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// UNDER THE SURFACE

EFFECT OF TURFGRASS MANAGEMENT ON WATER QUALITY IN THE CHESAPEAKE BAY WATERSHED

Chantel Wilson, Stephen Schoenholtz, Ph.D. and Erik Ervin, Ph.D.

High-quality turf on golf courses is maintained with fertilizer, irrigation and pesticide inputs. As a result, they are perceived as significant contributors to water pollution. Hundreds of courses are located in the Chesapeake Bay Watershed, where there is a history of nutrient pollution and eutrophication problems, resulting in major declines in fish and shellfish populations.



Chantel Wilson measuring velocity at one of the participating golf course research streams, January 2014.

No completed studies have investigated the connection between golf course turf management and nutrient deposition or attenuation in Virginia streams. The project goal is to quantify effects of turf management on water quality by comparing areas upstream (INs) and downstream (OUTs) of courses. Data will be compared to the Chesapeake Bay Total Maximum Daily Loads for nitrogen and phosphorus, clarifying if future regulation of water quality is warranted for golf course management.

Data for 11 seasons at six courses in the James River Basin within the Chesapeake Bay Watershed have been collected. No significant impairment trends of dissolved oxygen, conductivity, temperature or pH have been observed to date. Nitrate-N was always below the 10 mg L-1 EPA drinking water standard. Phosphate-P in downstream waters was below

the 0.05 mg L-1 EPA recommendation. There appears to be no significant differences between the IN and OUT locations at all sites for ammonium-N and phosphate-P.

A weak significant increase in nitrate-N was observed at one stream, but is at a low level. Overall, no significant degradation of local water quality appears from the six golf courses studied.

Funding: GCSAA/EIFG, Virginia GCSA, Virginia Agricultural Council

Chantel Wilson, Stephen Schoenholtz, Ph.D. and Erik Ervin, Ph.D., Virginia Tech. Contact Chantel at cwilson5@vt.edu for more information.

ON THE MOVE

PAUL KOCH JOINS UNIVERSITY OF WISCONSIN-MADISON DEPARTMENT OF PLANT PATHOLOGY

Paul Koch was recently hired as an assistant professor in the Department of Plant Pathology at the University of Wisconsin – Madison. The position has a 70 percent extension appointment, 20 percent teaching and 10 percent research. His research will likely focus on the impact of environmental conditions on fungicide persistence on turfgrass, snow mold diseases and root-infecting diseases.



Koch received his Ph.D. in Plant Pathology from the University of Wisconsin – Madison in 2012, with a minor in Molecular and Environmental Toxicology.

Before joining the faculty, Koch managed the Turfgrass Diagnostic Lab (TDL) for the University of Wisconsin from 2005 to 2013. The TDL is a non-profit diagnostic facility specializing in fast, accurate diagnoses from both professional and do-it-yourself turfgrass managers across the country. Koch will continue to oversee both the TDL and the fungicide testing program.

Koch can be reached via email at pikoch@wisc.edu, by phone at 608-576-2673, or via Twitter at @uwpaul.

“IF NICKEL LEVELS CAN BE INCREASED VIA GRANULAR FERTILIZER APPLICATION, FERTIGATION OR INJECTION TECHNIQUES... FOLIAR-APPLIED UREA MAY BE MORE EFFICIENTLY ABSORBED.”

Richard J. Hull, Ph.D.
(see full story on page 34)

//IT'S ELEMENTARY

How turfgrasses use urea-nitrogen

By Richard J. Hull, Ph.D., Haibo Liu, Ph.D. and N. Menchyk, Ph.D.

