USGA GREEN SECTION

RECORD

A publication on Turfgrass Management September-October 2007

Soil Fertility and Turfgrass Nutrition 101

Contents

September-October 2007 Volume 45, Number 5

USGA

USGA President
Walter W. Driver, Jr.

Executive Director
David B. Fay

Green Section Committee Chair
Patrick W. McKinney
37 Legare Street
Charleston, SC 29401

Turfgrass Environmental Research Chair
Steve Smyers
2622 W. Memorial Blvd.
Lakeland, FL 33815

Editor
James T. Snow

Associate Editor
Kimberly S. Erusha, Ph.D.

Cover Photo
Turfgrass fertilization is both an art and a science, but these days more emphasis needs to be placed on the science.

Soil Fertility and Turfgrass Nutrition 101

Some important concepts you might have missed in or outside of the classroom.

BY JAMES H. BAIRD

Few would dispute that there are both an art and a science to growing high-quality turf. However, these days it seems that soil fertility and turfgrass nutrition practices are becoming less scientific and more illogical than artistic.

While science continues to move forward, it appears to me that most of the new theories or so-called *advancements* are professed by companies or individuals who stand to gain by selling their products or consultation services. Most turf managers won't hesitate to apply a new product if they believe that it won't hurt anything and could only help their situation. Unfortunately, applying the wrong nutrient or too much of a nutrient can result in deficiencies of other nutrients, greater potential for disease outbreak due to changes in soil acidity, or perhaps unfavorable changes in soil physical properties. Given today's uncertain economy and increased scrutiny over chemicals applied in the turfgrass environment, all turf managers need to re-evaluate their fertilization practices by using science as the foundation upon which personal experience and *feel* are built.

Soil fertility and plant nutrition are complex subjects, but they're far from incomprehensible. An article of this length cannot begin to address all of the basic principles of soil fertility and turfgrass nutrition. Rather, the objective is to help

Table 1
General trends of soil pH on nutrient availability and various turf problems.

< 5.0	5.0 – 5.5	5.5 – 6.0	6.0 – 6.5	6.5 – 7.0	7.0 – 7.5	7.5 – 8.0
	Deficiency (<5.5) Nitrogen Phosphorus Potassium Magnesium Molybdenum Sulfur					**Deficiency (>7.5)** Phosphorus Iron Manganese Boron Copper Zinc
	Disease (>5.3) Spring dead spot		**Disease (>6.0)** Summer patch	**Disease (>6.5)** Pink snow mold Take-all patch		
Al, Mn Toxicity (<5)	Thatch Accumulation (<5.5)					N (urea) Volatilization (>7.5)

simplify several concepts that are critical to ensuring turf health and both environmental and fiscal responsibility. Emphasis will be placed on soils and turfgrass nutritional needs in the Northeast, although the principles will apply more broadly. For more information, please see the references that follow. Let's begin our lesson.

TAKE CHARGE OF YOUR SOIL TESTING PROGRAM

Before applying any nutrient, it's important to determine which ones are deficient and in what amounts. Nutrient deficiencies, including nitrogen (N), iron (Fe), and phosphorus (P), are sometimes visually detectable to the well-trained eye, although quantification of the supplemental amount required is difficult if not impossible. Tissue testing provides a much more objective and quantitative evaluation of the nutritional status of the plant. However, more research is needed to correlate nutrient levels in tissue with turfgrass response. Tissue testing is best used as a diagnostic procedure since a plant must be under nutrient stress for a deficiency to show.

Although far from perfect, soil testing remains the most common and best method of determining the nutrient availability to the turfgrass plant since it attempts to identify potential problems before they occur. Judging by the number of turf managers who hire soil consultants or the number of times I have been asked to interpret reports, I gather that many turf managers are uncomfortable with deciphering soil test results. In the reference section, several articles address soil testing in one capacity or another. The four principal components of soil testing are: 1) sampling, 2) laboratory analysis, 3) interpretation of results, and 4) recommendations for chemical changes, if needed.

DON'T UNDERESTIMATE THE IMPORTANCE OF PROPER SAMPLING

Improper sampling for soil testing can be one of the greatest sources of error in soil testing programs. A few things to keep in mind about soil sampling are: 1) take at least 20 sub-samples (cores) of a representative area to be pooled, mixed, and sampled for testing; 2) sample at a uniform depth (e.g., usually 2 to 4 inches for putting greens; 3) if a true thatch or topdressing layer is present, consider subdividing each core into thatch or mat and underlying soil to determine chemical and nutrient properties of each component; and 4) sampling time and frequency are important for determining consistency of test results and effectiveness of fertilizer applications. Chemical change following fertilization can occur within days or weeks in sandy soils compared to months or years in clay soils. In the Northeast on sand-based greens or tees, consider sampling in spring, prior to aeration, and again 6-8 weeks after fertilization with granular formulations as a follow-up analysis. Sample once again 6-8 weeks following aeration and fertilization in late summer.

BE CONSISTENT WITH LABORATORY ANALYSES

Several university and commercial laboratories are available for soil sample analysis. Be cautious about analyses and recommendations that are offered free of charge from fertilizer manufacturers or turf distributors. Also, it is important to know that results are likely to vary from laboratory to laboratory due to different extraction methods and chemicals used for analyses. See the articles by Carrow et al. (2003 and 2004) that describe differences among soil analytical procedures. For the sake of your soil testing program, it is important to choose a laboratory that uses procedures and nutrient ranges that are appropriate for the soil types on your golf course. Once that information is gathered, the important thing is to use the same laboratory year in and year out to analyze trends in nutrient availability and deficiencies.

YOU TOO CAN INTERPRET A SOIL TEST REPORT

Interpretation from the laboratory or a consultant aside, every turf manager should feel comfortable with understanding soil test results. The following is a description of information likely to be found on a soil test report in the Northeast.

Soil Acidity or pH

Soil acidity or pH is the negative logarithm of the hydrogen ion concentration on a scale from 0 to 14, with 7 being neutral (concentration of hydrogen ions equals hydroxide ions). Table 1 shows a diagram of nutrient deficiencies and other turf problems that are likely to occur at varying pH levels. In general, soil acidity at or near neutrality ensures maximum availability of all essential nutrients in the soil. This pH range favors the nutrients being in a plant-available form. This is one of the simplest and most important principles to remember about soil fertility and plant nutrition.

Lime Requirement

Lime requirement is the quantity of limestone ($CaCO_3$) required to raise the pH of an acid soil to a desired level. A buffer solution is added to the soil to determine buffer pH. The value itself is not significant to the turf manager, but it is instead used by the lab to determine liming rate recommendations, when necessary. The ability to lower pH of alkaline soils with the addition of sulfur or acid is largely dependent upon free lime present in the soil, with higher quantities providing greater buffer capacity against pH change. Thus, it is not recommended that pH reduction be attempted in soils with even a low percentage of lime due to the very large acid quantities required and the potential for turf injury.

SOLUBLE SALTS

Measurement of soluble salts is especially important for determining salinity on salt-affected soils. Electrical conductivity (ECe) is reported in units of decisiemens/meter (dS/m) or millimhos/centimeter (mmhos/cm). An ECe above 4.0 dS/m is considered saline. The saturated paste extract (SPE) is considered to be the standard procedure for measuring ECe, sodium absorption ratio (SAR), and boron (B) concentration. Although not typically reported on a test in the Northeast, the SAR is a measure of the potential for excess sodium (Na) to cause structural deterioration of soil. SAR levels above 12 are considered problematic for soil and plant health, whereas ideal levels should be 3 or lower. If soil tests reveal problems with soluble salts or Na, it is important to have the water source tested and seek help from a qualified consultant or university specialist.

Soil test results are likely to generate very different results when samples are taken at varying depths. In the case of a longer soil sample, separate and analyze the upper sandy portion of the profile separately from the mineral soil below.

ESSENTIAL NUTRIENTS

Laboratories use chemical extractants to estimate the levels of soil nutrients that are readily available to plants. Values are reported in parts per million (ppm) or pounds per acre (lbs/A). In addition, most labs will categorize each nutrient in terms of availability to the plant from below optimum to above optimum, or very low to very high. This method is referred to as the sufficiency level of available nutrients (SLAN), which attempts to correlate plant response to extractable soil nutrients. Although it could be said that there are limited data directly correlating soil nutrient levels with specific and desirable

Table 2
Essential nutrient elements, their function, and potential for deficiency or toxicity in plants.

Essential Macronutrient	Chemical Symbol	Plant-Available Form	Primary Role	Mobility in Plant	Frequency of Deficiency in Turfgrasses	Deficiency Occurrence	Toxicity or Excessive Occurrence
Carbon	C	CO_2	Many	—	Sometimes	Drought stress	—
Hydrogen	H	H_2O	Many	—	Sometimes	Drought stress	—
Oxygen	O	CO_2 / O_2	Many	—	Sometimes	Compaction; waterlogged conditions	—
Nitrogen	N	NO_3^- NH_4^+	Constituent of amino acids, amides, proteins, nucleic acids, nucleotides, coenzymes, etc.	Mobile	Common	Sandy soils; high leaching; clipping removal; denitrification; low pH (<4.8)	Salt toxicity; excessive growth; succulence
Phosphorus	P	$H_2PO_4^-$ HPO_4^{-2}	Component of sugar phosphates, nucleic acids, nucleotides, coenzymes, phospholipids, etc.; key role in reactions involving ATP	Mobile	Sometimes	Sandy, low CEC, irrigated soils; low pH (<5.5); high pH (>7.5-8.5); high clay content soils; subsoils; high P demand during establishment; reduced uptake in cold soils; clipping removal	Excessive P may induce Fe deficiency under some conditions
Potassium	K	K^+	Required as a cofactor for many enzymes; stomatal movements; maintains electroneutrality in plant cells	Mobile	Sometimes	High rainfall or leaching; sandy or low CEC soils; acidic soils (pH<5.5); clipping removal; sites receiving high Ca, Mg, or Na additions; under high N fertilization; soils high in vermiculite, illite, or smectite at high pH	Salinity stress; suppresses Mg, Ca, or Mn uptake; fertilizer burn
Calcium	Ca	Ca^{+2}	Constituent of middle lamella of cell walls; required as a cofactor by some enzymes	Immobile	Rare	Low pH (<5.5) conditions on low CEC soils receiving high Na levels or with high Al, Mn, or H; high leaching; true deficiencies are most probable in root rather than shoot tissues	Excessive Ca can induce Mg, K, Mn, or Fe deficiencies
Magnesium	Mg	Mg^{+2}	Constituent of chlorophyll molecule	Mobile	Sometimes	Low pH (<5.5); sandy soils due to low CEC and high Al, Mn, H; under high Na, Ca, or K addition; high leaching	Excessive Mg can induce deficiencies of K, Mn, and Ca
Sulfur	S	SO_4^{-2}	Component of some proteins	Somewhat mobile	Sometimes	Low OM; sandy, low CEC soils; high rainfall and leaching; low atmosphere additions; high N with clipping removal	Foliar burn; induces extreme acidity in soils not buffered by free lime; contributes to black layer under anaerobic conditions
Iron	Fe	Fe^{+2} Fe^{+3} Fe-chelates	Constituent of cytochromes and nonheme iron proteins involved in photosynthesis, N_2 fixation, and respiration	Immobile	Common	High pH (>7.5); poor rooting; excessive thatch; cold and wet soils; high soil P at high pH; high pH calcareous soils in arid regions; irrigation water with high HCO_3, Ca, Mn, Zn, P, or Cu; low OM soils, heavy metals from sewage sludge	High foliar Fe can blacken leaves, possibly causing tissue injury; can induce Mn deficiency; acidic, poorly drained soils can produce toxic levels of soluble Fe for roots
Manganese	Mn	Mn^{+2} Mn-chelate	Required for activity of enzymes and photosynthetic evolution of O_2	Immobile	Sometimes	High pH, calcareous soils; peats and muck soils that are at pH>7.0; dry, warm weather; high levels of Cu, Zn, Fe, Na, especially on leached, low CEC soils	Toxicity to roots in acidic soils (pH<4.8); anaerobic soils, high Mn levels can induce Ca, Fe, and Mg deficiencies; Si and high temperatures increase plant tolerance to Mn toxicity
Zinc	Zn	Zn^{+2} $ZnOH^+$	Constituent of enzymes	Somewhat mobile	Rare	Alkaline soils; high levels of Fe, Cu, Mn, P, or N; high soil moisture; cool, wet weather and low light intensity; highly weathered, acidic soils	Some municipal wastes may be high in Zn; high Zn may cause chlorosis by inducing Fe or Mg deficiencies
Copper	Cu	Cu^{+2} $Cu(OH)^+$ Cu-chelate	Constituent of enzymes	Somewhat mobile	Rare	Strong binding of Cu on organic soils; heavily leached sands; high levels of Fe, Mn, Zn, P, and N; high pH	Toxic levels can occur from some sewage sludge or pig/poultry manures
Molybdenum	Mo	MoO_4^{-2} $HMoO_4$	Constituent of nitrate reductase, essential to N_2 fixation	Somewhat mobile	Rare	Deficiencies are usually on acid, sandy soils; acid soils high in Fe and Al oxides; high levels of Cu, Mn, Fe, S suppress uptake	Mo toxicities are important for grazing animals and are associated with high pH soils that are wet
Boron	B	H_3BO_3 BO_3^{-3}	Indirect evidence for involvement in carbohydrate transport	Somewhat mobile	Rare	High pH can induce deficiencies, especially on leached, calcareous sandy soils; high Ca can restrict B availability; dry soils; high K may increase B deficiency on low B soils	B toxicity is much more likely than deficiencies due to irrigation water high in B; soils naturally high in B; overapplication of B; use of some compost amendments
Chlorine	Cl	Cl^-	Required for photosynthesis reactions involved in O_2 evolution	Mobile	Never	Cl uptake is suppressed by high NO_3^- and SO_4^{2-}	Cl is a component of many salts that can be directly toxic to leaf tissues and roots; more often it reduces water availability by enhancing total soil salinity
Nickel	Ni	Ni^{+2}	Essential part of enzyme urease, which catalyzes hydrolysis of urea to CO_2 and NH_4^+	—	Never	Conditions associated with Ni deficiency are not clear due to the rare occurrence of Ni deficiency	Ni toxicity can arise from use of some high Ni sewage sludges

Adapted from Carrow et al., 2001

responses of all of the turfgrass species, overall SLAN has been the most tried and true method for estimating plant-available nutrients.

Remember, the numbers that you see on your report and the associated sufficiency levels are based upon factors such as type of extractant used and the specific sufficiency index chosen for interpretation. The articles by Carrow et al. (2003 and 2004) contain information about what are considered medium ranges for various nutrients based on the extractant used. It is possible that the recommended range provided in your report is so high that almost every situation would indicate fertilizer need. It is all right if a lab uses a slightly different range as long as it brackets the ranges provided in the articles. Your decision, whether or not to apply fertilizer based on these results, should take into account the likelihood for nutrient deficiencies to occur in your situation (see Table 2) as well as existing turfgrass health and performance.

