of 5 years or more.

Soil temperatures of over 68° are generally required for germination of goosegrass.

Crabgrass can set seed at exceptionally low mowing heights, and in optimal conditions can produce several hundred seeds per plant. Viable crabgrass seed will persist in the soil from year to year, although the majority of seed decomposes during one growing season. However, if seed production is prevented, one can significantly reduce seed present in the weed seed bank over a longer period of 5 years or more. Collecting lawn clippings while mowing when crabgrass is setting seed may reduce the spread of seed in the landscape.

Goosegrass, Barnyardgrass and Foxtails

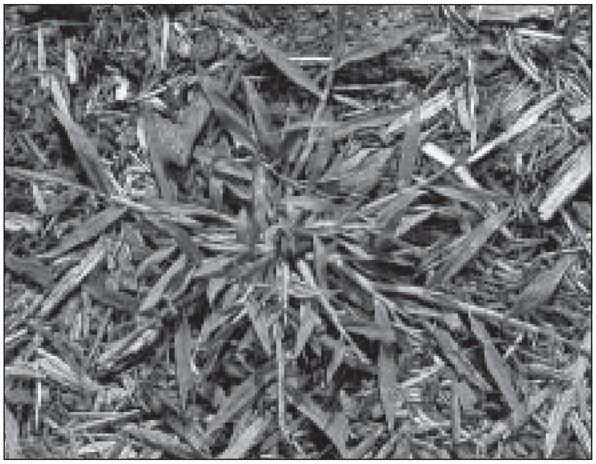
Goosegrass is sometimes referred to as silver crabgrass and can be confused with crabgrass due to its coarse, prostrate growth habit. However, goosegrass has very flat leaf sheaths which have a silver color and a deeper fibrous root system. Like crabgrass, it has fingerlike seedheads producing ample quantities of seed, but these seed stalks have a distinct zipper-like appearance, if one looks closely. Typically one finds goosegrass on compacted soils low in fertility. Goosegrass is often unsightly in a fine turfgrass mixture due to its coarse appearance. Reducing soil compaction with aeration or cultivation followed by overseeding can reduce the infestation of this weed over time. In athletic fields, goosegrass can present a significant problem for players, as uniform field surface conditions are influenced by its presence, and it can be a safety concern for players moving at high rates of speed. Soil temperatures of over 68° are generally required for germination of goosegrass.

Barnyardgrass and foxtails are also summer annual species which infest agronomic and horticultural cropping systems, besides turfgrass. These species tend to infest turfgrass which is less densely established, and in newly seeded or mowed stands, and can be very unsightly. These weeds also tend to germinate at soil temperatures greater than 65°.

Management Practices

What is the best way to manage these weeds from a long-term perspective? Clearly, any practice that encourages the establishment of a dense, vigorously growing turf will discourage the germination and successful infestation of annual grasses through competition for space, moisture and light. The choice of an improved turfgrass cultivar or mixture will play a key role in successful weed management as well. Newly improved turfgrasses have been selected for their ability to readily establish and form dense turfs with strong aesthetic appeal. In comparison to older cultivars or clones, cultivars recommended for this state are often more competitive with annual weeds. Certain turfgrasses,

Crabgrass infestation in a highly-trafficked area where turf is thin.



Large crabgrass. (photo credit: Weeds of the Northeast *by R. Uva, J. Neal and J. DiTomaso.)*

such as the fescue spp. also appear to possess allelopathic potential to reduce weed germination through production of bioactive root exudates, which reduce seed germination of summer annual grasses.

Obviously, mowing, fertilization and irrigation will all impact density of turf establishment. Check your soil pH and fertility to determine if liming or fertilization should be supplied to enhance the vigor of your turf. Adequate nitrogen applied in spring and fall should be considered, as well as phosphorus fertilization in newly seeded turf to encourage turfgrass vigor. Mowing at too low a height, repeatedly, will also tend to reduce the competitiveness of the turf, and result in enhanced establishment of annual grasses. Try to mow less frequently, if possible, and maintain turf height greater than 2 inches to allow the turf to effectively compete with grass weeds.

Yellow foxtail. (photo credit: Weeds of the Northeast *by R. Uva, J. Neal and J. DiTomaso.)*

Irrigation should be applied deeply, if at all, to encourage turfgrass root and shoot growth. Frequent and lighter watering encourages germination and establishment of many shallow-rooted annual weeds, at the expense of the turfgrass. In addition, management practices that discourage the infestation of insects and diseases in turf settings also will result in reduced weed interference. Eliminating any potential niche that annual grasses can invade, due to turfgrass injury and resulting gaps in the turf, will prevent rapid germination by these weeds. In areas less conducive to turf growth, such as heavy shade where stands are less dense and weeds can interfere, the use of an alternative groundcover more adapted to that setting may be an important consideration. If you have to disturb the soil surface, consider performing core cultivation, dethatching or power raking during the fall when turf is actively growing and weed seeds are less likely to germinate.

Chemical Controls

Chemical controls for crabgrass include the use of standard preemergence herbicides, generally timed for application 8–10 days before crabgrass is expected to germinate. After considering the safety of the herbicide in terms of turfgrass injury, consider products such as pendamethalin, benefin, DCPA, and oxadiazon, which are generally safe on Kentucky bluegrass, ryegrass and tall fescue but may injure fine fescues. Other products such as prodiamine and dithiopyr have longer soil persistence and generally provide a longer period of control of crabgrass. Dithiopyr (Dimension) can also be applied as an effective postemergent herbicide for crabgrass, if applied before the 3 tiller stage. In some cases, one application of these more persistent products may provide nearly full-season control.