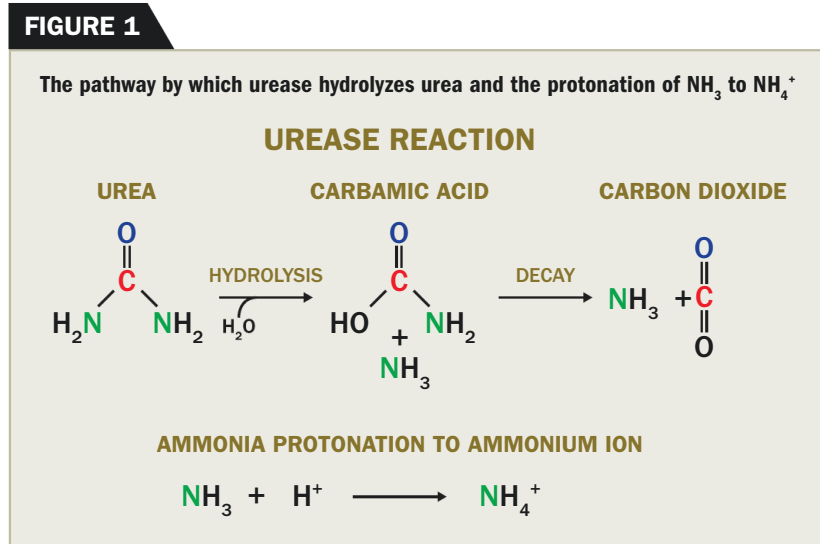
Nitrogen (N) is the most abundant mineral element in turfgrasses, comprising three to five percent of leaf dry weight. Consequently, N is the fertilizer nutrient applied to turf in a greater quantity than any other (two to five lbs per 1000 sq. ft. per year). Most of this N is applied to turf as urea, either as free urea, coated-urea granules or polymerized methylated urea.

Because of the perennial sod character of turf, most fertilizer N is applied directly to grass leaves in granular form or as an aqueous solution. Only during turf establishment is fertilizer spread directly on the soil. While most crops utilize less than 50 percent of fertilizer nitrogen (Witte, 2011), turfgrasses do much better, often recovering 85 to 90 percent (Hull & Liu, 2005).

Even with this relatively good performance, N recovery by turfgrasses may still be improved. Since urea is the major N source applied to turf, its absorption and assimilation will be critical factors in working for improved N use efficiency. Recent research has discovered some aspects of the uptake and metabolism of urea-N that may be exploited by turf managers to reduce their N use and prevent its off-site movement.

HOW UREA-N IS ABSORBED BY TURFGRASSES

It has long been assumed that urea-N is not absorbed directly by plant roots but rather as ammonium (NH_4^+) or nitrate (NO_3^-) and by leaves as ammonia (NH_3) or NH_4^+ . Urea is not stable in the soil or on leaf surfaces due to the ubiquitous



presence of the enzyme urease that hydrolyzes urea to carbamic acid and one free ammonia. The unstable carbamic acid then spontaneously decays to another ammonia and a carbon dioxide (CO_2) molecule (Fig. 1). Both NH_3 and CO_2 are gases that would diffuse into the atmosphere and be lost were it not for their high solubility in water. CO_2 can combine with water to form carbonic acid that under slightly acid pH conditions, dissociates to a bicarbonate anion and a free H^+ .



On the other hand, in an acid solution, NH_3 will acquire a H^+ (become protonated) to form the stable ammonium cation (NH_4^+) (Fig. 1). The pKa for NH_3 protonation is 7.2 (the solution pH at which the concentrations of NH_3 and NH_4^+ will be equal). Therefore, if the soil solution or the liquid on a leaf surface is more alkaline

than 7.2, much nitrogen from hydrolyzed urea will remain in the gaseous NH_3 form and readily defuse from solution into the atmosphere.

Fortunately, leaf surfaces and soil solutions are generally acid, so nitrogen derived from urea fertilizers will be maintained in the stable NH_4^+ form. In that form, nitrogen can enter plant cells via cation transporters and become assimilated into amino acids and eventually into nucleic acids, proteins, chlorophyll and other N-containing molecules.

However, in the soil, NH_4^+ will be oxidized rapidly to nitrate (NO_3^-) by nitrifying bacteria and in that form will be actively absorbed into root cells via specific NO_3^- transporter proteins imbedded in the plasma membranes of most plant cells. Nitrate ions are not subject to volatilization from the soil solution but they can leach in rain or irrigation water through the root zone and be lost to the water table.

Thus, urea applied to the soil should be treated much as inorganic nitrogen materials, with respect to leaching and potential ground water contamination.

Urea is a natural chemical in most living things. It is formed during biosynthesis of the essential amino acid arginine and likely during the normal metabolism of nucleic acids (Hull 2003; Witte 2011). Urea can be regarded as a waste product and as such must be eliminated from the organism. This is no problem for animals that have a circulatory system. For plants, such wastes pose more of a problem.