Cation Exchange Capacity and Base Cation Saturation

Soils have a net negative charge, which attracts positively charged ions. Thus, cation exchange capacity (CEC) is a measure of the amount of cations that a soil can hold at a given pH that are potentially exchangeable for plant uptake. CEC is often expressed on a weight basis as milliequivalents (meq) per 100 grams of dry soil or centimoles per kilogram (cmol/kg). A 100 g sample of soil with a CEC of 1 meq (considered very low) contains 6.02×10^{20} (602,000,000,000,000,000,000) negative charge sites. Without other information about a sample, knowledge of the CEC can provide some indication of the soil texture. Sands with low organic matter by weight (1-2%) typically have very low CEC values ranging from 1-3 cmol/kg, whereas most clay or clay loam soils are 20 cmol/kg or greater.

The CEC is the sum total of basic or base (K^+, Ca^{+2}, Mg^{+2}, and Na^{+2}) and acidic (Al^{+3} and H^+) cations. The amount of each listed in the report, divided by the CEC, is the saturation of that ion. It appears that a majority of turf agronomic consultants (excluding the USGA Green Section and university scientists) subscribe to the Basic Cation Saturation Ratio (BCSR) theory for interpretation of soil test results and fertilizer recommendations. The theory is based upon having a base saturation of 80% comprised of 65% Ca, 10% Mg, and 5% K. Fertilizer recommendations are made to attain not only these percentages, but also desired balances between any combinations of the nutrients. Having listened to presentations by those who purport this "feed the soil" theory, I am not surprised that a significant number of turf managers buy into this theory, as it is an impressive display of pseudoscience and salesmanship.

Unfortunately, the BCSR theory is largely unfounded, and those who attempt to balance soil cations on a routine basis are simply wasting their time and the club's money. To be more specific, subscribing to the BCSR theory will likely lead to the following: 1) Increased fertilizer recommendations and usage that are not necessary relative to the SLAN method. 2) Raising base saturations in sand-organic matter soils to near 80% can result in a significant increase in soil pH, which may lead to other problems such as greater incidence of take-all or summer patch diseases. 3) When relying on percentages rather than quantities of nutrients present in the soil, it is possible to have a sub-optimum percentage of a basic cation such as K^+ but sufficient levels of extractable K^+ or vice versa. 4) The theory often overestimates soil Ca and underestimates soil CEC in greens or other areas containing calcareous sands or after continuous irrigation with Ca- and Mg-rich water. 5) It usually results in over-application of one base cation, which in turn depletes the availability of the others. Overall, Ca and Mg deficiencies are rare in plants except in unusual circumstances (Table 2).

Until recently, the BCSR theory has not been tested on turfgrass. However, research conducted thus far further substantiates the lack of validity of the theory. When appropriate amounts of basic cations are applied, based on sufficiency data, the percent levels of cations adjust naturally according to soil type. Does all of this mean that the CEC and base cation saturation data should be ignored? Not necessarily. This information can be useful for managing salt-affected soils (i.e., high Na) and as a supplement to sufficiency levels to help determine and evaluate fertility programs.

Soil Nitrogen

Your soil testing laboratory may or may not report tests of soil N because most forms of this nutrient fluctuate too rapidly in the plant-soil system to be accurate and reliable predictors of available N. However, there is hope on the horizon with utilization of the Illinois Soil Nitrogen Test. The test, which predicts a more stable amino form of N, has been developed for use in production agriculture and currently is being used to predict either N fertility needs for turfgrass, or identify turfgrass areas that have increased potential for nitrate leaching if N fertilizer is applied. In the meantime, fertilizer recommendations for N are based on turf response and are adjusted by the turf manager depending on factors such as turfgrass species composition (e.g., *Poa annua* versus bentgrass), traffic, disease susceptibility, and environmental stress conditions.

ROOTS ARE THE PRIMARY SITE OF NUTRIENT UPTAKE

These days I hear a lot about foliar nutrient applications and products touted as being truly foliar in function. While nutrients can be taken up by shoots, primarily through trans-cuticular pores, let's not forget that foliar uptake of nutrients is minor compared to the effectiveness of the root system. When you think about it, the leaf is engineered to absorb light and prevent water loss. Factors that are likely to limit foliar uptake include cuticle thickness, rapid drying before uptake, removal by mowing or precipitation, and volatility. Last but not least, true foliar feeding requires a low volume of water (<1 gallon per 1,000 ft^2) for retention of spray droplets in the foliage; conversely, most turf managers that I know use higher sprayer carrier volumes to distribute turf protectants deeper into thatch or the underlying rootzone.

Sometimes it can be difficult to differentiate between a nutrient deficiency and a disease or insect problem. Examine the turf thoroughly. In this case, damage from the annual bluegrass weevil caused yellowing of the turf.

There is no doubt that light and frequent nutrient application is important in turfgrass nutrient management, especially on putting greens and other intensively managed areas. Call it semantics, but the term liquid fertilization would better describe the practice whereby nutrients are sprayed on the foliage, since uptake can occur by both shoots and roots. The bottom line is, how much are you spending for your "true foliar" fertilizer?

NITROGEN UPTAKE

Nitrogen is taken up by the plant primarily in the forms of ammonium (NH_4^+) and nitrate (NO_3^-) ions and to a lesser extent as urea, which are then assimilated into amino acids and other important N compounds for growth and metabolism. The question then becomes, is it better or more efficient for plants to circumvent this process and absorb amino acids directly? Although uptake of amino acids is possible, my search of the literature revealed only a scant reference to amino acid uptake by arctic sedge! Yet again I pose the question, how much are you spending for products containing amino acids and other biostimulants? More research and product testing are needed to justify both the cost and efficiency of supplying nutrients to turf using products like these.

GET THE MOST OUT OF LATE-SEASON FERTILIZATION

Late fall, or what some call "dormant" fertilizer applications, are typical on cool-season turf in northern, temperate climates. The ultimate goal of late fall fertilization is to supply N to the plant for carbohydrate storage, which can enhance stress tolerance and early spring root growth. Additional benefits include early spring greenup and reduced need for early spring fertilization, which can further enhance shoot growth and increase mowing frequency. Since soil temperatures remain warmer than the air in the fall, roots are capable of taking up nutrients even though shoot growth has essentially ceased. At the same time, photosynthesis can still be active.

Disease or over-application of fertilizer? The granules tell the story.

Thus, proper timing is achieved between the time of the first hard freeze and continuous snow cover or ground freezing when true plant dormancy occurs.

Slow-release forms of N, including natural organics, are commonly applied in the late fall to avoid an unwanted flush of growth in the unlikely event that temperatures rise to above normal. Unfortunately, depending on the carrier, much of the N is not likely to be available to the plant until the following spring, which defeats the purpose of promoting root rather than shoot growth. Furthermore, N may be lost in runoff or leached into groundwater.

It would be better to apply soluble, readily available forms of N such as ammonium sulfate to ensure maximum root uptake and carbohydrate storage in late fall. If slow-release N sources are to be used, then application should be timed earlier in the fall, when warmer temperatures permit availability and root uptake. Less than 1.0 pound of N per 1,000 ft^2 applied when the turf is able to take up and utilize N will help to avoid potential losses due to leaching or runoff. There is little evidence that late fall application of N contributes to low-temperature injury of cool-season turfgrasses as long as proper rates and timing are followed. On the other hand, late fall N fertilization may enhance snow mold activity on turf without a preventative fungicide application; however, the added N can also help to hasten turf recovery from disease or other winter damage.

POTASSIUM FERTILIZATION: MORE IS NOT ALWAYS BETTER

In addition to its role in important physiological processes, K also influences tolerance to drought, cold, high temperature, wear, and salinity stresses. We also associate the term "luxury consumption" with K, in that tissue levels adequate for stress tolerance may be above what is considered

Liquid application can be an effective turf fertilization method, but be skeptical of claims that hype foliar uptake when root uptake is more common.

sufficient for growth. Knowing this, it appears that some turf managers have adopted the "more is better" approach and apply 2-3 or more times more K than N on an annual basis. With the exception of situations involving salt-affected soils and salt-tolerant species, research has demonstrated optimal turfgrass stress tolerance when soil K is maintained in the sufficient range. Remember that excessive K can contribute to salinity stress; suppress Mg, Ca, or Mn uptake; and promote greater incidence of snow mold diseases.

SUMMARY

Soil fertility and turfgrass nutrition can be daunting subjects to many turf managers. I hope this article has helped to clarify and simplify key principles and practices, and has empowered you, the turf manager, to take charge of your turfgrass nutrient program. It doesn't require a lot of money or guessing to meet the nutritional needs of your turf. Let science be your teacher.

REFERENCES

Carrow, R. N. 1995. Soil testing for fertilizer recommendations. Golf Course Management. 63(11):61-68.

Carrow, R. N., D. V. Waddington, and P. E. Rieke. 2001. Turfgrass soil fertility and chemical problems: Assessment and management. Wiley, Hoboken, N.J.

Carrow, R. N., L. Stowell, W. Gelernter, S. Davis, R. R. Duncan, and J. Skorulski. 2003. Clarifying soil testing: I. Saturated paste and dilute extracts. Golf Course Management. 71(9):81-85.

Carrow, R. N., L. Stowell, W. Gelernter, S. Davis, R. R. Duncan, and J. Skorulski. 2004. Clarifying soil testing: II. Choosing SLAN extractants for macnutrients. Golf Course Management. 72(1):189-193.

Carrow, R. N., L. Stowell, W. Gelernter, S. Davis, R. R. Duncan, and J. Skorulski. 2004. Clarifying soil testing: III. SLAN sufficiency ranges and recommendations. Golf Course Management. 72(1):194-197.

Chapin, F. S. III, L. Moilanen, and K. Kielland. 1993. Preferential use of organic N for growth by a non-mycorrhizal arctic sedge. Nature. 361:150-153.

Gardner, D., and B. Horgan. 2006. 2006 Turfgrass and Environmental Research Summary. p. 15.

Happ, K. A. 1994. Tissue testing: Questions and answers. USGA Green Section Record. 32(4):9-11.

Happ, K. A. 1995. Sampling for results: The methods are important. USGA Green Section Record. 33(5):1-4.

Kopittke, P. M., and N. W. Menzies. 2007. A review of the use of the base cation saturation ratio and the "ideal" soil. SSSAJ. 71(2):259-265.

Kussow, W. R. 2000. Soil cation balance. The Grass Roots. 29(2):58-61.

Marschner, H. 1995. Mineral nutrition in higher plants. Academic Press, New York, N.Y.

Skorulski, J. E. 2001. Unlocking the mysteries: Interpreting a soil nutrient test for sand-based greens. USGA Green Section Record. 39(1):9-11.

Skorulski, J. E. 2003. Digging deeper into soil nutrient testing. Tee to Green. 33(1):3-5.

Skorulski, J. E. 2003. Micro-managing. USGA Green Section Record. 41(5):13-17.

St. John, R., and N. Christians. 2007. Basic cation ratios for sand-based greens. USGA Turfgrass and Environmental Research Online. 6(10):1-9.

Taiz, L., and E. Zeiger. 1991. Plant physiology. Benjamin/Cummings. Redwood City, Calif.

Woods, M. S. 2006. Nonacid cation bioavailability in sand rootzones. Ph.D. dissertation. Cornell University, Ithaca, N.Y.

THANKS TO *Drs. Robert N. Carrow, University of Georgia; Paul E. Rieke, Michigan State University; and James A. Murphy, Rutgers University; for their assistance.*

JIM BAIRD *is a Green Section agronomist in the Northeast Region, where he visits golf courses in Connecticut, New Jersey, New York, and Ontario, Canada.*

USGA Sponsored

Research *You Can Use*

Dew the Right Thing

Superintendents often remove dew from fairway turf during the early morning as a courtesy to golfers, but are there more benefits to this practice than golfer satisfaction?

BY ALEX ELLRAM, B. HORGAN, AND B. HULKE

For years, superintendents have dragged ropes, hoses, chains, and nets across fairway turf to remove the heavy dew that annoys early morning golfers. Dragging is employed on mornings when fairways are not mowed, usually every other day. Experienced superintendents have noticed that the last fairways to be mowed or dragged are the fairways that tend to develop the most severe dollar spot problems. Is there an explanation for this relationship between dew removal and dollar spot?

Dollar spot, caused by the fungus *Sclerotinia homoeocarpa*, is the most common disease observed at golf courses that maintain cool-season turf species. The fungus infects turf at temperatures from 59°F to 86°F and is capable of causing damage throughout most of the golf season. As a result, multiple fungicide applications are needed to maintain an acceptable level of turf quality during periods of intense disease activity. An important cultural method of limiting dollar spot is to reduce the time that leaf tissue remains wet, often referred to as leaf wetness duration.[1,2,3]

Dollar spot is the most common disease seen on cool-season golf course turf. It requires long periods of leaf wetness to infect leaf tissue.

EXPERIMENTAL DESIGN

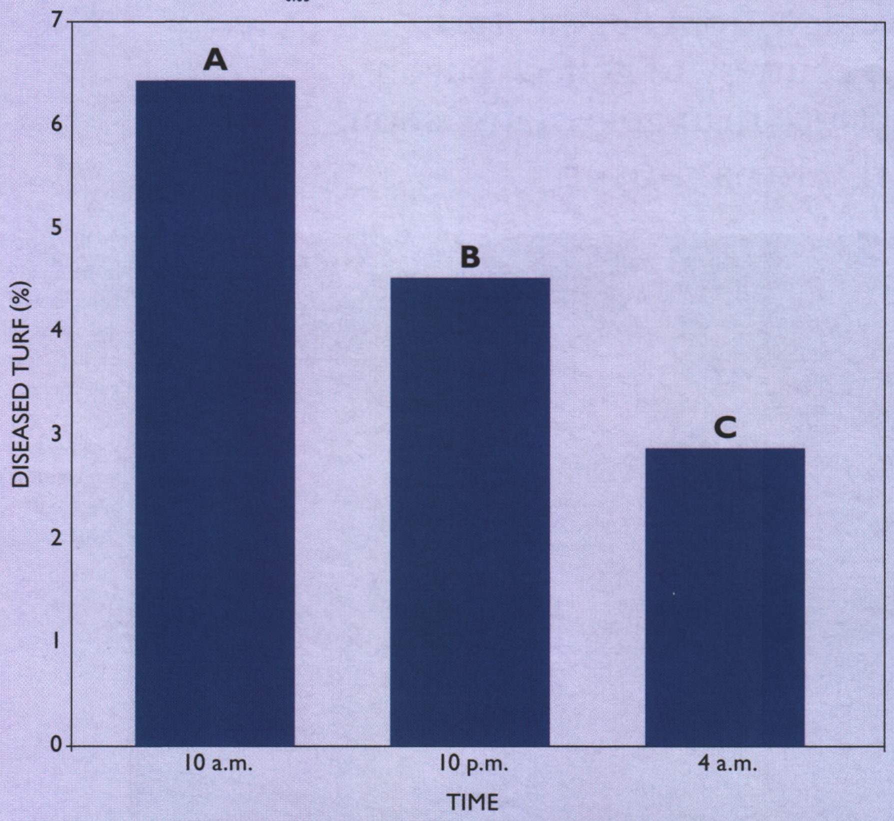
The objectives of the field study were to determine the effects of different mowing times (4 a.m., 10 a.m., or 10 p.m.) on leaf wetness duration (dollar spot incidence) of creeping bentgrass/annual bluegrass turf, determine the effect of daily mowing versus mowing every other day, the effects of dragging versus mowing, and the effects of using a sharp versus dull mower (Table 1).