In general, preemergence herbicides should be applied uniformly and watered in within 2–3 days of application if rainfall does not occur. One thing to consider is that goosegrass germi-

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Program Spotlight

The Roots of Success

Questions Answered by Urban Horticulture Institute Director, Professor Nina Bassuk

Why is an adequate soil volume important for tree growth?

The soil provides many resources for the tree, primary among them being water, oxygen, nutrients, and a medium for root growth. When soil volume is limited, tree growth suffers because so much of the top growth of the tree is dependent on what the roots can deliver and that in turn depends on how large a resource pool there is. It is possible to grow trees in quite small containers as long as water, nutrients and oxygen are supplemented—something not easily done in urban areas.

However, we are beginning to learn that roots not only are the conduits of resources to the tops of the trees, they also produce growth factors that are necessary for growth as well. Roots need to grow in order to produce these growth factors. Therefore, if root growth is restricted, top growth will also be restricted even if water and nutrients are plentiful.

How much soil volume does a tree need?

Several researchers have looked at this question. Although variables such as size of the tree canopy, site conditions and tree species will have an enormous effect on determining an adequate soil volume, a few generalities can be drawn. We found that for much of the United States, a soil volume of two cubic feet for every square foot of canopy crown projection is a good place to start. This work applies to mesophytic, deciduous trees, not trees specially adapted to arid or swampy areas or evergreens.

Most of the climatic conditions in the United States would be satisfied by this relationship except for the desert southwest where there is an extremely high atmospheric demand for water and very little replenishing precipitation.

When we reinterpret other researcher's soil volume calculations, a similar relationship of between one and three cubic feet of soil volume per square foot of crown projection can be generated. It is easy to calculate the crown projection of an existing or envisioned tree by calculating the area under the drip line of the tree which is the same as crown projection. By using the formula for area of a circle (Pi r squared), the crown projection may be calculated. By doubling that figure and calling it cubic feet, we can come to a reasonable starting place to discuss adequate soil volumes for most urban trees.

How can this information be used to reduce tree/sidewalk conflicts?

One might reasonable assume that soil under pavements may be accessed by tree roots in their search for water, nutrients and oxygen. However, the need to compact soils under pavements to give them strength and prevent pavement subsidence often makes soil impenetrable to tree roots. This purposeful compaction can severely limit the potential rooting space for a tree surrounded by pavement.

Because soils under pavements are compacted, roots are generally relegated to growing upwards towards the surface of the soil where there is an interface between pavement and base course that allow for root growth exploitation. This sets them up for direct impact on pavements as the roots expand and grow radially. In a forest situation, large buttressing tree roots normally taper down as these roots grow away from the tree, in the first 6 feet or so. It is these large roots, near the base of the tree, that cause the most damage to pavements.

One suggestion for reducing this problem would be to leave a larger cutout section of pavement so as not to interfere with these largest of tree roots. Another suggestion would be to use a structural soil that could be compacted to meet engineers' specifications while still allowing tree roots to grow deeper.

Structural soils could be used to channel roots safely under pavement into an open grass area adjacent to the pavement or to be the sole rooting area. Either way, structural soils should be at least 24" deep and preferably 36" deep and extend for a large area at least equal to what the soil volume calculations predict.

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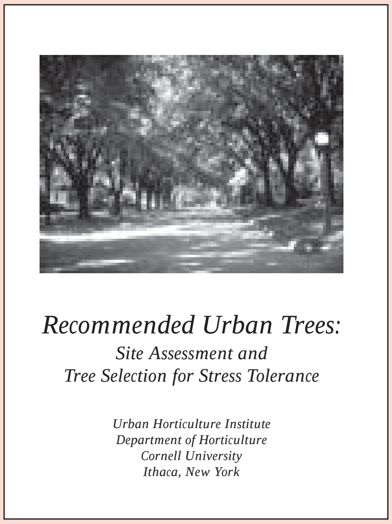
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Regarding The Precautionary Principle

Readers Respond

As we informally polled the Assembly later, we found that a startling number of legislators voted for it due to political concerns, many knew little about it. Ms. Snedeker is correct when she writes that "action should not be taken on a perceived risk."

I feel kind of funny asking a Cornell researcher to show us the science first, before we make public policy decisions that will have cataclysmic impact on our lives and our environment.
—Larry Wilson

To the Editor,

In the Winter 2004 issue of *CUTT* appeared an article written by Suzanne M. Snedeker, Ph.D. entitled "Do No Harm: The Precautionary Principle". The article cites precedent for applying the precautionary principle and points out that the recent legislation in Canada was based on precautionary policy. It is pretty much unanimous among those working in commercial horticulture in New York State that the recent Canadian laws go too far, some of them banning all chemicals used outdoors on lawns and ornamentals. Ms. Snedeker sort of glosses over the impact that similar laws would have on our industry in New York and attempts to put a happy face on the impact by telling us that our industry could find new products. We are doing that at present, although getting new products registered in New York is like moving a mountain.