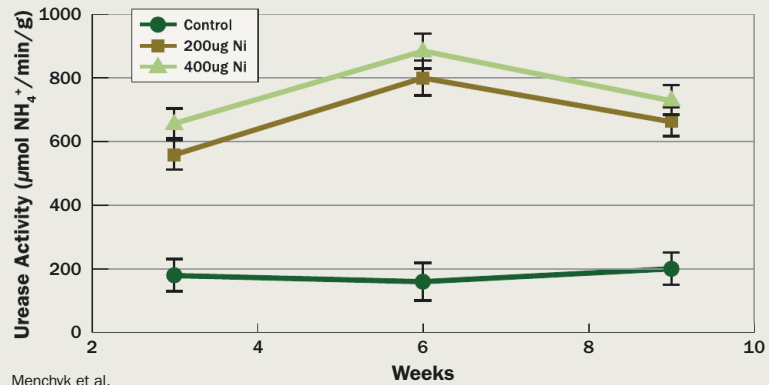
Normally plant byproduct wastes are deposited in cellular vacuoles, where they are excluded from the sensitive metabolic machinery within the cytoplasm and where some recycling may occur. However, waste products from major metabolic pathways could be made in quantities large enough to overwhelm vacuolar sequestration and contribute to nutrient inefficiency especially when they are N-rich chemicals like urea. Since most plants are normally N-limited and could not tolerate such inefficiency, they have evolved a method for metabolizing urea and recycling its N. Urease is at the core of urea-N recovery.

The presence of the urease enzyme in most plant cells permits urea-N to be efficiently returned to the plant's N assimilatory pathway and reutilized for the synthesis of essential N-containing compounds. The presence of urease makes plants, algae and many bacteria among the most N-efficient life-forms on earth. If a plant lacks the urease enzyme, urea can accumulate to toxic concentrations and eventually cause plant death. This occurs in mutant plants that fail to synthesize functional urease or when Nickel (Ni), an essential metallic component of urease, is deficient.

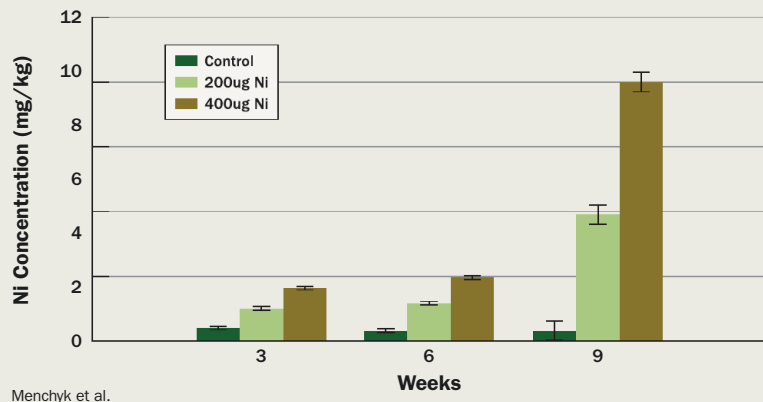
Nickel is the latest mineral element to be added to the list of essential nutrient elements in plants. When grasses are grown in solution cultures

FIGURE 2

Urease activity in leaf tissue of Diamond zoysiagrass and TifEagle bermudagrass as influenced by Ni levels in three harvest dates over nine weeks.

**FIGURE 3**

Nickel concentration in leaf tissue of Diamond zoysiagrass and TifEagle bermudagrass as influenced by three nutrient solution Ni levels in three harvest dates over nine weeks.



lacking Ni, severe leaf tip burn is observed resulting from an excessive accumulation of urea in this oldest part of a grass leaf (Hull, 2003). Because Ni is required in such small amounts (~0.1 ppm in dry leaf tissue) and grass leaves normally contain at least three to five times that amount, Ni deficiency has never been observed in the field (Menchyk et al. 2013).

Even so, Ni may have a role to play in the use of urea fertilizers applied to turf. We will get back to that later.

CAN UREA BE ABSORBED BY PLANTS AS AN INTACT MOLECULE?

Because urease-endowed organisms are so abundant in nature, it has been assumed that urea-N applied as fertilizer is readily hydrolyzed and absorbed by plants primarily as NH₄⁺. While this is generally true, recent evidence indicates it may not be the whole story (Witte 2011). For example, plants can be grown in sterile solution culture with urea as the only N source.

Continued on page 36

Continued from page 35

Such plants fail to grow as well as plants receiving a mixture of NH_4^+ and NO_3^- but they still grow reasonably well, indicating that intact urea must be entering root cells.