Table 1
Dollar spot mowing study treatment combinations.
Treatments 7-9 = mowing or squeegee on alternate days for daily dew removal.

Treatment	Mowing Time	Blade Sharpness	Dew Removal Method	Mowing Frequency
1	4 a.m.	Sharp	Mower only	Daily
2	10 a.m.	Sharp	Mower only	Daily
3	10 p.m.	Sharp	Mower only	Daily
4	4 a.m.	Dull	Mower only	Daily
5	10 a.m.	Dull	Mower only	Daily
6	10 p.m.	Dull	Mower only	Daily
7	4 a.m.	Sharp	Mower 3X Dew squeegee 4X	Daily (alternate methods)
8	10 a.m.	Sharp	Mower 3X Dew squeegee 4X	Daily (alternate methods)
9	10 p.m.	Sharp	Mower 3X Dew squeegee 4X	Daily (alternate methods)
10	4 a.m.	Sharp	Mower only	3X/week
11	10 a.m.	Sharp	Mower only	3X/week
12	10 p.m.	Sharp	Mower only	3X/week
13	4 a.m.	Dull	Mower only	3X/week
14	10 a.m.	Dull	Mower only	3X/week
15	10 p.m.	Dull	Mower only	3X/week

Figure 1
Actual mean percent diseased area by mowing time for all disease assessment dates.

Each mean is averaged across all dew removal methods. Means with different letters are significantly different ($LSD_{0.05}$) after means were log transformed to stabilize variance.

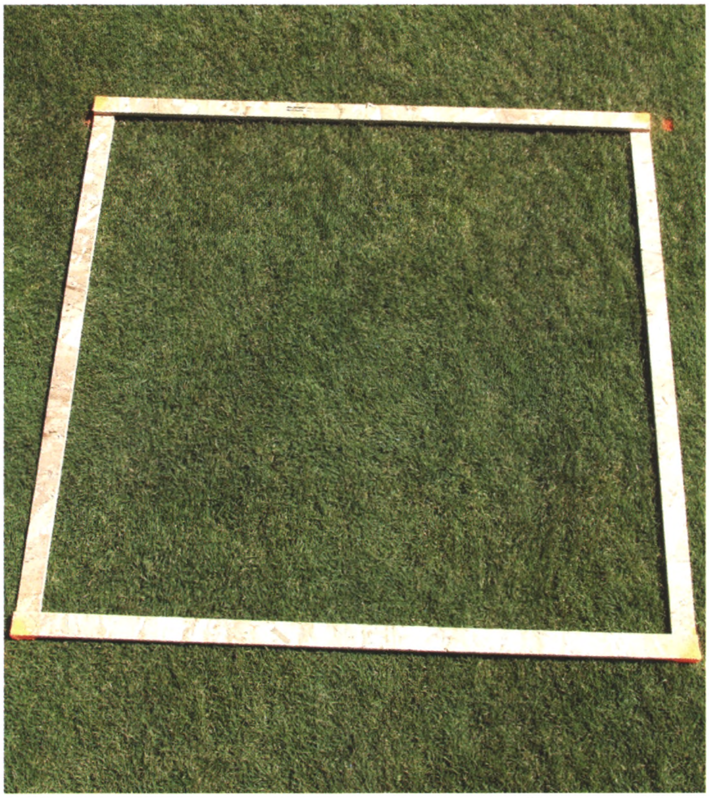


RESULTS AND DISCUSSION

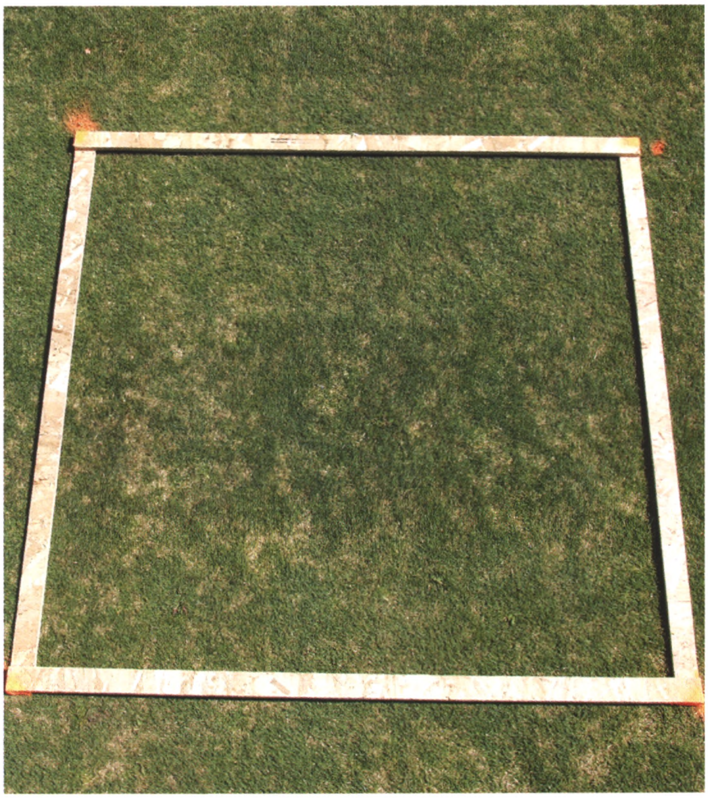
Mowing and squeegee treatments conducted at 4 a.m. significantly reduced dollar spot compared to treatments conducted at 10 a.m. and 10 p.m., and 10 p.m. treatments significantly reduced dollar spot compared to treatments at 10 a.m. (Figure 1).

Plots treated at 4 a.m. or 10 p.m. had a shorter duration of continuous leaf wetness, which reduced dollar spot. During these studies, dew typically set around 9 p.m. and lifted at 10 a.m., so removing dew at 4 a.m. typically divided the period of continuous leaf wetness in half. The 10 p.m. treatments reduced the leaf wetness duration only slightly by directly removing early-setting dew on some evenings and delaying dew set on other evenings. The 10 a.m. treatments had little or no effect on leaf wetness duration because dew had already evaporated by the time plots were treated. Daily dew removal resulted in less dollar spot infected turf than when treatments were conducted on alternate days, regardless of dew removal method.

Dragging fairways with hoses, ropes, nets, and chains is an early morning maintenance operation employed to remove dew from fairways on days the turf will not be mowed. Can these cultural practices help reduce disease pressure from pathogens that require long periods of leaf wetness to infect the plants and, in turn, reduce pesticide use?



Turf inoculated with dollar spot fungi developed minimal disease activity when mowed every day at 4 a.m. with a sharp mower. The treatment removed dew before the pathogen had an opportunity to infect the turf.



Turf inoculated with dollar spot fungi developed significant injury despite being mowed every day at 10 a.m. with a sharp mower. Under this treatment the dew remained on the turf long enough to allow infection of leaf tissue.

There was no difference in dollar spot incidence among plots that were mowed with a sharp mower blade and those with a dull one. This result contradicts the popular belief that dull mowers increase dollar spot because a dull mower blade shreds leaf tissue, weakening the plant and leaving more wounded tissue for pathogen invasion. The data also indicate that using a squeegee on alternate days was not as effective as mowing in reducing dollar spot. However, removing dew with a squeegee on alternate days still reduced dollar spot compared to not removing dew on alternate days.

Timing dew removal so that it divides the length of continuous leaf wetness in half and minimizes leaf wetness duration was most effective in reducing dollar spot. For dew removal, mowing was more effective than dragging a squeegee. Daily dew removal substantially reduced dollar spot as compared to dew removal on alternate days. Although mower blade sharpness impacted turf quality, dull mowers do not appear to increase dollar spot severity.

CONCLUSIONS

In practical terms, mowing and other dew removal methods should be done as early in the morning as possible. Dew should be removed daily by mowing or by other methods like dragging and rolling when mowing is impractical. Areas that are shaded and dry slowly in the morning should be given extra attention.

As environmental stewards, turfgrass managers should strive to reduce pesticide use in managing turfgrass diseases and other pests. Integrated approaches utilizing pesticides as a part of a management plan, supplemented by cultural and biological management methods, will help sustain healthy turfgrass and a healthy environment for future generations.

LITERATURE CITED

1. Huber, L., and T. J. Gillespie. 1992. Modeling leaf wetness in relation to plant disease epidemiology. *Phytopathology* 30:553-577.

2. Walsh, B. K. 2000. Epidemiology and disease forecasting system for dollar spot caused by *Sclerotinia homoeocarpa*. F. T. Bennett, Ph.D. dissertation, University of Guelph, Guelph, Ontario, Canada.

3. Williams, D. W., A. J. Powell, C. T. Dougherty, and P. Vincelli. 1996. Dollar spot on bentgrass influenced by displacement of leaf surface moisture, nitrogen, and clipping removal. *Crop Science* 36:1304-1309.

ALEX ELLRAM, PH.D., *(ellramar@cobleskill.edu) is an assistant professor in the Department of Plant Science, State University of New York, Cobleskill.* BRIAN HORGAN, PH.D., *is an associate professor in the Department of Horticultural Science, and* BRENT HULKE *is a research assistant in the Department of Agronomy and Plant Genetics at the University of Minnesota, St. Paul.*

The Voice of Experience

Making your staff feel important is the key to good crew management.

BY KENNETH A. GORZYCKI, CGCS

Without even being aware of it, I began developing my people skills long before I became a golf course superintendent. My first recollection of how to treat people in the work place came in the early 1970s when I was working on the maintenance crew at a municipal golf course in my home town in central Texas. There were only about four or five guys on the crew and we were "supervised" by the crew foreman, John. I am sure my perspective was rather slanted at the time, being a teenage kid working on my first golf course and my first *real* job, but my perception was very real to me and it had a great impact on who I became and how my career evolved.

I have to be honest — John was about the *worst* supervisor I have ever had, but I probably learned more valuable life lessons from him than anyone I have ever known besides my father. It was my impression at the time that all John did was ride around the course in his utility vehicle to make sure we were not sleeping under a tree. It was not like John could sneak up on anyone. He cruised the course in an old truckster that I am sure still had the original muffler, or what was left of it.

John never got closer than about 100 yards from us, never waved, never came over to say hello, and never asked how you were doing or to see if you needed some help. He just kept his distance and cruised right by you. At the time, I was young and naive enough to interpret his behavior as being distrusting, and I found it to be offensive and unmotivating.

So, as any typical brash teenage kid would probably do, I found myself loafing between John's rounds. Heck, I was not the only one. In fact, I was probably peer-pressured into that attitude from the older guys on the crew. We would slack off until we heard John's truckster approaching a couple of holes away, pick up the pace until he passed by, and then go back to slacking off again. I guess that was our way of getting even with him.

The classic story about John occurred on a day that Corky was push-mowing the creek bank on the right of the sixth hole; this was before the days of the Weedeater. John came into the shop that afternoon bragging about how hard Corky was working every time he came by. One of the things John did not know, nor was he told, was how Corky spent most of that day sleeping against a tree in the woods. When he heard John approaching, he hopped up and pushed that mower up and down the creek banks until John passed by. The funny part was that John never knew that the mower was never even running!

I finally realized my behavior was against my character and integrity. Just because I resented John's method of *supervision*, it did not justify my actions. Once I came to that realization, I made a conscious commitment to never treat my employees that way if I ever had the chance.

As chance would have it, I did have that opportunity several years later and I have never forgotten the valuable lessons I learned from John on how *not* to treat people.

Some of those valued lessons include:

1. Call your employees by name and make a sincere effort to wave and make eye contact whenever you see them.
2. Treat your employees with respect and honor.
3. Never embarrass an employee in front of others.
4. Clearly tell your employees what you want done and let them tell you how they plan to get it accomplished.
5. The best ideas come from the employees performing the tasks.
6. Do not ask your employee to do anything you are not willing to do or have not done yourself.
7. Let your employees know you are not too good to do their job and that you actually can do it.
8. Be dependable, honest, reliable, and consistent.
9. Do not play favorites.
10. Make your idea their idea and then give them the credit.
11. Be a better listener than a talker.
12. Employees work *with* you, not *for* you.
13. Always *ask* your employees to do things rather than *telling* them.
14. Support your employees' decisions and then coach them on how to do better the next time.
15. Leave home at home and work at work.
16. Avoid being buddies with your employees, but still have fun with them.
17. Always stay professional.
18. Lead by example.

When riding the golf course, I try to call the members and employees by name and visit with them whenever possible. Even if just passing by at a distance, I will at least make the effort to smile, wave, and make eye contact. This gives them an opportunity to get my attention if needed.

During my earlier years (more so than now), I would have the opportunity to assist the crew with their job assignments or give the crew a short break while I operated their equipment. I'd tell them to take my cart and go get a drink of water while I finish mowing their fairway or rough. This also gave me a chance to evaluate the performance of their piece of equipment and showed them I actually knew how to do what I assigned them to do.

A few times a year, I like to treat the employees to a staff appreciation day. This year, our Men's Golf Association board found out we were treating the crew and wanted to get involved to show their appreciation for all the crew does for them throughout the year. They donated enough additional funds to upgrade our menu to steaks, and they even volunteered to serve and wait on the staff during lunch at the maintenance shop. Some of them were surprised when they realized we had about 100 employees for them to serve. Several of them even donated gift cards and items for a crew drawing. That day made a huge impression on both the crew and the members. The crew now recognizes those members on the course, and the members enjoy that personal connection when they see those crew members on the course.

For foreign-speaking employees, little things like attempting to speak to them in their own language puts you on their level, shows respect for their culture, and shows that you care about who they are. Make the effort to get to know a little about your employee's family and show a genuine interest in their well-being.