Ms. Snedeker proceeds to criticize the criticisms that she raises to the precautionary principle. The criticism that The Precautionary Principle is not science based is all too apparent. The chemicals that lawn care relies upon are probably some of the most scrutinized chemicals ever conceived. Most of them have been around for decades, and have withstood countless studies, many by Cornell University researchers. It's nice that she acknowledges that "evaluations by independent agencies and researchers are *also important.*"

When Ms. Snedeker mentions "policy makers", bells start to ring. Too many policy makers that I have spoken with have admitted that on many key pieces of pesticide legislation passed in New York in recent memory, that decisions were made on a *political basis*. When neighbor notification passed in the New York State Assembly, it passed *unanimously*. Does anybody think that all 150 Assembly members can be unanimous about anything on ideological merit? As we informally polled the Assembly later, we found that a startling number of legislators voted for it due to political concerns, many knew little about it. Ms. Snedeker is correct when she writes that "action should not be taken on a perceived risk."

We wish! Unfortunately, that is precisely what is happening, and the precautionary principle will only add fuel to the fire.

Another criticism of the precautionary principal, that Ms. Snedeker discounts as well, is that the risk assessment procedure takes too long. Without even examining *why* that is true, we get to the heart of the matter. After undergoing the five or ten year testing period as cited by Ms. Snedeker, as the chemicals that we use *have;* after undergoing study by independent researchers all over the world, should they be removed from the manufacturing stream as a precaution? She makes a case for doing just that. I disagree with that premise and when you begin to use the precautionary principle for making policy decisions on chemical use, as has been seen in Canada, I think that everyone engaged in commercial horticulture in New York State should sit up and take notice, we are talking about the demise of our industry.

We applaud you and your department for presenting sound scientific information to our industry on the products that we use. I have always respected your wish to remain distant from the realm of public policy when making judgments about the impacts upon Integrated Pest Management made by various public policy issues. While we commend her scrutiny of methyl-bromide in previous articles, Ms. Snedeker's apparent endorsement of the use of the precautionary principle in public policy decisions seems like a departure of sorts from what we have seen from Cornell. The public policy arena is a very complicated place where science sometimes gets hijacked for political purposes. I feel kind of funny asking a Cornell researcher to show us the science first, before we make public policy decisions that will have cataclysmic impact on our lives and our environment. So be it.

Thank you again!
Larry Wilson, Chairman
New York Alliance For Environmental Concerns

Dr. Snedeker responds:
Dear Mr. Wilson,

Dr. Frank Rossi, editor of *CUTT* was kind enough to forward a copy of your letter written in response to the article I wrote on the Precautionary Principle which appeared in the Winter 2004 issue. The article that ran in *CUTT*, was a shorter version of a more in-depth article I had written entitled "What is the Precautionary Principle? How is it taking shape nationally and globally?" which appeared in vol. 8 no. 3, 2003 edition of *The Ribbon* newsletter (see http://envirocancer.cornell.edu/Newsletter/General/v8i3/precautionary.cfm).

I encourage you to read the entire text of the original article. The major themes covered in the original article included the history of the precautionary principle (which also appeared in the *CUTT* version), and how policy based on the precautionary principle was in the process of being enacted in Europe. Unfortunately, this portion did not appear in the *CUTT* version. This is important, since I was trying to show how the science-based policy that requires a scientific risk assessment was an important element of regulatory action based on the precautionary principle in Europe. I attended a talk by the Danish Minister of the Environment in December 2002 outlining the European approach, and was impressed with the requirement to conduct full-risk assessments as part of the proposed European Union policy on the regulation of new and old chemicals.

I fully agree with you that regulatory decisions can't be made based purely on politics. The entire point of my article, which I am sorry I did not convey as fully as I had hoped, is that the precautionary principle must be science-based, and using a precautionary approach does not eliminate the need for risk assessments. As I mentioned in the article, invoking "monsters under the bed" is criticism and a potential pitfall of the precautionary principle when a science-based approach is not used. Again, I emphasized "the precautionary approach does not eliminate the need for assessing harmful effects of chemicals. The definitions of the precautionary principle outlined earlier in this article do have the common element that precautionary action should be taken when there is credible, scientific evidence of harm. Action should not be taken because of a perceived risk." If the legislation being considered or enacted in Canada is based on a perceived risk, then I share your concern of such regulatory action. It must be science based, and based on evidence of harm due to exposure to the chemical(s) in question. On this point, we are in agreement.

The entire point of my article was to pull away from "catchy phrases" and to put the precautionary principle in a science-based context, to show that when used in this way it can be effective, as I outlined in my examples of regulations and policy being proposed in Europe as well as in U.S. legislation. I would disagree with your letter that I advocated that chemicals whose risk is well characterized that do not show evidence of harm should be removed from the manufacturing stream. But, the absence of studies does not show an absence of risk. In all cases, risk assessments are needed.

Again, numerous times I emphasized in my article that there needs to be credible evidence of harm to invoke regulatory action based on the precautionary principle. You say, "show the science first;" I could not agree more. That is my point. That is the reason I wrote the article to educate those who have misconceptions about the precautionary principle, that it can be based on a perceived risk. It cannot by any of the definitions I outlined, and this certainly is not how it is being used in Europe. Perhaps we have much to learn from our neighbors across the Atlantic.