In addition, plants have been shown to possess dedicated high affinity urea transporter proteins in their cell membranes that permit urea uptake and distribution throughout the plant. Once inside plant cells, urea is readily hydrolyzed by their abundant urease or loaded into vacuoles by urea transporters that are also present in their tonoplasts (membrane enclosing a vacuole). The induction of these urea transporters appears to be stimulated by external urea and suppressed by the presence of other soluble N sources, e.g. NO_3^- , NH_4^+ and amino acids.

Urea transporters are most abundant in N-starved plants, especially when urea is introduced to their external environment and when plants are provided no N-source except urea.

The urea transporters discussed

above facilitate secondarily active urea uptake. That is, urea crosses a membrane accompanied by a proton (H^+) in a co-transport process. During normal root growth, the surface (epidermal) cells pump H^+ s through their plasma membrane from the cell's interior into the external cell walls via a H^+ -transporting ATPase (H^+ pump).

Put more simply, for each two H^+ s pumped out of a cell, an ATP molecule is expended. ($\text{ATP} + \text{H}_2\text{O} \rightarrow \text{ADP} + \text{H}_2\text{PO}_4^- + 2\text{H}^+$). Since ATP is the chemical energy currency of metabolism, H^+ pumping is an energy expending process that is driven by ATP hydrolysis. As this process continues, the H^+ content within the cell walls increases (becomes more acid) relative to the cell interior that remains the same or actually becomes less acid. This pH gradient across the plasma membrane constitutes an energy gradient equivalent to the energy lost by ATP when it gives up a phosphate and becomes ADP.

How is this H^+ gradient used to pump urea into a plant cell? When urea is introduced as an N-fertilizer, it diffuses into the walls of root or leaf epidermal cells where it activates the synthesis of urea transport proteins in their plasma membranes. These transport proteins have aqueous pores through which H^+ s can move from the cell walls back into the cell's interior. The structure and chemistry of the pores is such that an H^+ can pass through the pore only if accompanied by a urea molecule. Since the H^+ concentration in the cell wall is greater than it is within the cell interior, influx of H^+ is energetically favored. Urea will always be transported inward because the influx of H^+ , its transport partner, is an energetically favored process.

There is recent evidence that urea may also enter plant cells and move across internal cell membranes via aquaporins, the membrane channels by which water enters cells (Witte 2011). Like water, urea is a small, uncharged molecule that probably would not be

excluded from moving passively with water through aquaporin channels. Whether urea can enter cells as an intact molecule by active or passive mechanisms is less important than the emerging idea that urea-N can be absorbed by roots and leaves without first being released as free NH_3 .

MANAGING UREA-N UPTAKE BY TURFGRASSES

To a turf manager, all this may seem pretty academic and of little practical value toward keeping grass green and healthy by maintaining an adequate N supply. Such a judgment may be premature when the vulnerability of NH_3 -N to volatility losses is considered. We know that as much as 30 percent of urea-N applied to turf can be lost to the atmosphere unless it is watered into the thatch/soil by irrigation immediately following application (Hull and Liu 2005). This precaution fails to work very well if the soil is even slightly alkaline or the irrigation water has a pH greater than seven. Even if the soil is acid enough to convert NH_3 to NH_4^+ ion, it will be readily oxidized to NO_3^- that may be subject to leaching loss.

Foliar applied urea initially comes in contact with leaf surfaces that may be populated by enough urease-containing bacteria to cause most of the urea-N to be released as free NH_3 . However, leaf surfaces are generally acidic, so urea-derived NH_3 will likely become NH_4^+ ions in the spray solution retained on leaf surfaces. These NH_4^+ ions can penetrate the leaf cuticle and become absorbed by epidermal cells just as other nutrient ions are during foliar fertilization. If the spray solution dries on the leaf surface, any remaining NH_3 will be lost to the atmosphere.

Does an understanding of urea-N absorption and metabolism suggest ways of making urea use more efficient?

Recent research by our Clemson team (Menchyk et al. 2013) indicates that the efficiency of urea-N use by turf can be optimized by coordinating

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its application with management of the micronutrient, Nickel (Ni). They worked with two warm-season grass species, TifEagle ultradwarf bermudagrass (*Cynodon dactylon* x *C. transvaalensis*) and Diamond Zoysiagrass (*Zoysia matrella*). Plugs of these grasses were grown in greenhouse conditions with the nutrient solution supplemented with three levels of Ni (0, 200 & 400 µg Ni per liter). Nitrogen was supplied exclusively through weekly foliar applications of urea at a rate equivalent to 0.2 lbs. N per 1,000 sq. ft. (1.8 lbs. N per 1,000 sq. ft. during the nine-week duration of the experiment).