I have always tried to take good care of my staff; it is a fact that I cannot be successful without them. Whenever my wife and I clean out our closet or the garage or buy a new appliance or piece of luggage, I bring the discarded items to the shop and give them to the crew. Clothes and toys for the kids are always the first items claimed. My mother even saves things for me to bring to the crew. When my dad passed away, everything in my dad's closet the family did not want was given to my crew — boots, watches, clothes, belts, you name it. Someone always finds a use for everything and there is never anything left at the end of the day.

During the scorching Texas summers, we provide packages of Gatorade mix for the crew to mix in their water coolers. Not only is it a small treat for the crew, but it also provides a little additional safety for the crew from the stress of the grueling summer heat.

I cannot emphasize enough the importance of performing employee reviews on schedule; it may be the single most beneficial thing you can do for your staff and yourself. If you bring it up to them, they will generally be grateful you care enough about them to make the time to do their review and get their merit increase on schedule without them having to ask. They know when their review is due and feel disrespected and mistreated if their review is missed or delayed. By the time they finally get around to asking you about it, they will probably be dissatisfied with whatever review or increase they may get.

Having a good relationship with your members and staff is really one of the most rewarding things you can do in this business. Don't do it for them . . . do it for yourself. Achieving successful relationships is the result of developing good communication habits and mutual respect. Authority can be assigned, but respect has to be earned. Keep in mind that it is not what you get out of life that matters; it is what you leave behind.

Kenneth A. Gorzycki, CGCS, *Barton Creek Resort & Spa, Austin, Texas.*

A staff appreciation lunch is an excellent way to express thanks for the efforts of the staff. The Barton Creek Resort (Austin, Texas) Men's Golf Association board pitched in and served lunch at this year's event as a way to say thanks to the crew.

Research *You Can Use*

Bermudagrass DNA Fingerprinting

This powerful tool can be used to distinguish genetic differences that are important in protecting plant patents.

BY MICHAEL P. ANDERSON AND YANQI WU

The fingerprinting of plant, animal, and human DNA (deoxyribonucleic acid) has been practiced among researchers and forensic scientists for many years, especially garnering widespread attention from notorious criminal cases involving DNA evidence. DNA fingerprint analysis is powerful and capable of distinguishing one individual from another. Each of us has a unique DNA pattern, as do plant species and plant varieties.

DNA DIFFERENCES

All organisms, including grasses, have identifiable characteristics. These characteristics make an organism unique from all others. Physical characteristics in bermudagrass, such as leaf texture or leaf color, are obvious and readily discernable. However, some characteristics require detailed measurements, while others are more qualitative in nature. Some distinguishing features can be observed with little or no training, while others need close inspection by trained and experienced personnel. Many subtle differences among closely related bermudagrasses cannot be readily distinguished visually. Another method is necessary to differentiate these bermudagrasses: DNA fingerprinting.

Differences among organisms are coded by their DNA, which is a very long molecule made up of a specific sequence, in linear order, of four distinct chemicals called nucleotides. If human DNA were represented by single letters standing for each distinct nucleotide (adenine, cytosine, guanine, and thymine) on a blank page, the length of the alphabetic sequence would run at least to one million pages, enough to fill 1,000 large volumes.

The DNA sequence dictates the look of an organism and how it responds to the immediate environment, and it is different for every organism. Consequently, the DNA sequence can be used to distinguish one organism from another. DNA fingerprinting is nothing more than a sophisticated technique to sample an organism's DNA sequence, projecting the differences as a kind of *bar code* for ready identification and comparison.

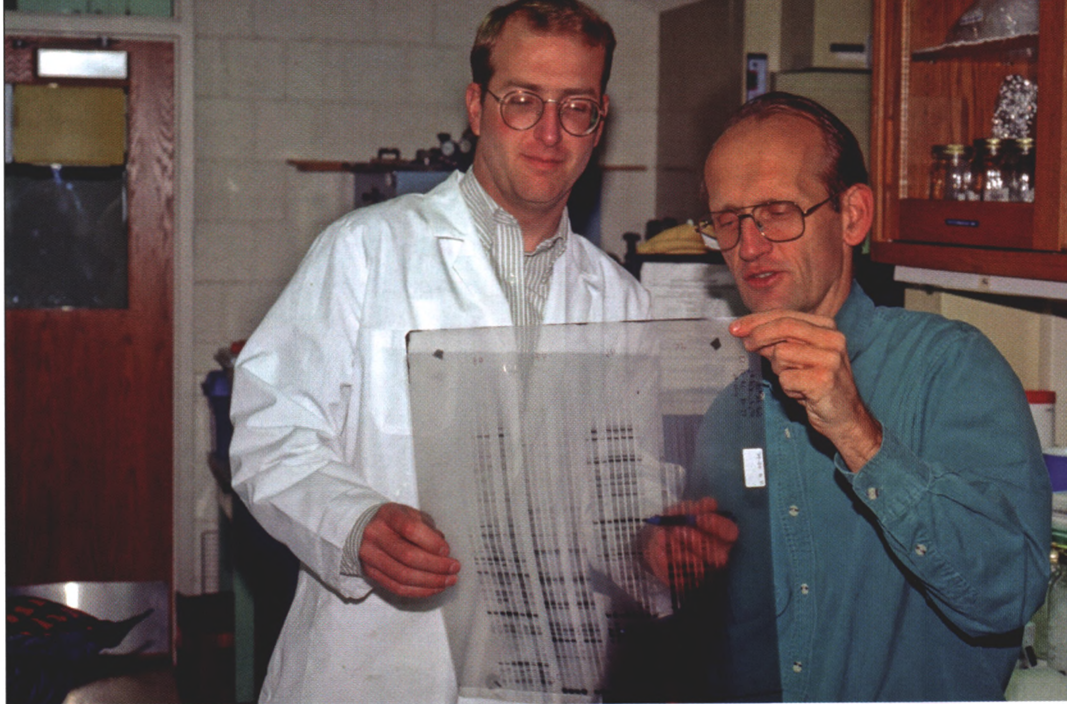
Most DNA fingerprinting depends on a technique known as PCR or *polymerase chain reaction*. PCR was developed in the mid-'80s to efficiently amplify specific segments of DNA many-fold. The PCR technique uses short DNA segments composed of anywhere from 6 to 20 nucleotides known as primers, which are complementary to segments of the target DNA. The primers figuratively scan for matches in the target DNA sequences. Once a match is found, then amplification of that segment begins. If there are many matches, many segments will be amplified.

This mixture of amplified segments, known as *amplicons*, can be separated on an electrophoretic gel system, which effectively sieves amplicons based on size. The gel is stained with fluorescent dyes to reveal what looks like a banding pattern or a bar code. Multiple primers can be used to scan different portions or the total genomic DNA, revealing additional bar coding. Fingerprinting with many primers is capable of differentiating even the most closely related of all organisms. Thus, while two bermudagrasses may be physically indistinguishable from each other, the DNA fingerprinting can highlight the intrinsic differences in their DNA by using PCR-based techniques.

All organisms can be fingerprinted and their DNA patterns stored and analyzed. Analysis of the banding pattern is performed using a variety of statistical techniques known as *cluster analyses*. The data are inputted in the form of presence or absence of a particular PCR amplicon or *electrophoretic band* and cluster analysis analyzes the data and connects those organisms that show similar patterns. However, to be effective, there must be enough similarities, as well as differences, in the pattern to reveal relationships among all tested organisms.

A number of fingerprinting techniques exist. These techniques differ in the ability to differentiate organisms, the amount of labor required, the extent of automation available, the expense of use, and the nature of the specific targeted DNA segments. AFLP (Amplified Fragment Length Polymorphism), DAF (DNA Amplification Fingerprinting), SSR (Simple Sequence

Repeats), and RAPD (Random Amplification of Polymorphic DNA) are a few of the more commonly used techniques used to fingerprint DNA. All of these utilize PCR to amplify segments of DNA based on the DNA sequence. Sophisticated and expensive commercial packages and instrumentation exist to automate and increase the resolution of the fingerprinting procedure.



Drs. Mark Gatschett (left) and Mike Anderson use advanced biotechnological and molecular genetic tools to understand the genetics of Oklahoma State University's bermudagrasses.

HOW IS DNA FINGERPRINTING USED?

We have used DNA fingerprinting to look at the genetic relationship among a wide range of bermudagrasses. Some of the first work highlighted the differences among high-quality commercial cultivars and select bermudagrasses found in germplasm collections. Caetano Anolles et al[2] surveyed 13 bermudagrass cultivars, including African, common bermudagrass, and several interspecific hybrids for genetic relatedness using DAF. Results showed that DNA fingerprints were easily distinguishable, and the analysis showed clear genetic relationships among all bermudagrass varieties.

To probe the limits of the ability to distinguish bermudagrasses, we fingerprinted Tifway and its irradiation-induced mutant Tifway II, which presumably differed in one or a few nucleotide changes in the DNA sequence. In order to differentiate these very closely related varieties, we found it necessary to use 81 distinct primer combinations to find a one-band difference among all 81 fingerprints.[2] From this early work, it was clear that investigators can differentiate and draw genetic relationships even among the most closely related bermudagrasses.

Breeders often collect from around the world a wide range of plant introductions in the hope of finding specific genetic traits that may be put to productive use. The genus *Cynodon* (bermudagrasses) is comprised of 9 species.[4] Oklahoma State University is home to a worldwide collection of bermudagrass varieties and plant introductions that was initiated by the geneticist Jack Harlan. Charles Taliaferro, and more recently Yanqi Wu, two bermudagrass breeders at OSU, have added significantly to this collection, making it one of the most comprehensive collections of *Cynodon* germplasm in the world. Understanding the genetic relatedness among *Cynodon spp.* and varieties gives us a better understanding of the genetic makeup of the *Cynodon* genus.

At times, doubts about the genetic identity of a particular variety surface. In previous work, our laboratory responded to the need to evaluate the widely used variety U3 for genetic fidelity.[1] U3 was an early success made up of bermudagrasses collected from golf courses in the southern U.S. in the 1930s. U3 showed moderate cold tolerance and fine-textured leaves and was a general improvement when compared to previous cultivars.

DNA fingerprinting was employed to distinguish the current labeled U3 from presumably authentic U3 collections assembled from around the country. Results showed that the currently labeled U3 varieties differed substantially from the presumably authentic U3 varieties. How these differences came about could not be addressed by the fingerprinting technique, but the research underscored the need for evaluating current varieties for genetic stability and purity. In addition, our research, as well as that of others,[9] has discovered a few other discrepancies between the historical pedigree claims of several varieties and their actual genetic relationships using fingerprinting techniques.

GAINING BERMUDAGRASS DIVERSITY WORLDWIDE

New bermudagrass germplasm has been and is now being collected and assembled into worldwide collections from many sources. There are areas where collections have only recently been assembled from specific locations such as southern and southeastern Asia. Recently, a number of bermudagrasses from China were added to the OSU germplasm collection. DNA fingerprinting using the AFLP technique was used to evaluate the diversity within this germplasm.

The Chinese collection seemed surprisingly diverse[7] and distinct from other bermudagrasses from other locations around the world.[6] Further work in our laboratory easily separated the Chinese collection from all U.S. varieties tested. Overall, the work indicated a source of significant variation in the new Chinese collection, which may contain valuable genes for bermudagrass development. Additional diversity assessments need to be done on collections from India and other areas not previously surveyed.

The same techniques used for DNA fingerprinting are also used for molecular genetic analysis of specific traits. The goal here is to locate specific genetic elements or genes that contribute substantially to those traits. This is performed by first constructing populations with significant variation in a particular trait of interest, and then performing the DNA fingerprinting technique on members of the population to identify specific genetic elements that correlate with the expression of that trait. These genetic elements are visualized as unique bands on electrophoretic gels that appear to correlate with traits of interest. The bands are valuable in that they can serve as genetic markers, markers that are based on the DNA sequence rather than some physical characteristic of the plant.

Sophisticated computer software analysis can gauge the contribution of the DNA element associated with the marker to the genetic makeup of the phenotype. These markers can be used to increase the efficiency of selection in a process known as marker-assisted selection. Marker-assisted selection has been shown to be very effective in enhancing germplasm improvement in a variety of cropping systems.[3,5,8] Constructions and evaluation of mapping populations, and utilization of molecular genetic analysis, are major goals of the OSU bermudagrass team.

Oklahoma State University is home to a worldwide collection of bermudagrass varieties, much to the credit of Dr. Charles Taliaferro (pictured). Dr. Mike Anderson and his colleagues are using DNA fingerprinting techniques to understand the genetic relatedness and gene function of this important turfgrass.

DNA fingerprinting of individuals within a population provides information concerning the genetic makeup of a population. The individual makeup of the population may change with time, depending on natural selection and genetic inflow from neighboring bermudagrasses. To observe these shifts, DNA fingerprinting can be used to document and track alterations in population makeup of seeded bermudagrasses under a variety of environmental conditions over time.

PLANT PATENTING

DNA fingerprinting can have an impact in the area of patent protection. Many years of effort are expended to develop commercial varieties. Institutions have a substantial investment in developmental costs and are increasingly desirous of recovering some of those costs through plant variety protection and the collection of royalties from consumers. To support the patent application process, differences in morphology, cultural characteristics, and pedigree need to be presented in order to distinguish the proposed variety from those that are currently available. DNA fingerprinting is currently being used on a limited basis to document the genetic differences of new varieties in the patent process. Any infringement on the patent would have to use the DNA fingerprints and other characteristics to justify a patent infringement lawsuit. The process may be costly and subject to interpretation by experts, but it may be worth the effort when the stakes are large.

In summary, DNA fingerprinting is a valuable technology that is being used to assist producers, breeders, geneticists, and researchers in evaluating bermudagrass populations and germplasm for genetic diversity and background. Information from DNA fingerprinting techniques allows researchers to make informed decisions concerning progress in developing high-quality bermudagrass lines. DNA fingerprinting technology remains a powerful technique to assess the genetic diversity of bermudagrasses worldwide and to protect plant varieties from infringement. At OSU, our projects have been involved in using DNA fingerprinting to further bermudagrass improvement.

ACKNOWLEDGEMENT

The authors acknowledge the contributions of Dr. Charles Taliaferro, Praveen

CONNECTING THE DOTS

An interview with Drs. Michael Anderson *and* Yanqi Wu *regarding DNA fingerprinting.*

Q: *As you note, most of us are aware of DNA fingerprinting from criminal cases, but from a research perspective, how long have DNA fingerprinting techniques been available?*

A: Fingerprinting has been around for quite some time. In plants, some of the earliest DNA fingerprinting involved a technique known as RAPD, which was developed in the late 1980s. Bermudagrass fingerprinting did not take place until about the early 1990s. Advancement in fingerprinting mainly comes from the use of high-resolution instrumentation that greatly increases the accuracy and resolution of the technique, but at a cost. Instruments typically cost from $70,000 to $500,000, and the kits for doing the fingerprinting are expensive as well.