Another paragraph not in the *CUTT* article was a summary of the *Canadian Healthy Lawn Program* developed through collaboration between Health Canada's Pest Management Regulatory Agency and provincial and territorial governments in Canada. This IPM-based program is discussed online at www.healthylawns.net. This program was presented at the North American Pesticide Applicator Certification and Safety Education Workshop last August as a model of a national policy to promote integrated pest management techniques.

In closing, risk assessment of pesticides and whether they may or may not affect human health or cause other environmental concerns is a constantly evolving process. I served as a special expert to the National Advisory Panel to the Agricultural Health Study this past February. This National Cancer Institute-sponsored study is evaluating whether the risk of cancer, neurological problems connected to Parkinson's disease or farm-related injuries, respiratory disease, and retinal degeneration are related to past exposure to pesticides or other agricultural chemicals and practices.

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The article that ran in CUTT, *was a shorter version of a more in-depth article I had written entitled "What is the Precautionary Principle? How is it taking shape nationally and globally?" which appeared in vol. 8 no. 3, 2003 edition of* The Ribbon *newsletter.*

The definitions of the precautionary principle outlined earlier in this article do have the common element that precautionary action should be taken when there is credible, scientific evidence of harm. Action should not be taken because of a perceived risk. If the legislation being considered or enacted in Canada is based on a perceived risk, then I share your concern of such regulatory action.
—Suzanne Snedeker

Regarding the Precautionary Principle

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While the majority of pesticides may not pose a risk, it is important to continue to study and evaluate the few that may. When credible scientific evidence shows harm from exposure, a precautionary approach is a prudent action to protect public health and those with occupationally related exposures. As a member of the American Public Health Association (APHA), and the American Association for Pesticide Safety Educators (AAPSE), I support such a science-based, public health policy.

Sincerely,
Suzanne M. Snedeker, Ph.D.
Associate Director of Translational Research
Program on Breast Cancer and Environmental Risk Factors (BCERF)
Division of Cancer and the Environment
Sprecher Inst. for Comparative Cancer Research
Cornell Univ. College of Veterinary Medicine

http://envirocancer.cornell.edu

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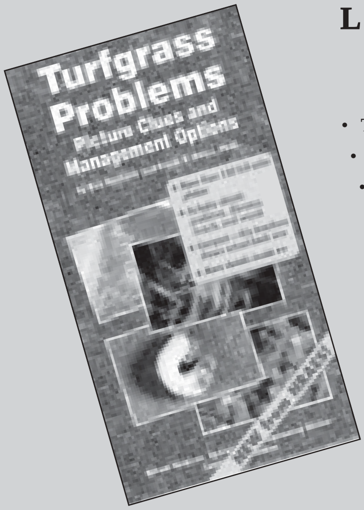

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Annual Grassy Weeds

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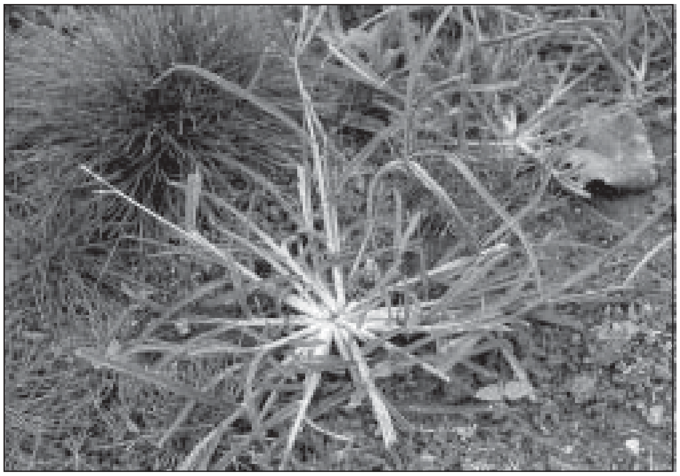
nates later than crabgrass so preemergence herbicide applications specifically designed to control goosegrass should occur several weeks after crabgrass control materials are applied. To obtain season long control, reapplication of a product is often required within 6–8 weeks following initial application. With late season applications, poor control may be obtained depending on weather conditions. In these cases, postemergent herbicides could be used to control preexisting grass weeds.



Above: goosegrass. Below left: barnyardgrass. (photo credit: Weeds of the Northeast *by R. Uva, J. Neal and J. DiTomaso.)*

Postemergent products can be effectively used to control established grass weeds in turf. In some cases, spot application can be used to treat only the area where emergence has occurred. Postemergent products are often more costly than preemergent herbicides. For these products to be effective, the annual grass weed must be uniformly covered by the herbicide, so application should be made when these weeds are clearly visible. Use a surfactant, if the product is not already formulated with a surfactant, to enhance foliar spreading.

The methanearsonates (MSMA and DSMA) are an old family of herbicides which may injure desirable turf species at high temperatures over 80°. Repeat applications may also be needed for complete control of established grassy weeds. Fenoxaprop-ethyl (Acclaim) is a slowly-translocatable product which can effectively control established summer annual grasses in one application. It is generally safe on most cool-season turfs but can cause injury on Kentucky bluegrass. Remember, this product is less effective when tank mixed with 2, 4 D or other phenoxy herbicides.