The addition of Ni to the nutrient solution substantially increased the leaf Ni content at a rate that increased throughout the nine weeks of the experiment (Fig. 2). This resulted in a dramatic stimulation of leaf urease activity that, unlike the Ni content, leveled off after six weeks (Fig. 3). The amino acid content of leaves increased steadily following a pattern very similar to Ni increase.

Not surprisingly, these changes contributed to greater leaf growth in both grasses. However, with this stimulated N metabolism occurring, the total leaf N concentration actually declined. Others have observed this and attributed it to a dilution of plant nitrogen by increased leaf growth. In this experiment, all N was being introduced from foliar applied urea. As growth was stimulated throughout the plant, its demand for N would increase, causing a drain in leaf N.

This study reveals ways by which Ni manipulation, as a way of regulating urease activity, might become a management tool for increasing N use efficiency. If urea-N can enter grass roots or leaves as intact urea molecules, and by applying Ni, internal urease activity can be stimulated, the concentration gradient of urea across the plasma membranes of root and leaf epidermal cells can be increased. Such a steepened urea gradient would stimulate urea influx, especially via aquaporin-like

membrane channels.

This probably has less potential benefit for soil-applied urea since the natural sources of urease are so abundant there, that urea would have a short half-life in most soils. However, if urease inhibitors are used in conjunction with urea absorption stimulation techniques, direct urea absorption by roots could be enhanced with less urea-N lost via NO_3^- leaching.

The greatest potential for increased urea-N recovery by turf may be in the foliar application of urea. If Ni levels in turfgrasses can be increased via granular fertilizer application, fertigation or injection techniques, thereby increasing urease activity within leaf cells, foliar-applied urea may be more efficiently absorbed. Applying foliar urea in the evening at concentrations that have little burn potential and delaying irrigation until morning could significantly increase the opportunity for intact urea adsorption. Including a surfactant in the urea solution would increase leaf coverage and also favor absorption. Of course, using mildly acidic water will keep any free NH_3 in the NH_4^+ form that will be more readily absorbed.

These are suggestions. They have a reasonably sound scientific basis for working. In any event, they can do no harm, and are worth trying.

Richard J. Hull, Ph.D., is a professor emeritus of plant science at the University of Rhode Island and adjunct professor of horticulture at Clemson University. Haibo Liu, Ph.D., professor of turfgrass science and N. Menchyk, Ph.D. are at Clemson University. Dick Hull can be contacted at rjhull34@yahoo.com for more information.

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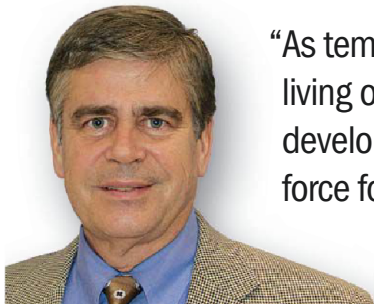
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“As temperatures increase, plants and living organisms begin to grow and develop. Temperature is the driving force for all biological activity.”

KARL DANNEBERGER, PH.D., *Science Editor*

Spring triggers growing degree-days

With the arrival of spring, the warmth of the sun is most evident. As temperatures increase, plants and living organisms begin to grow and develop. Temperature is the driving force for all biological activity. One method of using temperature to describe and predict the development of living organisms is accumulative growing degree days. In a previous column I described how growing degree days are calculated and used to predict annual bluegrass seedhead emergence (*Golfdom*, March 2010). In this column, I look more in-depth at ways to calculate growing degree days.

There are three ways to calculate growing degree days (GDD). The most common is the Average Method where the daily minimum temperature is added to the maximum temperature for that day and then divided by two. The base temperature, which can vary depending on the plant model, is subtracted from the average. If the calculated growing degree day is greater than zero, it is added to the cumulative total that has occurred since the start date. If the GDD is less than zero, it is set to zero. The base temperature can vary widely depending on the GDD model ranging from 32 to 55 degrees F with some models. The most common base temperature used is 50 degrees F (10 degrees C).