Q: *Do you think that at some time in the future, in order to receive a plant patent for a new cultivar, breeders will have to submit DNA fingerprint evidence that establishes this new cultivar as genetically unique from existing cultivars?*

A: Currently this is not a requirement, but it may be advisable. A patent contains morphological descriptions that distinguish the new cultivar from those already released. Whether it becomes a requirement depends on the decisions of the courts. Patents are granted for inventions (including new varieties) that are useful, new, and non-obvious. The DNA fingerprint establishes whether a new variety is new genetically, but it does not indicate utility. The utility factors must also be documented to distinguish the new variety.

Q: *You mentioned the use of primers to characterize specific genotypes. Is there a ballpark number of primers that are necessary to adequately characterize a genotype, or does it depend completely on the relatedness of the genotypes?*

A: It depends on how closely related your cultivars are and what technique you are using. When using AFLP, you may need from 8 to 14 primer pairs to differentiate bermudagrasses adequately. With DAF you need anywhere from 4 to 12 primer pairs. If the bermudagrasses are very divergent, 4 primers give satisfactory results. There is an additional technique known as mini-hairpin DAF or MHP-DAF, which scans the amplicons created in the first DAF reaction for additional differences. With this technique it is possible to distinguish even very closely related bermudagrasses with no more than 4 MHP-DAF primers.

Q: *You mentioned that the use of DNA fingerprinting can be used to protect plant patents. Have there been cases where DNA fingerprinting has been used and either found patent infringement or a situation where the plant cultivar was not what it was supposed to be?*

A: I am not aware of any at this time. Patent lawyers who specialize in plant variety protection would be aware of the legal history behind this particular question. In answer to your second question, yes, there are cultivars out there that claim a certain pedigree, but in reality they are not closely related to the described variety. I know of three such cases. The most obvious one is the U3 variety referred to in the article. It seems to me that if a company is selling a variety labeled as a protected variety and if the actual variety does not conform to the legal patent description, then that company's variety is open to legal challenge as far as ownership is concerned.

Q: *How important are the Chinese bermudagrass germplasm additions to the bermudagrass breeding effort at OSU? Are there specific traits in the Chinese bermudagrasses that have a high priority for introduction into new bermudagrass cultivars here in the U.S.?*

A: Currently there is great interest in screening this collection for productive traits. Some of the germplasm have desirable seed yield, seed quality, genetic color, and/or some other traits related to turf performance. Our best guess is that some of the collections will be incorporated into our existing breeding program and contribute substantially to future OSU releases.

Q: *To your knowledge, are most breeding programs using marker-assisted selection (MAS) as an integral part of cultivar development?*

A: Most breeding programs are not using marker-assisted selection for their variety development. Part of the impediment to using the molecular techniques is due to lack of training and expertise. However, experience in molecular aspects of breeding is becoming very common for the breeders coming out of graduate school, so I expect the trend towards the acceptance of molecular approaches to continue with a newer crop of breeders.

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

Yerramsetty, and Carole Anderson, and appreciate the funding from the USGA Turfgrass and Environmental Research Program and the Oklahoma State Agricultural Experiment Station.

LITERATURE CITED

1. Anderson, M. P., C. M. Taliaferro, D. L. Martin, and C. S. Anderson. 2001. Comparative DNA profiling of U3 turf bermudagrass strains. *Crop Science* 41:1184-1189.

2. Caetano-Anolles, G., L. M. Callahan, P. E. Williams, K. R. Weaver, and P. M. Gresshoff. 1995. DNA amplification fingerprinting analysis of bermudagrass (*Cynodon*) — genetic relationships between species and interspecific crosses. *Theoretical and Applied Genetics* 91:228-235.

3. Mackay, I., and W. Powell. 2007. Methods for linkage disequilibrium mapping in crops. *Trends in Plant Science* 12:57-63.

4. Taliaferro, C. M. 1995. Diversity and vulnerability of bermuda turfgrass species. *Crop Science* 35:327-332.

5. Tuberosa, R., and S. Salvi. 2006. Genomics-based approaches to improve drought tolerance of crops. *Trends in Plant Science* 11:405-412.

6. Wu, Y. Q., C. M. Taliaferro, G. H. Bai, and M. P. Anderson. 2004. AFLP analysis of *Cynodon dactylon* (L.) Pers. var. *dactylon* genetic variation. *Genome* 47:689-696.

7. Wu, Y. Q., C. M. Taliaferro, G. H. Bai, D. L. Martin, J. A. Anderson, M. P. Anderson, and R. M. Edwards. 2006. Genetic analyses of Chinese *Cynodon* accessions by flow cytometry and AFLP markers. *Crop Science* 46:917-926.

8. Yamaguchi, T., and E. Blumwald. 2005. Developing salt-tolerant crop plants: challenges and opportunities. *Trends in Plant Science* 10:615-620.

9. Zhang, L. H., P. Ozias-Akins, G. Kochert, S. Kresovich, R. Dean, and W. Hanna. 1999. Differentiation of bermudagrass (*Cynodon spp.*) genotypes by AFLP analyses. *Theoretical and Applied Genetics* 98:895-902.

Editor's Note: *This complete paper can be found at the USGA's Turfgrass and Environmental Research Online (http://usgatero.msu.edu).*

Michael P. Anderson, Ph.D., *Associate Professor, and* Yanqi Wu, Ph.D., *Assistant Professor, Department of Plant and Soil Sciences, Oklahoma State University, Stillwater, Okla.*

Research *You Can Use*

Some Like It Hot

Rutgers University scientists continue to unravel the mystery of creeping bentgrass heat tolerance in hopes of improving this vital turfgrass species.

BY BINGRU HUANG AND YAN XU

High temperature is a primary factor causing summer bentgrass decline. One of the typical symptoms of summer bentgrass decline is leaf senescence, which is characterized by loss of chlorophyll and photosynthetic activities in leaves. Cool-season turfgrass species, such as creeping bentgrass (*Agrostis stolonifera*), are sensitive to heat stress and quickly lose color and suffer from a series of physiological injuries when exposed to temperatures above 30°C (86°F). Leaf senescence was observed after 20 days at 30°C and only 8 days at 35°C (95°F) for Penncross creeping bentgrass.[1,2]

Phytohormones are major biochemical factors that regulate leaf senescence. Ethylene, abscisic acid (ABA), and cytokinins are three major phytohormones that mediate signaling events involved in leaf senescence, but the mechanisms of heat-induced leaf senescence in turfgrass are largely unknown. Identification of physiological or metabolic factors associated with leaf senescence has practical value for developing practices that promote healthy turf during the summer, and it is important for revealing basic mechanisms of turfgrass heat tolerance.

One approach to understand mechanisms of plant tolerance to stresses has been to examine plants adapted to extremely stressful environments. Several cool-season grass species have recently been identified growing in geothermally heated areas in Yellowstone National Park. One of the two predominant grass species in thermal areas is *Agrostis scabra* (thermal rough bentgrass).

Recently, a cool-season grass species, *Agrostis scabra* (thermal rough bentgrass), has been identified growing in geothermally heated areas in Yellowstone National Park.[6] It survives and even thrives in chronically hot soils with temperatures up to 45°C (113°F).[23] Our studies demonstrated that when exposed to 35°C, thermal bentgrass exhibited much better heat tolerance than creeping bentgrass, exhibiting less leaf senescence, higher photosynthesis activity, more efficient carbon utilization, and better root growth.[4,5]

This study was designed to determine whether superior heat tolerance in the thermal bentgrass was associated with metabolic factors regulating heat-induced leaf senescence, specifically changes in the three major senescence-related hormones (ethylene, ABA, and cytokinins). Turf quality and the content of two pigments (chlorophyll and carotenoid) were measured to evaluate the degree of heat tolerance and leaf senescence. Quantitative changes in ethylene, ABA, and two major forms of cytokinins during heat stress were determined to examine their relationship with heat-induced leaf senescence.

EVALUATION OF HEAT-INDUCED LEAF SENESCENCE AND HORMONE PRODUCTION

Creeping bentgrass (cv. Penncross) plugs were collected from field plots at Hort Farm II, Rutgers University, N.J. Plants of *A. scabra*, originally collected from geothermally heated areas in Yellowstone National Park, Wyoming, were propagated in a greenhouse at Rutgers University. Both species were planted in plastic pots (15 cm diameter by 20 cm deep) filled with sterilized sand and fertilized weekly with full-strength Hoagland's solution. Plants of both species were exposed to 35°C/30°C (day/night, high temperature) or 20°C/15°C (68°F day/59°F night, optimum temperature) for 35 days in controlled-environment growth chambers.

Turf quality was evaluated based on color, density, and uniformity of the grass canopy using a scale of 0 to 9, with 9 representing fully green, dense turf canopy and 0 representing completely dead plants. Leaf chlorophyll and carotenoid were extracted from fresh leaves. Ethylene production of leaves was determined using a gas chromatograph. ABA and two forms of cytokinin (trans-zeatin/zeatin riboside and isopentenyl adenosine) were quantified by an indirect competitive enzyme-linked immunosorbent assay.

Soil temperature at a 2-inch depth was approximately 113°F at a thermal site in Yellowstone National Park (A), where thermal *Agrostis scabra* plants grow and the plant still possesses healthy roots and leaves. Heat-sensitive creeping bentgrass (B) is compared to heat-tolerant thermal *A. scabra* (C), where both species were exposed to elevated air/soil temperatures in a growth chamber.

RELATIONSHIP BETWEEN HORMONE ACCUMULATION AND HEAT-INDUCED LEAF SENESCENCE

Heat stress caused decline in turf quality in both bentgrass species, but the decline occurred three weeks later in the thermal bentgrass than creeping bentgrass. Chlorophyll and carotenoid content of the thermal bentgrass exposed to heat stress were maintained at the optimum temperature level for approximately 14 days without any significant decrease until 21 and 28 days, respectively. The decline in turf quality, chlorophyll, and carotenoid content was less severe for the thermal bentgrass than creeping bentgrass. The thermal bentgrass exhibited delayed and less severe leaf senescence under heat stress. Previous studies on root response to high temperatures for these two species also found that the thermal bentgrass exhibited higher tolerance to high soil temperature than creeping bentgrass, with smaller decreases in root growth rate, cell membrane stability, maximum root length, and nitrate uptake.[4,5]

The ethylene production rate of both bentgrass species increased significantly under heat stress, when there was a 20% decline in chlorophyll content. Leaf ABA content also increased under heat stress for both species. However, the increased production of ethylene and ABA in the thermal bentgrass occurred 14 days later than that in creeping bentgrass. This delay of ethylene or ABA accumulation in the thermal bentgrass was consistent with the delay of leaf senescence as manifested by decline in turf quality and chlorophyll and carotenoid contents.

The production of both forms of cytokinins (Z/ZR and IPA) consistently decreased under heat stress in both bentgrass species. In terms of species variation, the decreases of both forms of cytokinins were delayed for 7 days and were less severe after 35 days of heat stress in the thermal bentgrass than in creeping bentgrass. This suggests that maintenance of a higher level of endogenous cytokinin for a longer period of time may contribute to better heat tolerance.

We performed a correlation analysis between hormone accumulation and leaf senescence to determine whether changes in hormone production during heat stress are associated with heat-induced leaf senescence, and to determine which hormone is more important in controlling leaf senescence. The results suggested that endogenous ethylene and ABA production was negatively correlated and cytokinin production was positively correlated with turf performance under heat stress.

Researchers at Rutgers University are using thermal rough bentgrass (*Agrostis scabra*) plants collected from geothermal sites at Yellowstone National Park (left) to identify high-temperature tolerance genes. The goal is to identify the mechanisms in an effort to improve heat tolerance of other creeping bentgrass varieties.

PRACTICAL IMPLICATIONS

The results in this study suggest that approaches that can increase endogenous cytokinin levels or suppress ethylene production may lead to improved heat tolerance and delayed foliar senescence. Exogenous spray of cytokinin, or its derivatives, may be one possible method. Liu et al.[3] reported that applications of 1 and 10 mM zeatin riboside to the rootzone of creeping bentgrass increased cytokinin content in leaves and roots and mitigated heat stress injury in both shoots and roots.

Endogenous cytokinin levels may also be increased by transgenic approaches, introducing favorable genes. In another study, we transformed creeping bentgrass plants with a gene controlling cytokinin synthesis and found that transgenic plants exhibited superior heat tolerance compared to non-transgenic plants. This demonstrated that heat tolerance was associated with the maintenance of cytokinin production and leaf chlorophyll content during heat stress (unpublished data).

Conversely, since ethylene production was negatively correlated with heat-induced senescence, delayed leaf senescence may also be achieved by transgenic approaches or using ethylene inhibitors. In a recent study, we sprayed an ethylene inhibitor to the canopy of creeping bentgrass exposed to 35°C and found that treated turf maintained greener and higher photosynthetic activity for a longer period of time compared to untreated turf.

Our studies suggest that foliar application of cytokinins or ethylene inhibitors may be useful to suppress or delay leaf senescence and ultimately improve turfgrass performance during summer months. A field study is in progress at Rutgers University to test the effectiveness of exogenous application of cytokinins and ethylene inhibitors as well as biostimulants in preventing summer bentgrass decline.

CONNECTING THE DOTS

An interview with Dr. Bingru Huang, *Rutgers University, regarding heat-induced leaf senescence of creeping bentgrass.*

Q: *You stated that the mechanisms of heat-induced leaf senescence in turfgrasses are largely unknown. Are there other plant species for which the mechanisms of heat-induced leaf senescence have been established that can serve as a working model for turfgrasses?*

A: Winter wheat has been the most studied plant species in terms of heat-induced leaf senescence. It is also a cool-season plant species and can be used as a working model for cool-season turfgrasses.

Q: *Your work involves investigations with* Agrostis scabra, *which is adapted to the high air and soil temperatures surrounding geothermally heated areas of Yellowstone National Park. How did you become aware of this remarkably adapted grass species?*

A: While searching for literature on heat tolerance mechanisms of grass species, we found an article published by Richard Stout and his associate (Montana State University) on *Dichanthelium lanuginosum*, a predominant flowering plant in geothermal areas with soil temperature >40°C at 2-5 cm depth in Yellowstone National Park. This species has wide leaf blades, which is not suitable for turf use. We inquired about the existence of *Agrostis* species in geothermal areas, and luckily *Agrostis scabra* is found to grow in different geothermal sites in the park. We now have a collection of different ecotypes at Rutgers.

Q: *Is it your long-range goal to identify "heat tolerance genes" in* A. scabra *and eventually incorporate them into creeping bentgrass? If so, how long of a process is this? When might golf course superintendents see new creeping bentgrass cultivars with these "heat tolerance genes" from* A. scabra?