Summary

The maintenance of a dense, vigorous turf is the best line of control for annual grasses in turfgrass settings. When needed, herbicide applications can be utilized to reduce weed populations to reasonable levels. Although new preemergence turf herbicides for enhanced broadleaf control are available at this time, older products currently offer adequate solutions for annual grass management. Preventative preemergence products are very effective in reducing numbers of most annual grasses over time, with the exception of annual bluegrass.

Consult the *Cornell Turfgrass Recommends* for further specifics regarding herbicide use in turfgrass settings. By utilizing cultural practices to prevent weeds from setting seed, weed seed numbers present in the soil weed seed bank can be significantly reduced over time. With careful management, crabgrass, in particular, as well as other summer annual grasses, can be eliminated as serious weed problems from landscape and turf settings.

Leslie Weston, Ph.D.

Dithiopyr (Dimension) can also be applied as an effective postemergent herbicide for crabgrass, if applied before the 3 tiller stage. In some cases, one application of these more persistent products may provide nearly full-season control.

Postemergent products can be effectively used to control established grass weeds in turf. For these products to be effective, the annual grass weed must be uniformly covered by the herbicide, so application should be made when these weeds are clearly visible.

Turfgrass Management and Water Quality

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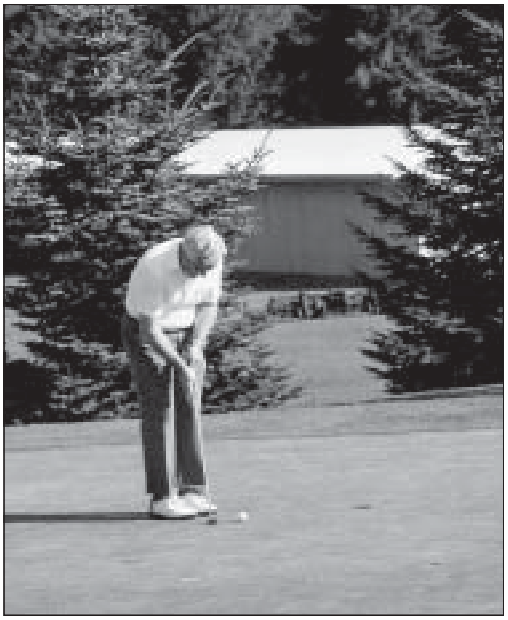
Phosphorus

As with pesticides, P transport to water supplies was once thought to be of minor importance, due to the ability of the soil to tightly bind, or precipitate P out of solution. However, P has the potential to cause eutrophication in surface water at levels as low as 0.035 mg L^{-1} and 0.05 mg L^{-1}, making detection below the EPA MCL of 2 mg L^{-1} still a concern.

Findings vary on where the majority of P is lost. Quinton et al., saw that P, being relatively insoluble and easily bound, was not at risk to be lost in the soluble form, but was more at risk to be lost with sediment, through erosive processes. Quinton et al. and Cox and Hendricks both observed that as sediment loss increased, so to did P loss, due to the P being sorped to soil particles.

Conversely, Shuman et al. state that most of the P lost from grassed pastures is lost in the soluble form presumably due to negligible sediment losses. Gross et al. and Krenitsky et al. also found significant sediment reduction from turf. Bush and Austin found that 90% of the P loss in runoff from a perennial pasture was soluble P. The form of P loss in runoff is generally site specific, with densely vegetated sites contributing more soluble P, and sites prone to erosive losses contributing more insoluble P. Efforts to reduce erosion can reduce both the dissolved soluble P and the particulate insoluble P, however reducing soluble P losses alone is much more difficult.

In many cases, fertilization on a crops N needs results in over-application of P, especially with the use of manures. Sharpley and Smith saw an 800% increase in soil P content following manure application. P levels in the first run-off after fertilization can be orders of magnitude higher than following runoff events. Pote et al. found that the concentrations of both N and P in runoff increased following application of swine manure.



Manures generally have the potential to contribute more P to both ground and surface water. Ebeling et al found that both the concentration and total P load was the highest in runoff from plots treated with high P diet dairy manure. Sharpley and Moyer measured very high P levels in leachate, 75 mg L^{-1}, from dairy and swine manure.

Phosphorus Transport

Phosphorus transport follows some complicated processes. It is found in both soluble and insoluble forms, which can be moved with water, or sediment. It can be sorbed out of solution by metal cations such as iron or aluminum, effectively binding the P to cation exchange sites removed from solution by mineral precipitation, or taken up by the plant. In soils with macropores or preferential flow component P may bypass the soil matrix, and be transported directly to ground water. Saturation of the soils cation exchange sites with the metal PO_4^{3-} ions can result in subsequent transport of P offsite.

Once these CEC sites are saturated, P removal and unsaturation can take a long time and is dependent heavily on the solubilization rate, plant needs and uptake rate. Robertson and Wilhelm et al. explored this in greater detail and found that once these CEC sites are saturated, PO_4^{3-} movement is retarded, but only attenuated by 25%, and ultimately mobile. At steady state PO_4^{3-} concentrations, all exchange sites are presumed to be saturated, thus further attenuation of P results from mineral precipitation. Robertson and Harmon found that once in the ground water zone PO_4^{3-} attenuation slows dramatically, and as a result, most is ultimately mobile.