The second method is the Modified

Average Method, which calculates GDD the same way as the Average Method except if the minimum temperature is below the base temperature; the base temperature is used as the minimum temperature in the calculation. This calculation has an advantage over the Average Method when temperatures fluctuate above and below the base temperature that occurs often in the early spring. When fluctuation occurs above and below the base temperature, the Average Method underestimates the number of GDDs. From an application perspective, timing a mefluidide (growth regulator) application for *Poa annua* seedhead control would be best based on the Modified Average Method of calculating GDD.

The Modified Sine Curve Method is the third and most accurate means of calculating GDD. It is based on the assumption that the daily diurnal temperature pattern is similar to a sine curve. The GDD calculated is the area under the curve. The Modified Sine Curve calculation is considerably more complex than the previous two methods and often requires a computer program.

The Modified Sine Curve Method also accounts for a high temperature threshold. In other words an upper temperature limit can be set where GDD are calculated to the threshold and not above. The upper threshold concept can be used to calculate Stress Degree Days that may help define and predict the summer stress period.

Lastly, there is the start date. With all GDD models, a set start date is given, which is sometimes referred to as biofix. The common start date is January 1st, but this can vary depending on the model. Early GDD models that predicted annual bluegrass or Kentucky bluegrass seedhead emergence had a start date of April 1 and March 1, respectively.

Recently, applications of the growth regulator trinexapac-ethyl are being recommended based on the work of Kreuser and Soldat (2011) at the University of Wisconsin. Based on GDD, they have proposed applications being timed around 200 GDD (base temperature zero degrees C). Repeated applications can be made on 200 GDD increment, or the GDD is reset to zero and accumulation starts again.

When creating or using a GDD model, be aware of the method used to calculate GDD, the temperature units used (Fahrenheit or Celsius), the base temperature and the start date used.

Karl Danneberger, Ph.D., *Golfdom's* science editor and a professor at The Ohio State University, can be reached at danneberger.1@osu.edu.

Will my putting green turf survive winter?

Jim Skorulski is a USGA Senior Agronomist in the Northeast Region. Jim has made over 2,000 Course Consultation Service visits in over 20 years of service with the USGA. Jim can be reached at j Skorulski@usga.org.

Q What has this winter been like so far in the Northeast?

There have been at least three severe temperature swings that occurred since November with the last occurring in January when temperatures in many areas reached the upper 50s and then plummeted into single digits or lower within a 48 hour period. Currently, most golf courses in the southern part of the Region are clear but those in more northern parts of the region and in Canada are not. There are reports of significant ice layers present in those areas.

Q Has the turf survived the winter so far?

Yes, as of the end of January the reports from the field have been positive. This is based on a limited number of superintendents who have grown out turf plugs taken from greens. This is great news but we all know there is plenty of winter ahead and it is impossible to predict what might happen going forward.

Starting about mid-February the health of annual bluegrass can change rapidly as it begins to deacclimate and becomes more susceptible to rapid drops in temperature.

Q Are there any other diagnostic tools to help a superintendent determine if the turf has survived?

The only definitive way to tell if the

turf has survived is to pull turf plugs and bring them indoors to see if they grow. This is a reliable technique, provided the plugs are taken from a representative area of the green.

We also recommend monitoring for the presence of an anoxic or anaerobic condition beneath the ice. It can occur fairly quickly under some circumstances, such as when the ground is not fully frozen, or soils are high in organic matter. A distinctive odor will be present that has been termed the "smell of death." Begin monitoring for the condition under ice sheets that have been in place for three to four weeks, especially on greens that have a history of low temperature injury.

Q Should a superintendent consider removing accumulated snow/ice from greens?

There are no guarantees when it comes to snow and ice removal from greens. There is always risk involved when the covered turf is exposed to lower temperatures, knowing that hardiness of those plants may be compromised. Removal of an ice layer should be considered on annual bluegrass greens if it is creating an anoxic condition. Initiate the work based on a favorable forecast for moderate day and night time temperatures. A winter cover or snow can sometimes be used to protect recently exposed surfaces.

Q What are your thoughts about drainage as the snow and ice melt?

It is critical to keep water from collecting on the surfaces whenever possible. Open paths through snow and ice layers that impede water flow from the surface. Be sure that any snow that

is cleared from the surface is piled far enough away from a green so that snowmelt does not flow back onto the green.

Q Anything else you would like to add?