A: Our long-term goal is to develop better heat-tolerant creeping bentgrass, utilizing the genes identified in the thermal grass species either through molecular-marker associated breeding or genetic engineering. Currently, we focus on identification and development of molecular markers of heat tolerance that may be used in breeding to select for heat-tolerant germplasm in creeping bentgrass and other cool-season turfgrass species. We have already found several genes that are highly up-regulated in this grass species when exposed to heat stress, and they may be used as molecular markers. We are in the process of using these markers to screen creeping bentgrass cultivars that differ in heat tolerance in the lab. Field screening trials may be conducted in the next few years. At this point, we are not certain about the future of transgenic plants on golf courses, and therefore we may work on gene transformation in the near future.

Q: *Although* A. scabra *will grow and thrive at elevated air and soil temperatures, will it also perform well at temperatures that are typically found associated with creeping bentgrass? How feasible is it that cultivars of* A. scabra *could be developed for heat-prone areas such as the southern United States?*

A: *A. scabra* plants are able to grow actively at the temperature requirement range for creeping bentgrass, except it has a higher upper temperature limit. Developing cultivars of *A. scabra* may not be feasible, at least in the near future, due to National Park regulation of plant conservation and other issues. We are exploring the possibilities.

Q: *Your paper seemed to suggest that significant ethylene production occurred only after a 20% decline in chlorophyll content. In light of that, do you think ethylene inhibitors would be an effective way to limit heat-induced leaf senescence?*

A: Ethylene inhibitors may be able to suppress heat-induced leaf senescence, but not eliminate the problem.

Q: *Your work with exogenous applications of cytokinins was very interesting in that such applications mitigated heat-stress injury in both shoots and roots. Do you think it is feasible that such applications (e.g., seaweed extract) will become an accepted practice for limiting high-temperature injury to turfgrasses?*

A: Most of our research and others' research on cytokinins effects on heat tolerance were conducted in controlled environmental conditions. Most studies used pure cytokinins. The feasibility of using cytokinin-containing products such as seaweed extract for limiting summer heat injury in creeping bentgrass under natural field conditions needs to be further investigated.

Q: *What's the next step in this research, and what can golf course superintendents expect to come out of this work?*

A: We will explore practical means of preventing or controlling summer bentgrass decline based on the physiological and molecular information. Field studies will be conducted to further confirm our findings from the controlled-environment studies.

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

REFERENCES

1. Huang, B., and H. Gao. 2000. Growth and carbohydrate metabolism of creeping bentgrass cultivars in response to increasing temperatures. *Crop Sci.* 40:1115-1120.

2. Huang, B., X. Liu, and J. D. Fry. 1998. Shoot physiological responses of two bentgrass cultivars to high temperature and poor soil aeration. *Crop Sci.* 38:1219-1224.

3. Liu, X., B. Huang, and G. Banowetz. 2002. Cytokinin effects on creeping bentgrass responses to heat stress: I. Shoot and root growth. *Crop Sci.* 42:457-465.

4. Lyons, E., J. Pote, M. DaCosta, and B. Huang. 2006. Whole-plant carbon relations and root respiration associated with *Agrostis* grass responses to high soil temperatures. *Environ. Exp. Bot.* (in press).

5. Rachmilevitch, S., H. Lambers, and B. R. Huang. 2006. Root respiratory characteristics associated with plant adaptation to high soil temperature for geothermal and turf-type *Agrostis* species. *J. Exp. Bot.* 57:623-631.

6. Stout, R. G., and T. S. Al-Niemi. 2002. Heat-tolerant flowering plants of active geothermal areas in Yellowstone National Park. *Ann. Bot.* 90:259-267.

7. Tercek, M. T., D. P. Hauber, and S. P. Darwin. 2003. Genetic and historical relationships among geothermally adapted *Agrostis* (bentgrass) of North America and Kamchatka: evidence for a previously unrecognized, thermally adapted taxon. *Amer. J. Bot.* 90:1306-1312.

ACKNOWLEDGEMENT

We would like to thank the United States Golf Association's Turfgrass and Environmental Research Program and the Rutgers Center for Turfgrass Science for funding this project.

Editor's Note: *For the original publication of this paper, visit USGA Turfgrass and Environmental Research Online (http://usgatero.msu.edu).*

Bingru Huang, Ph.D., *professor; and* Yan Xu, *graduate research assistant; Dept. of Plant Sciences, Cook College, Rutgers University, New Brunswick, N.J.*

Putting Your Muscle Where Your Heart Is

A special golf course with an extraordinary mission is managed and maintained by a devoted "band of brothers."

BY JAMES F. MOORE

Tom Loran, a veteran of World War II, is on the Tuesday crew and is charged with mowing fairways

Back in June of this year, golfers across the world enjoyed the action at Oakmont Country Club during the 2007 U.S. Open Championship. Approximately 10,000 volunteers and employees worked diligently to prepare the golf course for 156 competitors. Tens of thousands of spectators were fortunate to be on the course, while millions more watched on television as the best players in the world put everything they had into every shot. With the players struggling to meet Oakmont's challenges, commentators frequently employed metaphors such as "warrior," "hero," and "battling" to describe their play.

Two weeks prior to the Open, I was fortunate to visit warrior golfers of a different type. While none would qualify to play in the U.S. Open, their devotion to the game, their golf course, and their comrades is unmatched. To fully appreciate their remarkable story, it is first necessary to take a few brief trips back in time.

NORMANDY REGION OF FRANCE

On June 6, 1944, Private Lyle W. Hanks, a member of the 1st Infantry Division, 18th Regiment Anti-Tank Company, landed on Omaha Beach (Easy Red) during the first wave. Almost immediately, Lyle was wounded and lay in a bomb crater the rest of the day awaiting evacuation to England. Lyle spent six months in a hospital and then rejoined his unit in time to fight the Battle of the Bulge. Lyle was awarded the Bronze Star, Combat Infantryman's Badge, and Purple Heart.

On June 7, 1944, Private Leenan H. (Red) Burton landed on the same beach as a member of the 2nd Infantry Division, 15th Field Artillery. Red said it was a wonder that anyone lived through the first wave. Red received the Bronze Star and five battle stars while in Europe.

THE "PUNCHBOWL," NEAR CHORWON, KOREA

On May 17, 1952, 17-year-old Private Richard Webster was at Heartbreak Ridge with the 45th Division, 179th Infantry Regiment. On his 17th birthday, Richard's unit was overrun and he was bayoneted in his foxhole. While recovering from his wounds, Richard went AWOL from the hospital to rejoin his unit and was blown out of his foxhole while under siege. Richard was awarded the Silver Star, Bronze Star, and two Purple Hearts while in Korea.

VIETNAM

The year was 1968 when Force Recon Marine Sergeant Russell A. Carlson endured the siege of Khesanh for nearly three months. Just after the siege had ended, Russell was hit by a mortar. His arm was shredded and his left leg was blown off. Russell spent in excess of two years in various hospitals in theater and stateside recovering from his injuries.

In 1972, First Lieutenant Bruce McKenty was assigned to F Troop, 9th Cavalry, 1st Cavalry Division, at Bien Hoa as an AH-1G Cobra helicopter pilot. On August 23 he was wounded with shrapnel from a 51-caliber armor-piercing round when his Cobra was shot down just south of the Cambodian border. After treatment at the 3rd Field Hospital in Saigon, he returned to duty. On December 3, his Cobra was hit by a SA-7 heat-seeking missile at 2,000 feet. Hitting the ground at more than 80 mph, he suffered a broken back, fractured skull, and multiple lacerations and burns. He received the Distinguished Flying Cross, Bronze Star, three Air Medals with "V" for valor, and two Purple Hearts.

In 1967, SSGT Mike Kearney was a crew chief at a forward air control post near Can Tho. Mike was responsible for the conduct of his unit's air combat operations in the Mekong Delta and supervision of 11 operations and maintenance crew members. For his efforts, Mike was awarded the Bronze Star.

JUNE 2007 — AMERICAN LAKE VETERANS GOLF COURSE, TACOMA, WASHINGTON

As amazing as these stories are, these are but a few of the 130 volunteers who run the American Lake Veterans Golf Course at the Veterans Hospital in Tacoma, Washington. These veterans, many of whom are highly decorated, are from all wars and all services. Amazingly, this small nine-hole golf course brings this band of brothers, and in many cases their spouses, together again for a common cause — helping other vets.

Dedicated in 1929, the American Lake Veteran's Hospital added a golf course to its grounds shortly after World War II. Unfortunately, the course was not designed for people with disabilities in mind. Even so, for decades, soldiers with injuries of all types have found the golf course a haven. The VA hospital staff long recognized the value of golf as a rehabilitation resource for injuries of all types. Then, in 1995, the U.S. Government eliminated funding for operation and maintenance of all VA golf courses, placing the future of American Lake in jeopardy. Volunteers kept the course going, and in 2004 a group of concerned citizens (veterans and non-veterans alike) created the non-profit corporation "Friends of American Lake Veterans Golf Course." Their goal was not only to keep the course in operation, but also to launch a fund-raising effort to support a wide range of improvements to make the golf course more accessible to those with disabilities. Bigger tees, accessible greens, a larger practice area, and wider and smoother paths are just a few of the improvements that needed to be made. Plus, based on their hands-on experience with the challenges mobility-impaired golfers face, the group recognized the need to modify the driving

American Lake Veterans Golf Course thrives under the watchful eyes of a multitude of volunteers who work together to produce a beautiful and enjoyable golf course. Back row, left to right: Lyle W. Hanks, Pat Gailey. Front row, left to right: Russel A. Carlson, Harold "Pepper" Roberts (yellow shirt), Richard Webster (print shirt), Mike Kearney, and Bruce McKenty.

Like a lot of the volunteers, some of the equipment is a little dated, but it works hard and gets the job done.

The Friends of American Lake Veterans Golf Course provide instruction and encouragement to help disabled players find their swing.

range, allowing it to be converted into a three-hole short course. This course is specifically designed as an introductory area to help players learn the game of golf and maneuver their specialized carts around a golf course.

Their efforts have been remarkably successful, with more than $470,000 raised and invested in the course. And every dollar is stretched to the maximum, thanks to the willingness of the volunteers who do so much of the work on their own. For example, a new irrigation system was installed at less than half of the normal cost, as a result of the back-breaking manual labor performed by volunteers — the average age being 76! The driving range/short course has been completed, new paths installed, and a much wider practice tee put into place.

Volunteers are organized into crews who perform all the golf course maintenance tasks (with good-natured competition existing between the crews). Yet another volunteer maintains the equipment. Volunteers also staff the small clubhouse and pro shop. Most importantly, volunteers are available any time of the day whenever a disabled player needs help.

While players fortunate enough to qualify for the Open at Oakmont received keys to a new Lexus for the week, the disabled golfer who comes to American Lake receives the key to a solo-rider golf cart, specially designed for golfers with amputations and mobility disabilities. And a voluneer will be there to help the player learn how to use the cart and offer assistance in getting around the course.

The golf course even has a volunteer teacher of the game. Retired golf coach "Pepper" Roberts organizes clinics to introduce players to the game, regardless of the types of their injuries. Pepper's efforts are supplemented by other golf professionals who come from all over the country to help out during these clinics. The instruction is coupled with the skills and knowledge of the VA hospital physical therapists and staff as they help disabled players utilize golf in their rehabilitation.

All of these efforts are paying off in many ways. For example, on Mondays, residents of the Orting Soldiers Home in Orting, Washington, join the patients of the American Lake VA hospital for golf lessons and a picnic lunch. Sgt. Jerry Reed of the 654th Medical Holdover Company at the Madigan Army Medical Center and approximately 20 other soldiers charged with the care of veterans also make the trip and enjoy a little downtime at the course.

Along with all of these dedicated volunteers, Lyle, Red, Richard, Russ, Bruce, and Mike once again find themselves on a mission for the military. Fortunately, this time their duties are much less dangerous. Lyle repairs golf clubs and has been a volunteer for 18 years. Red, together with his wife Ronnie, volunteers behind the desk at the caddie shack. Richard takes care of the driving range, picking up the balls, washing them, and making sure the electric carts are charged. Russ works behind the counter at the caddie shack and works with disabled golfers who are learning to play golf. Bruce is a volunteer course marshal and member of the board of directors of the American Lake Veterans Golf Course. Mike is the manager of the golf course, is also on the board, and has logged more than 9,000 volunteer hours.

As I toured the course with Pepper and Pat Gailey (Pat is a retired construction manager who has successfully twisted the arms of practically everyone in Tacoma in the construction business to donate equipment and materials), I was amazed at the quality of the playing conditions the volunteers had achieved. From personal experience as a golf course superintendent, I know firsthand how difficult it was for me to get 15 to 20 paid employees on the same page when it came to golf course maintenance. At the American Lake Veteran's Course, somehow more than 130 volunteers work together to produce a beautiful and enjoyable golf course with just a tiny budget. The obvious secret to their success is the shared desire to help their comrades in arms recover as well as possible and to play the game of golf in its purest form — for fun.

EDITOR'S NOTE: *It should come as no surprise that many of the photographs used in this article were taken and donated by yet another American Lake volunteer — Rick Scott of IFTS Digital Photography. Rick retired from the Army after 27 years and is proud to be one of the Friends of American Lake.*

The USGA, through its "For the Good of the Game" Grants Initiative, has awarded a $35,000 grant to the Friends of American Lake Veterans Golf Course to improve the accessibility of the course's teeing grounds for the many individuals with disabilities served by the facility. Information about the USGA Grants Initiative can be found in the Grants section of www.usga.org.