Increased levels of aluminum and aluminum chloride had a significant impact on P runoff reduction by reducing the pH and hence the solubility. In this study swine manure was treated with Al to reduce the P solubility and the potential to runoff.

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Observed P concentrations in runoff fell from 5.75 mg L^{-1} for swine manure with no Al addition to <1 mg L^{-1} for swine manure with 430 mg Al L^{-1} added to the manure.

The Al, Ca and Fe oxides in the soil reduce P solubility by lowering pH and causing P to form metal ions and be bound at exchange sites. Torrent and Delgado also explored the role of Al and Fe oxides in P sorption process, stating that these are the most active P fixing ions in the soil. As such, soils with high metal oxide levels are better able to remove P from the soil solution, and thus reduce its mobility in runoff and leachate. However, soils high in macropores have been shown by Sinaj et al. to allow increased P losses. The macropores reduce contact of the Al and Fe oxides with the soil, allowing P and the metal oxides to leach from the profile.

Outflow from the lysimeters in this study was observed very quickly, < 5 min to travel 70 cm and contained P transported through the preferential flow paths. Turner and Haygarth found that erosive processes in the macropores can contribute significant P to vadose zone water by physical detachment and transport of bound P. The role of Ca precipitation and pH was explored by Harris et al., who found that despite high pH and abundant calcium, there was essentially no Ca-P mineral formation, indicating a high P availability was still present in the matrix. At higher pH P leaching may be reduced by precipitation with Ca. Organic carbon can increase P losses by coating binding and precipitation sites in the soil.

Shuman et al. observed PO$_4^{3-}$ concentrations of 2.7 mg L^{-1} during the first runoff event following fertilizer application, but levels declined rapidly thereafter. Maximum leachate concentrations were even higher, greater than 3 mg L^{-1}. The concentrations increased in the fall because of reduced plant uptake. Young and Ross observed mean porewater PO$_4^{3-}$ concentrations as high as 7 mg L^{-1} in from soils with high levels of extractable P. Low PO$_4^{3-}$ concentrations (0.046 mg L^{-1}) were detected in soils with low levels of extractable P. Turner and Haygarth saw concentrations of about 0.5 mg L^{-1} in drainage water from lysimeters, which was highest in the spring, presumably due to solubilization in saturated soils.

Shuman et al. observed PO$_4^{3-}$ concentrations of 2.7 mg L^{-1} during the first runoff event following fertilizer application, but levels declined rapidly thereafter.

Bush and Austin measured TP concentrations in runoff and leachate of > 90 mg L^{-1} in the first irrigation event following fertilizer application. Concentrations decreased to < 6 mg L^{-1} in runoff and < 4 mg L^{-1} in leachate following the second irrigation event. Subsequent events resulted in an exponential decline in TP levels. Quinton et al. saw concentrations as high as 25 mg L^{-1} in runoff due to erosive losses. Gallimore et al. recorded dissolved P concentrations in runoff from manure treated plots as high as 17 mg L^{-1}. Cole et al. measured PO$_4^{3-}$ concentrations of 9.57 mg L^{-1} in runoff.

Runoff and leachate from fertilized areas is not the only source of P in water. A study implemented by the United States Geological Survey (USGS) and compiled by Waschbusch et al. found that forested areas, roofs, and streets all contributed significant amounts of P in water, higher in many cases than losses from fertilized areas.

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Nitrogen

Nitrogen found in water supplies can cause eutrophication, algal blooms and impaired water quality at levels well below those considered safe for human consumption. However, this is only when P is not limiting which is usually not the case in the temperate Northeast. Walker and Branham state that NO$_3^-$ concentrations as low as 1 mg L^{-1} can have negative implications for water. Casey and Kline found that levels above 0.4 mg L^{-1} cause problems for marine organisms. Mallin and Wheeler found that even lower levels of 0.1 mg L^{-1} NO$_3^-$ cause problems in water. While P is the primary limiting agent in freshwater, N can be the limiting agent for eutrophication in many estuarine and marine systems. Nitrate at levels above 2 mg L^{-1} can cause hypoxia in water, and NO$_3^-$ concentrations >0.05 mg L^{-1} can cause decline in costal fish habitat. Clearly there is a threat to water from over fertilization.

In a turfgrass system, establishment is the most dangerous from an N loss standpoint, as fertilization rates generally do not change significantly. Lower plant N needs, coupled with undeveloped root systems and lack of soil cover, leads to greater leaching and runoff losses. This presents a good argument for sodding potentially dangerous sites. Sod has been shown to work better than essentially any other material at reducing sediment and runoff losses.

In a study by Snyder and Cisar NO$_3^-$ levels in leachate from a sand green were 20-200 mg L^{-1} for three months following establishment. Leachate losses from fairways were an order of magnitude lower, likely attributable lower sand and higher clay content of the soil. Following

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Turfgrass Management and Water Quality

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establishment, concentrations in leachate from both the fairway and greens were generally below 10 mg L^{-1}. Greater than 100% of the applied N was recovered from the lysimeters indicating that excess N can stimulate mineralization or microbial release of NO_3^- from the soil. In a study by Rosenthal and Hipp, extremely high NO_3^- levels of > 300 mg L^{-1} were measured in runoff from turfgrass. Owens et al. found that the majority of N leaving a grass pasture was associated with water leaching past the root zone.