Hopefully, our luck will continue through the rest of the winter season. However, if you end up having to deal with damaged playing surfaces, it is critical to be out front with the problem with club officials, golfers

"SOME SUPERINTENDENTS CALL THESE ODORS THE 'SMELL OF DEATH.'"

and other professional staff at your facility. Develop a sound recovery plan, procure the necessary resources and be realistic when estimating the length of the recovery process and importance of using temporary greens. Finally, it is a good idea to get the irrigation system charged up early if you expect some degree of damage has occurred. Early season irrigation may be critical to the survival of the weakened plants and a necessity for the establishment program.

Editor's Note

Jim Ross and his colleagues at the Prairie Turfgrass Research Centre at Olds College in Alberta, Canada conduct winter injury research on turfgrass and their information can be found at <http://www.oldscollege.ca/ptrc/home.html>.



Clark Throssell, Ph.D., loves to talk turf. Contact him at clarkthrossell@bresnan.net.

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NEW PRODUCT HIGHLIGHTS // **HERBICIDES**

HERBICIDES TO THE RESCUE

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BY **SETH JONES** // *Editor-in-Chief*

1. Clipper

Clipper Aquatic Herbicide from **VALENT PROFESSIONAL PRODUCTS** is now available for use by superintendents. Clipper controls many tough aquatic plants including duckweed and watermeal, and has activity on some algae. It's easy to handle, easy to mix and easy to apply. It also provides consistent results: Activity is observed within three to five days after application. Available in a convenient new 1-lb. package, Clipper dissipates quickly from the water column and does not accumulate in the sediment. It has minimal irrigation restrictions and does not require perfect coverage for

maximum results. Available as a water dispersible granule for easy mixing, transport and application, Clipper can be easily applied to small ponds with a backpack sprayer from the shoreline.

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2. Katana

University trials prove **PBI GORDON'S** Katana Turf Herbicide controls grassy and broadleaf weeds with postemergent and some preemergent activity. Highly selective in Bermuda, zoysia, centipede and buffalo grasses and seashore paspalum, Katana controls a much broader spectrum of grassy and broadleaf weeds

WHILE AT THE SPORTS TURF MANAGERS

ASSOCIATION CONFERENCE & EXPO last month, we ran into Jared A. Hoyle, Ph.D., assistant professor and extension turfgrass specialist at Kansas State University. The native North Carolinian reports that he's enjoying having Kansas as his new turf region. For a video interview with Hoyle, visit Golfdom.com. While we had him, we also asked him for some key advice on applying herbicides. See below for his top tips.

than other products of its type, especially in cooler weather, the company says. pbigordon.com

3. Tribute Total

From **BAYER CROPSCIENCE**, Tribute Total post-emergent herbicide can now be used on zoysiagrass. It delivers broad-spectrum control in one complete solution to help golf course superintendents selectively remove troublesome grassy and broadleaf weeds, sedges and kyllingas. Approved for use on bermudagrass and now zoysiagrass, it is effective against 55 grassy and broadleaf weeds including dallisgrass, crabgrass, and yellow and purple nutsedge. At a use rate range of 1 to 3.2 oz. per acre, each 6-oz. container of Tribute Total treats between 1.875 and 6 acres. After application, the product is readily absorbed by the foliage and carried to the site of action in the growing points of the susceptible weed. Additionally, with a 60.5% water-dispersible granule formulation, Tribute Total requires less storage space, transportation, and less frequent container disposal. backedbybayer.com

4. Hammerkop HydroCap

Featuring an encapsulation technique, Hammerkop HydroCap is a water-based formulation of pendimethalin with improved mixing and handling characteristics. This exclusive formulation from **PHOENIX BRANDS BY UPI** also reduces odor and potential staining. Hammerkop HydroCap contains 3.8 lbs. of pendimethalin per gallon to control more than 45 troublesome weeds and grasses including: henbit, spurge, *poa annua*, crabgrass, goosegrass and oxalis plus 40 more. Hammerkop HydroCap is labeled for use on golf courses, sod farms, athletic fields, commercial and residential lawns and landscapes, Christmas tree and other tree nurseries, field and container nurseries as well as non-crop areas. phoenixenvcare.com

TIPS FROM DR. HOYLE

- Always remember that the best weed control is a healthy turf stand.
- Remember to apply at the proper timing. (At the correct growth stage of the weed.)
- Always keep records so you can look back at what chemistries and rates you used in the past.
- It's never a bad idea to have a check plot to see what would have happened if you did not apply the herbicide. Keeping a check plot in a similar area of turf can let you compare the two and see if the results were worth the money and effort.



CONTINUED ONLINE

For more listings of herbicides, go to: golfdom.com/category/products