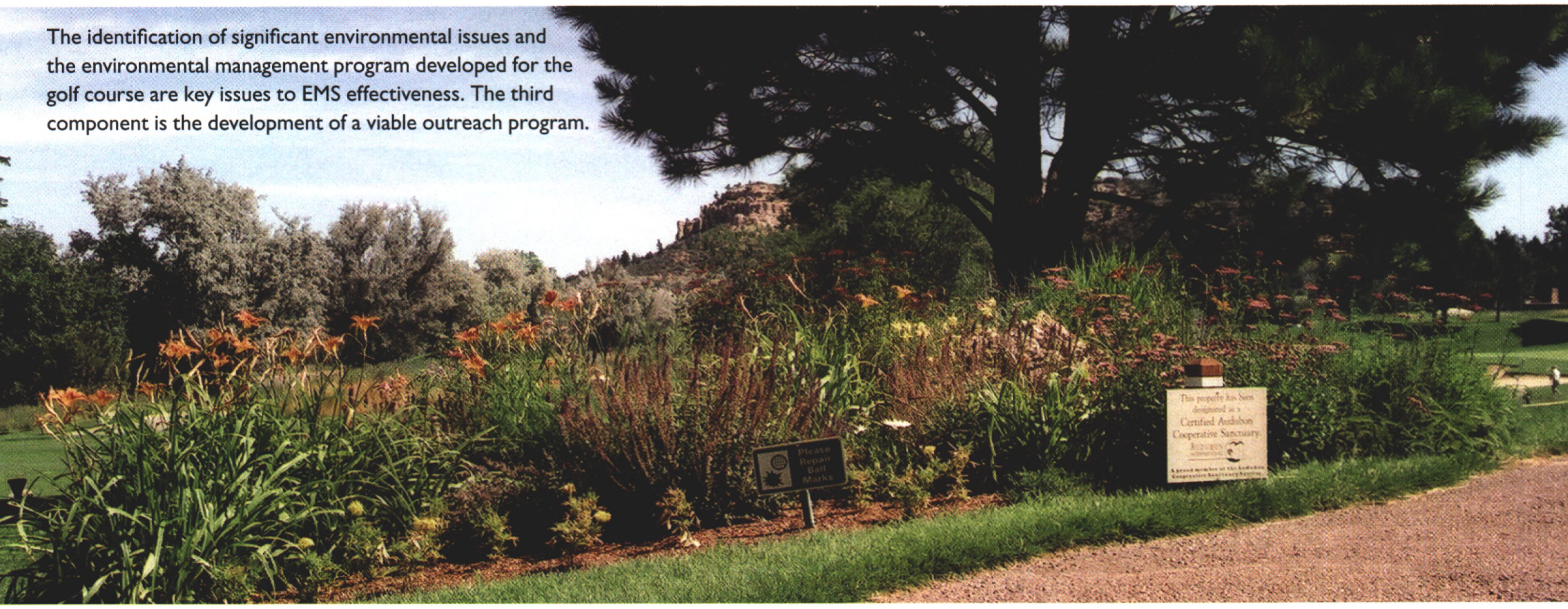
JAMES F. MOORE *is director of USGA Green Section Construction Education.*

As is the case with every aspect of the golf course operations, the "caddie shack" is run by volunteers who take turns making certain everyone is welcome at the American Lake Veteran's Golf Course.

The Devil is in the Details

Environmental Management Systems (EMS) and golf courses.

BY ROBERT N. CARROW AND KEVIN A. FLETCHER



The identification of significant environmental issues and the environmental management program developed for the golf course are key issues to EMS effectiveness. The third component is the development of a viable outreach program.

Environmental Management Systems (EMS) are an increasingly prevalent approach to managing all environmental issues on a site — whether a golf course, manufacturing plant, agricultural production or processing facility, or any other entity. It is a voluntary, standardized, systematic approach to manage environmental issues that is adapated across all industries and on an international scale. In a companion paper (*Green Section Record*, July/August 2007), the EMS concept was defined along with its history (Carrow and Fletcher, 2007). In this article, focus is on the EMS concept and golf courses — implementation, challenges, opportunities, and implications.

Are there already EMS programs in the golf industry? The answer is yes. In agriculture, horticulture, and golf courses, the EMS concept is most advanced in Australia. The February 2007 issue of the *Australian Journal of Experimental Agriculture* was devoted to EMS in agriculture and horticulture (http://www.publish.csiro.au/nid/72.htm), while *Environmental Business Solutions* (EBS 2007) recently developed an EMS program entitled e-PAR™ for golf courses. The e-PAR™ program was developed by Terry Muir of EBS Australia in conjunction with the AU EPA and the Australian Golf Course Superintendents Association and is the most advanced program in the world applying the EMS concept to golf courses. Within the U.S., some individual clubs have used e-PAR™ or information on EMS in general and developed their own EMS.

Audubon International has three programs based on the EMS model and encompassing many of the EMS elements (Audubon International, 2007) — Audubon Cooperative Sanctuary, Audubon Classic, and Audubon Signature Programs. Their programs illustrate the necessity for flexibility within an approach and for adapting any environmental approach, including the EMS concept, to encompass new developments or additions (planning, construction, long-term management), as well as existing facilities. Recently, Ron Dodson, president and CEO of Audubon International, elaborated in the book *Sustainable Golf Courses — A Guide to Environmental Stewardship* on many of the key environmental issues encompassed in the EMS concept when applied to golf facilities (Dodson, 2005). Additionally, the University of Georgia and Audubon International cooperatively developed a web-based educational guideline for golf courses that describes the EMS concept, history, elements, assessment of environmental issues, development of Best Management Practices (BMPs) for each environmental issue, and lists resources for those interested in this concept (Carrow and Fletcher, 2007a).

The U.S. Air Force's Golf Club Environmental Management (GEM) program is based on EMS (GEM 2007). The Air Force mandated that all installations "develop and implement an environmental management system (EMS) to sustain, restore, and modernize natural infrastructure to support mission capability." GEM is an EMS designed for golf facilities situated within the military structure and method of operation.

Other groups have developed programs or information sources that relate to certain components of EMS but are not EMS programs, such as:

- The Michigan Turfgrass Environmental Stewardship Program (MTESP) (http://mtesp.org/). This is an Environmental Management Program (EMP) developed through collaborative efforts of Michigan State University, government agencies, the turfgrass industry, and advocacy groups. The MTESP has elements that an EMS would incorporate, but it isn't an EMS. Note: An EMP is similar to a BMP to manage a specific environmental issue.
- Club Managers Association of America's Environmental Performance Audit (http://www.cmaa.org/onlinesurveys/environmentalaudits/EAdetail.asp?1ngEAID=1). The CMAA's Full Facility Environmental Audit (FFEA), developed by Audubon International, states that it "is an internal, self-assessment or evaluation that uses standard, widely accepted environmental management practices to measure overall environmental performance." This is not an EMS or EMP, but could potentially be used to develop an audit for an EMS, provided it addresses all the audit criteria listed in the EMS.
- Environmental management on golf facilities is a topic of concern around the globe. Mackay (2006) recently surveyed a number of organization Web sites around the world containing information on some aspects of environmental stewardship on golf courses.
- The USGA's *Green Section Record* and its Turfgrass Environmental Research Online (TERO) (http://usgatero.msu.edu/currentpastissues.htm) site has considerable environmental information related to golf courses.
- Environmental Institute for Golf (EIFG) (http://www.eifg.org/). The EIG is a component of the Golf Course Superintendents Association of America, and their Web site is a portal for environmental information from various sources related to golf clubs.

Use of alternative irrigation water sources is just one example of infrastructure improvements that may already be implemented on the golf course prior to an EMS assessment.

One point that is clear from the above listing is that acronyms abound in the environmental area. It is important to understand the difference between EMS (a holistic program that includes EMPs/BMPs and Environmental Assessment [EA]) and individual components of an EMS — EMPs/BMPs, EA, and other components or elements. In the USA, as the EMS concept becomes more defined and developed, various entities will create tools, programs, literature, and other resources to assist golf clubs in efficiently developing their site-specific EMS or in auditing of EMS.

ELEMENTS OR FRAMEWORK OF GOLF COURSE EMS

The authors have adapted the basic elements of the generic USEPA EMS, but with some changes to better fit the golf industry. Key EMS components appropriate for golf clubs are suggested as: **Plan, Implement, Monitor, and Review**. These components are the framework for **18 practical steps** or elements suggested for developing a golf course EMS plan and are illustrated in Figure 1. Although the EMS framework may evolve within the golf course industry, these suffice to adequately illustrate the EMS concept. Each of the steps or elements of an EMS is briefly defined in the first article (Carrow and Fletcher, 2007) and in more detail in their Web-based document on EMS (Carrow and Fletcher, 2007a).

In this article, the focus is on elements that are especially important for the golf course industry but that are not dealt with in detail in more generic EMS documents, namely: identification of significant environmental issues or impacts; environmental management programs or BMPs for each environmental issue; and outreach. The first two are central to EMS effectiveness,

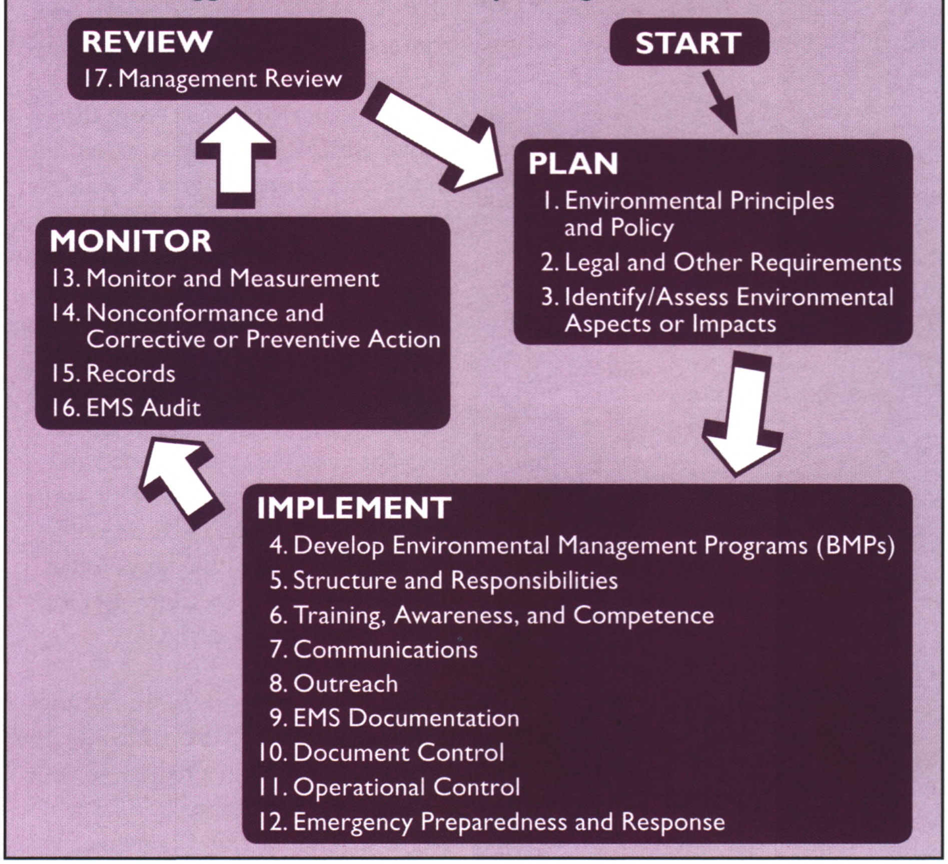


Figure 1
Suggested elements or steps in a golf course EMS.

and the third is a key opportunity for golf courses.

IDENTIFICATION

Identification of Significant Environmental Impacts/Issues (Element 3 of Figure 1): In this step, how the golf course interacts with the environment is assessed by identifying the club's environmental aspects and impacts and determining which are significant. Some of the environmental aspects may be regulated, while others may not be. A comprehensive assessment of environmental impacts may require outside assistance and involve considerable effort. However, a comprehensive assessment is normally a one-time process. It would involve the whole golf facility — course, other grounds, clubhouse, maintenance, etc. When reviewing the general information on EMS concepts by the USEPA or other sources, the documents will not contain specific information on this element since the particular environmental impacts are specific to an industry. However, this step is "the key element" in ultimately developing a successful EMS.

During the environmental impact assessment process, courses should identify specific products, operations, and activities from which any environmental aspects/impacts arise. Likewise, any monitoring that is performed on these operations or activities for environmental purposes can be noted. For example, if generation of waste products is noted as a significant environmental aspect, it would help to know which operation(s) generate the wastes. It might also help to know whether these are monitored or otherwise measured in some manner. Thus, during the environmental impact assessment, the following information may arise that will assist in later EMS steps:

- Current management practices to mediate or manage the particular environmental impact.
- Infrastructure improvements that are being or have been made to mediate or manage the particular environmental impact.
- New or altered practices or infrastructure changes to improve BMPs for the issue may be identified or become apparent.
- Monitoring practices already in process.
- Monitoring practices that will be necessary in the future.

We encourage golf courses to carefully define what current practices and current/past infrastructure improvements have been made to assist in alleviating or preventing a particular environmental issue. In Table 1, examples are provided of practices and infrastructure improvements related to the environmental issue of "Water-Use Efficiency/Conservation" that many courses have instituted but that may not be readily recognized by regulatory agencies, environmental activities, or the general public. A general estimate of costs associated with current practices and infrastructure improvements would be useful in demonstrating the commitment of the course to more sustainable environmental management.

The primary environmental issues in a golf course environmental assessment are summarized below. If after the assessment a particular issue does not reveal an environmental problem or concern, it still should be included in the EMS along with any BMPs and monitoring that is related to the issue. While some of these issues are routinely included in current environmental assessment schemes, others are not. Carrow and Fletcher (2007a) provide the reasoning for inclusion of issues not normally considered, such as items 3, 5, 9, and 10, where each of these is an emerging environmental concern.

1. Environmental planning and design of golf courses, additions, and renovations.

2. Sustainable maintenance facility design and operation.
3. Turfgrass and landscape plant selection.
4. Water-use efficiency/conservation.
5. Irrigation water quality management.
6. Pesticides: water quality management.
7. Nutrients: water quality management.
8. Erosion and sediment control: water quality management.
9. Soil sustainability and quality.
10. Stormwater management.
11. Wildlife habitat management.
12. Wetland and stream mitigation and management.
13. Aquatic biology and management of lakes and ponds.
14. Waste management.
15. Energy management.
16. Clubhouse and building EMS concepts.
17. Climatic and energy management.

Conducting a site assessment related to the above environmental issues may require considerable time and effort when, for instance, water-use efficiency/conservation and use of alternative irrigation water sources are critical issues for a golf course — a situation that is becoming more common. In most cases, development of a comprehensive BMP water-use efficiency/conservation plan for a golf course is a process that is best done over a 1- or 2-year period, especially if alternative irrigation water sources or poor water quality sources are part of the plan. In other cases, where the water supply is known and adequate in quantity and quality, site assessment is somewhat easier. In other instances, the "site assessment" or information gathering process requires contracting companies to do detailed water audits of the existing irrigation system and water source options, along with water quality assessment and other rather complex information gathering tasks. Carrow et al. (2007) presented a detailed discussion of these factors and a template to follow, including irrigation system design.

Assessment of water-use efficiency/conservation should be done with attention to the future, since it may involve costly and time-consuming challenges related to the various strategies, especially irrigation system design, irrigation system capability for scheduling, landscape design alterations, and changes necessary for use of one or more alternative irrigation water sources. Ultimately, the BMP plan for water conservation within an overall EMS can be no better than the information that goes into the decision-making process. Thus, site assessment in this area is especially important.

So, this initial plan can be made, but it may change over time as additional information is gained — for example, an anticipated irrigation water source may be deemed unacceptable due to quality or quantity constraints after a more detailed assessment is conducted. An initial EMS plan may be developed with a central component of the plan consisting of laying out how and when the full site assessment information

Table 1
Examples of water-use efficiency/conservation practices and infrastructure improvements that may already be implemented by a golf course prior to an EMS assessment.