In a study completed by Quiroga-Garza et al. that factored in day length, NO_3^- levels in leachate were extremely high, 100-190 mg L^{-1}, accounting for 9% of applied N. This was because of reduced turfgrass vigor and growth from shorter photoperiod. Brown et al. saw levels of NO_3^- in leachate up to 100 times higher from highly soluble NH_4NO_3, than from less soluble urea formaldehyde. This finding was verified in another study by Owens et al. who found that ground water below grass pastures fertilized with NH_4NO_3 had significantly higher NO_3^- concentrations than pastures fertilized with slow release N.

Baird et al. speculated that sulfur-coated urea contributed lower surface water N levels due to reduced solubility of the prills, and hence a slower, more controlled release. Rate can also play a role in N loss; high rates applied to sandy soils during times of excessive rainfall or irrigation are much more prone to leachate losses.

Baird et al. speculated that sulfur-coated urea contributed lower surface water N levels due to reduced solubility of the prills, and hence a slower, more controlled release. Rate can also play a role in N loss; high rates applied to sandy soils during times of excessive rainfall or irrigation are much more prone to leachate losses. Application timing was associated with NO_3^- peaks observed in leachate by Shuman et al. The peaks were higher following fall fertilization than for summer due to reduced turf growth and uptake of NO_3^-. Lui et al. found that leaching potential fluctuated seasonally and was strongly related to precipitation, relative plant growth rates, fertilization source and timing. Quiroga-Garza et al. observed that late season N applications resulted in significantly higher N leaching losses. Conversely, Miltner et al. state that N fertilization of turf in late fall does not pose a threat to groundwater.

Nitrogen Loss

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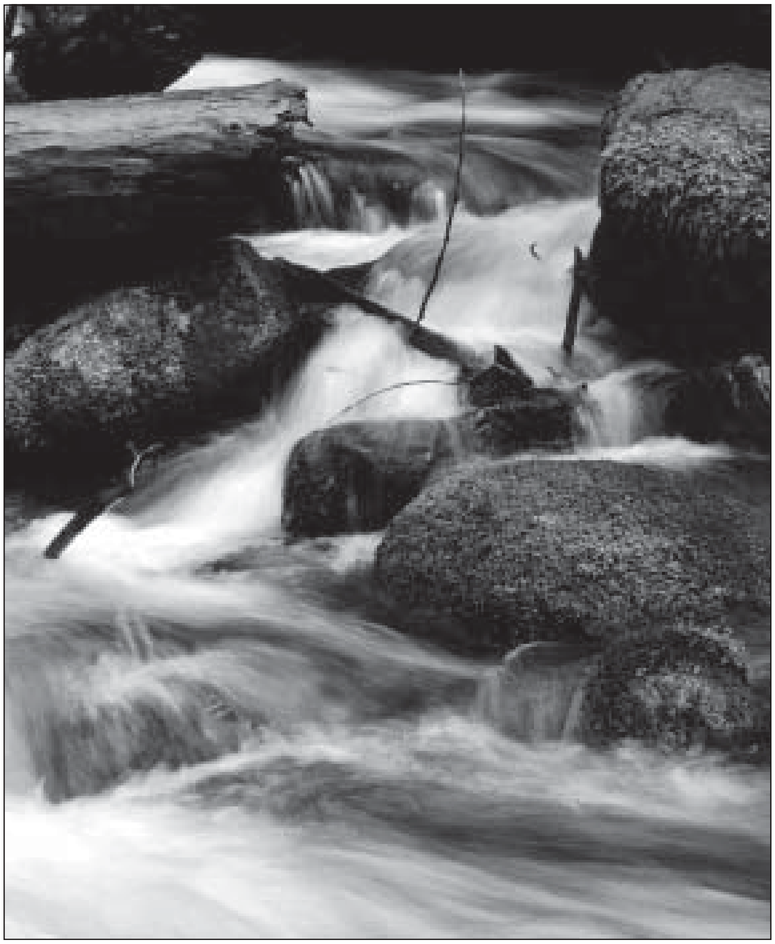
With established turfgrass, clippings are generally the largest sink of N, accounting for 25-60% of applied N. Miltner et al. recovered well over 50% of applied N in clipping, verdure, and thatch. The N bound in turf tissue does not generally represent a threat to water quality, as it is utilized by the plant, and prevented from entering water supplies.



Most of the N lost is via leachate. While runoff can contain high concentrations of nutrients, fluxes are much lower from runoff than from leachate. Owens et al. saw average NO_3^- levels in runoff of only 2 mg L^{-1} in the 10-year study. The low average NO_3^- concentrations may have been due in part to dilution, as the surface runoff depths were high, > 100 mm, for the growing season in some cases. They saw > 75% of the NO$_3^-$ lost in leachate. Concentrations of 20 mg L^{-1} were recorded in leachate. Miltner et al. measured a total of only 0.18% of N$_{15}$ labeled nitrogen in the leachate, and very low levels throughout the study, <1 mg L^{-1}. However, increased NO$_3^-$ concentrations were detected early in the study, which was attributed to mineralization of N due to soil disturbance.

Due to the mobility of NO$_3^-$ in the soil solution, and its solubility, ground and surface water are potentially at great risk for contamination. NO$_3^-$ can move rapidly through sandier soils which allows infiltration to proceed rapidly. Excessive irrigation following fertilization has been shown to mobilize NO$_3^-$ leaching. Starrett et al. found up to 30 times more NO$_3^-$ leached under heavy irrigation, and 95% occurred within 10 hours of irrigation. In total, 10% of the applied N was recovered in leachate from the soil within 10 hours. Lui et al. saw up to 30% of applied N leached, mainly in the winter when plant up take is minimal. Levels were as high as 12 mg L^{-1} in the winter. Petrovic came to the conclusion that leaching losses are high when temperatures are cool, precipitation is high, and plant up take is minimal.

While turfgrass generally has a high affinity and need for N, excess will move from the site. Soils planted with turfgrass will have an increase in organic matter due to root turnover, dieback and thatch deposition. The organic matter has the ability to hold large quantities of N, but will eventually reach equilibrium. Once reached, excess N will be lost, generally to leaching. Quiroga-Garza et al. also found that established stands will utilize and retain more N in the thatch.

Rooting depth was found by Bowman et al. to be a major factor affecting NO$_3^-$ leaching. They found that deeper rooted, i.e., more mature, turf was able to reduce the NO$_3^-$ concentrations in leachate by 100% over shallow rooted turf. Once the N has moved past the root zone, little attenuation will take place, and it can be assumed that it will reach the water table at the same concentration. Lui et al found that NO$_3^-$ will not move back up into the root zone once it has leached past. In addition they saw the highest losses of N in the winter, when the turfgrass plant was not actively growing, pulling the N out of the soil.

Turf to the Rescue

Despite this, turf has a great potential to remove nutrients and pesticides from water. Mallin and Wheeler note numerous cases when water flowing through golf courses was cleaner at the outflow than it was at the inflow. They state the P is much more difficult to remove from the water than was NH$_4^+$ or NO$_3^-$. Nutrient levels detected at the course outflow were always below MCLs, and in most cases below levels thought to cause problems for aquatic organisms. They reason that the reductions were due to the thick vegetated buffers of stream channels on the course.

As with P, water supplies receive significant input of N from non-fertilized sources. Owen et al. recorded concentrations of >1.0 mg L^{-1} NO$_3^-$-N, and >2.0 mg L^{-1} of mineral-N in precipitation, accounting for about 10% of total N input. In nitrogen loading studies conducted on an estuary, Valeila et al. estimate that wastewater input from septic fields accounts for 48% of N input, atmospheric deposition 30% on N input, and fertilization only 15% of N input to water bodies. Clausen et al. recovered about 1% of total N additions via rainfall.

Casey and Kline measured NO$_3^-$ concentrations of 7.7 mg L^{-1} in greens runoff. Increasing N fertilization on sand-based greens can result in impaired water quality. Thus, greens pose a threat to ground water supplies due to the sandy soil, intensive management and intensive input.

Zachary Easton
Ph.D. Candidate, Cornell University

Editors Note: Zach is currently pursuing his Ph.D. with Professor Marty Petrovic investigating landscape, watershed and water quality issues.

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Turfgrass Management Influence on Water Quality

Part 2: Nutrients

Editor's Note: This is the second of a three part series on the current status of water quality research as it relates to turfgrass management. Part 1, Pesticides, was published in the Winter 2004 issue of CUTT.

Concern about sources of agricultural pollution has raised questions about the contribution of turfgrass to water contamination and has motivated research on the role of pesticides and nutrients on contamination of water supplies. Turfgrass, while not the largest acreage crop, is in many cases the most intensively managed ecosystem. However, turfgrass management does not necessarily imply environmental degradation; in fact turf provides many benefits. The functional, recreational and aesthetic benefits provided to humans are unmatched by other crops.

Turf provides sediment reduction, runoff control, flood control, reduction in point- and non-point source pollution, water filtration, heat dissipation, and oxygen production. In many cases turfgrass has been used to remediate harmful chemicals leaving a site. Daniels and Gilliam found runoff transported from agricultural fields and flowing through a grass filter underwent significant sediment and chemical load reductions. In fact, the grass filter was more effective at reducing chemicals and sediments than the use of both a grass and a riparian filter.

Golf courses have been shown to be effective filters of surface water, especially for nutrients such as ammonium (NH_4^+-N) and, in some cases, nitrate (NO_3^--N). To be an effective filter, grass must produce a dense canopy, and deep, fibrous roots, which are capable of removing water from the soil at great depths. A dense canopy will slow and filter chemicals from runoff. Increased plant shoot density will reduce runoff and hence the chemical load leaving a site by creating a more tortuous pathway and increasing soil infiltration of water.

In any case, nutrients and pesticides found in water supplies can cause problems for both humans who rely on clean water for consumption, irrigation and recreation, and organisms that must have clean water for survival. The Environmental Protection Agency (EPA) has established maximum contaminant levels (MCL) for drinking water, above which human consumption is unsafe. The effect of these MCLs on aquatic organisms is generally much greater, suggesting that the use of aquatic toxicities may be a better indicator of water contamination. An in-depth review of the literature reveals a lack of work regarding the specific effect of pesticide use, differing nutrient sources and management practices on drainage water quality from turfgrass.

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A Healthy Ecosystem

Nutrients and pesticides found in water supplies can cause problems for both humans who rely on clean water for consumption, irrigation and recreation, and organisms that must have clean water for survival.

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