Management, Personnel, and Education Aspects

1. Scouting — costs
2. Hand watering — hours and costs
3. Night watering capability
4. Staffing in irrigation control and irrigation maintenance — irrigation assistant
5. Traffic controls and costs
6. Management for water conservation
   a. Height of cut
   b. Soil cultivation to promote root depth
   c. Evapotranspiration utilization for irrigation scheduling
   d. Selection and installation of drought-resistant landscape plants
   e. Natural vegetation areas
   f. Fertilization practices to minimize water use
   g. Pest management — early morning or late evening applications to reduce water loss; use of Integrated Pest Management protocols.
   h. Wetting agent usage
7. Record keeping and costs
8. Goal setting regarding water-use efficiency/conservation
9. Education efforts — education taken by superintendent or any club official related to water conservation; list benefits of golf courses and turf areas; publish water conservation plans; engage stakeholders (members, patrons, neighbors, general public) with the benefits of water conservation.

Infrastructure Improvements

10. Grass selection and establishment — adapted species and cultivars or climatic/soil conditions; use of drought-resistant grasses, such as bermudagrasses
11. Rain, leak, etc. loss controls and costs
12. Current irrigation controls and hard costs (parts, power)
13. Irrigation design and control improvements — zoning of heads into similar water use areas; irrigation system design to take into account factors that influence water-use efficiency (slope, soil type, wind, etc.)
14. Possible irrigation methods (plant-based, soil-based, budget approach, deficit, atmosphere based); on-site weather station
15. Use of alternative (non-potable) irrigation water sources — reclaimed, water-harvesting from runoff, stormwater, saline sources, etc.
16. Metering — installation and ongoing calibration and replacement
17. Infrastructure improvements made due to using alternative irrigation water — water treatment, soil treatments, extra cultivation, drainage, etc.

Development of new low-water-use grasses for golf courses is an important continuing effort. The USGA Turfgrass Environmental Research Program is funding research at Colorado State University in the development of saltgrass (*Distichlis spicata*), a turfgrass species with exceptional salinity tolerance and growth potential in hot environmental conditions.

may be obtained and then integrated into a future plan. That is the nature of EMS and BMP — not all the answers to questions need to be obtained before an initial plan is developed. EMS is cyclic in nature and is intended to continue the processes of planning/implementation/monitoring/review and continue the cycle again.

EMP ACTION PLAN

Develop Environmental Management Programs (Element 5 of Figure 1). An important part of the planning effort is defining what your organization intends to achieve in the environmental area. To achieve your objectives and targets, you need an **action plan** — also known as an environmental management program (EMP) or BMP (Carrow et al., 2005). Essentially, for each environmental issue identified in Element 3 "Identify/Assess Environmental Aspects or Impacts," BMPs should be developed that are specific to the issue. The various BMP programs should be linked directly to your objectives and targets — that is, the program should describe how the organization will translate its goals and policy commitments into concrete actions so that environmental objectives and targets are achieved (Audubon International, 2002). The BMPs can be combined into the overall EMS. For each environmental issue, the BMP should entail the following:

- Include all current practices and past infrastructure improvements in the BMP.
- Add additional practices as required.
- Include comments on any infrastructure improvements that are planned that will enhance management of the issue. An EMS is an ongoing, cyclic process that allows and encourages improvements over time.

Identification/assessment of environmental issues coupled with the various BMPs to manage these issues is the heart of an overall EMS. As noted, specific information on these two aspects will not be found in general EMS documents. It is beyond the scope of this article to present detailed BMP templates for each environmental issue, but several of the environmental issues have well-developed BMPs through Audubon International (2007, 2002), Carrow et al. (2007), and other sources. In some cases for the emerging environmental issues, BMPs will need to be better defined within the industry.

OUTREACH

Outreach (Element 9 of Figure 1). The USEPA EMS consists of 17 elements, but we have broken out "communications and outreach" into two elements (USEPA 2007). In addition to internal communication directed toward EMS improvement, golf courses should strongly consider becoming an aggressive **outreach and education resource for the community**. The community is interested in the environment and may not be very well informed on the environmental sustainability and stewardship activities of a golf course. An EMS provides an excellent vehicle to use in community outreach and education. Audubon International (2007, 2002) has several fact sheets and other information related to this topic. Outreach and education activities will require a plan and commitment, such as:

Golf course maintenance facilities should be sustainable both in their design and operation.

• Identify the key education person at the facility.
• Develop educational tools — displays, newsletters, brochures, press releases.
• Continuing education plans and activities — turf managers, community, crew, site managers/owners.
• Formal training of turf managers — environmental turfgrass management or sustainable turfgrass management.
• Site use for educational activities. Develop educational programs for the community (such as schoolchildren, scouts).

IMPLICATIONS OF EMS FOR THE GOLF INDUSTRY

In Part One of this series on EMSs, some key implications of the application of the EMS concept for golf course management were noted (Carrow and Fletcher, 2007). Additional EMS key implications directly related to either a club or components of the turfgrass industry are:

• An EMS allows combining together into one system the various BMPs for each particular environmental issue. It becomes an overall grid to understand the diverse environmental issues and how to manage them.
• As the EMS evolves, there will be a substantial need for: educational materials, site-assessment protocols and tools related to each environmental issue, development of concise BMP protocols and tools for each environmental issue, auditing and certification protocols and tools, and services to conduct on-site environmental assessments and audits. Organizations, consultants, and associations that can provide these services will arise. Due to the comprehensive nature of EMS, it may be attractive to golf courses to seek service providers that can provide holistic service packages.
• Related to the previous statement, educational or information "packaging" must become more focused, targeted, and integrated. General information or even specific information in diverse places will not be nearly as useful when so many environmental issues must be addressed in one EMS. The systematic packaging of environmental information may be at various levels of detail, depending on the target audience, but for the turf manager, specific detail is necessary.
• As detailed BMPs are developed for each environmental issue, application to specific sites is essential since the very nature of BMPs and environmental issues is site-specific — one size does not fit all. A comprehensive BMP template must be refined for each site based on site knowledge and science.
• As "environmental management" evolves into the normal day-by-day operations of a facility in addition to the current daily agronomic, personnel, and economic considerations that managers must consider, environmental staff positions may arise, such as an assistant superintendent/environmental specialist.
• For complex issues, such as water-use efficiency/conservation, irrigation water quality (when water quality is challenging), and salt-affected turfgrass sites, consultants with in-depth understanding of these complexities will be in demand.
• Education of future turf managers must evolve as the EMS concept becomes integrated into all facets of the turf industry (not just golf courses). Students will require: course content to understand the complex issues in much more detail than is the current status; introduction to the terminology, concepts, and management related to each of the environmental issues (depending on the issue, the detail or intensity will vary); and ability to think and manage based on a "systems" approach.

In the end, whether individual golf courses adopt an EMS structure ad hoc or the industry at-large develops a common, accepted template for EMS delivery and verification of practices, one thing remains true: the devil is in the details. Systematically recognizing environmental issues for the facility to manage is important, but how they are managed is where substance parts with intent. It is our contention that any sustained effort at improving the environmental practices of golf course operations industry-wide must include some type of voluntary, verifiable EMS-like program and must be intentional, measurable, and real.

REFERENCES

1. Audubon International, *Guide to Environmental Stewardship on the Golf Course* (2nd Edition), 2002. http://www.audubon-international.org.

2. Audubon International. 2007. Audubon International Web site. Selkirk, N.Y. http://www.auduboninternational.org.

3. Carrow, R. N., R. R. Duncan, and D. Wieneke. 2005. BMPs: critical for the golf industry. *Golf Course Management.* 73(6):81-84.

4. Carrow, R. N., and K. A. Fletcher. 2007. Environmental Management Systems. *USGA Green Section Record.* 45(4):23-27.

5. Carrow, R. N., and K. A. Fletcher. 2007a. Environmental Management Systems (EMS) for Golf Courses. An educational guidebook developed by the University of Georgia and Audubon International. Posted on http://www.auduboninternational.org/e-Source/ and http://www.georgiaturf.com.

6. Carrow, R. N., R. R. Duncan, and C. Waltz. 2007. Best Management Practices (BMPs) Water-Use Efficiency/Conservation Plan for Golf Courses: Template and Guidelines. www.georgiaturf.com.

7. Dodson, R. 2005. Sustainable Golf Courses — A Guide to Environmental Stewardship. John Wiley & Sons, Hoboken, N.J.

8. EBS. 2007. Environmental Business Solutions Web site that includes e-Par™ information. http://www.epar.com.au.

9. GEM. 2007. The U.S. Air Force's Golf Club Environmental Management (GEM) Program Web site. http://www.afcee.brooks.af.mil/ec/golf/default.asp.

10. Mackay, J. 2006. Golf and the environment around the world. *USGA Green Section Record.* 44(5):33-34.

11. USEPA. 2007. USEPA Web site on Environmental Management Systems. http://www.epa.gov/ems/index.html.

DR. ROBERT N. CARROW *is professor, Turfgrass Stresses/Soils, The University of Georgia, Griffin Campus;* DR. KEVIN A. FLETCHER *is director of programs and administration, Audubon International, Selkirk, N.Y.*

Promoting Opportunities for People with Disabilities to Play Golf

Understanding the ADA is just the beginning.

BY CAROL WYNNE

An article on single-rider golf cars in the May/June 2007 issue of the *USGA Green Section Record* needs clarification. The Americans with Disabilities Act (ADA) specifies that public access golf courses cannot discriminate against golfers with disabilities. Contrary to the article's claim, single-rider golf cars are not specifically identified in the ADA as being required, nor does the ADA currently require any other specific type of device or equipment.

The U.S. Department of Justice (DOJ) is currently drafting a notice of proposed rule-making on this matter. The process will involve a public comment period spanning several months. Sometime after the comment period is closed, the DOJ will prepare and issue final regulations on whether single-rider golf cars or other mobility devices are required, and who is responsible for their provision. This rule-making process will be lengthy, and final regulations are not imminent.

The debate and misinformation about single-rider golf cars has unfortunately gotten in the way of the more important issue of implementation and consistent use of best practices for serving individuals with disabilities.

Golf course owners should find appropriate ways to accommodate all golfers, including those with disabilities. There is no single solution and golf course owners should work with golfers to provide a positive experience. This includes modification of policies and practices to ensure people with disabilities avoid discrimination. This may mean modifying cart path and golf car policies so golfers with disabilities have full access to the course; it may mean installing a telecommunications device for the deaf (TDD) and training staff to operate it; using automated practice range teeing devices that do not require bending over to tee up; or adapting a few standard golf cars to make them easier for use by those with disabilities — removing an armrest, adding a grab bar or adding hand controls.

For individuals who cannot walk or stand and must play from a seated position, single-rider golf cars may be a solution. Another solution may be to modify seats on standard golf cars so they swivel. Simply purchasing a single-rider car does not ensure appropriate accommodation is being provided.

Facilities need to know there is an untapped market of potential players with varying degrees of disability who want to play golf. According to a study conducted by the National Center on Accessibility (NCA) in cooperation with Clemson University, 10% of persons with some disability now play golf. However, 35% of individuals with disabilities not currently playing golf are interested in learning. A welcoming environment and knowledgeable staff are critical in attracting people with disabilities to the game.

According to NCA executive director Gary Robb, "Course owners should see significant growth in the number of golfers with disabilities, and thus profits, if they offer opportunities to learn the game through a staff trained to teach golfers with disabilities."

The National Alliance for Accessible Golf (www.accessgolf.org) offers information and resources for golfers, instructors, owners, and operators. A major initiative of the Alliance is GAIN™ (Golf: Accessible and Inclusive Networks), an instructional program that establishes community-based inclusive networks between individuals with disabilities, golf professionals, golf course operators, parks and recreation departments, therapeutic recreation and rehabilitation specialists, and advocacy organizations. Through GAIN™ and other programs, the Alliance advances its mission of ensuring individuals with disabilities have the opportunity to engage in the game of golf.

Just like with all the other golfers you serve, one size does not fit all with golfers with disabilities. There is no "magic bullet" to helping people with disabilities enjoy the game of golf. It takes a solid commitment to implementing best practices, and a dedication to serving those who need accommodation, education, instruction, and the opportunity to play.

CAROL WYNNE *is executive director of the National Alliance for Accessible Golf.*

PHOTOGRAPHS BY RICK SCOTT OF IFTS DIGITAL PHOTOGRAPHY

Specially equipped single-rider golf carts can be adjusted to give those with a wide range of disabilities the opportunity to enjoy the game of golf.

Who supports the National Alliance for Accessible Golf?

American Therapeutic Recreation Association

Club Managers Atssociation of America

Golf Course Superintendents Association of America

Ladies Professional Golf Association

National Center on Accessibility

National Golf Course Owners Association

National Recreation and Park Association

Professional Golfers Association of America

Professional Golfers Association Tour

United States Golf Association

. . . and others working to ensure the opportunity for all individuals with disabilities to engage in the game of golf

Additional Resources:

www.accessgolf.org

www.resourcecenter.usga.org

www.ncaonline.org

www.playgolfamerica.org

Great Sign!

Signage that makes a point.

BY JEAN MACKAY AND SHAWN WILLIAMS

E-Ryder Golf Course, Fort Bragg, N.C.: It's hard to beat this sign for showing off the course's certification as an Audubon Cooperative Sanctuary.

Over the last ten years, golf courses have made excellent strides in enhancing and protecting the nature of the game. Among the signs of progress are the many great signs now found on golf courses. Signage that points out a golf course's unique natural features or highlights the benefits of environmental stewardship is a simple and effective way to educate golfers and the public.

A 2007 Golf & The Environment Survey conducted by *Golf Digest* reveals that golfers are ammenable to learning about the environment while they play. Fifty-nine percent expressed interest in learning about wildlife, plants, and trees, while 63 percent of golfers were interested in how the golf course they play affects the environment.

Signs that highlight environmental projects, special habitats, or wildlife species call attention to valuable aspects of a golf course that might otherwise be missed. Signs also can be used to protect areas of special concern or to provide direction or instruction.

Dave Phipps, superintendent of Stone Creek Golf Club in Oregon, mounted signs to help inform people about the course's wetlands and waterways. "Golfers, and superintendents for that matter, get very focused on the turf under their feet," says Phipps. "We all need to stop and look at the big picture now and again. A well-placed sign helps people do just that, by calling attention to the beauty and diversity that make golf a great game."

The primary objective of any sign is to communicate your message concisely to all who will see it. Here, we offer tips for developing effective signage, as well as several examples of great signs created by Audubon Cooperative Sanctuary Program members.

TIPS

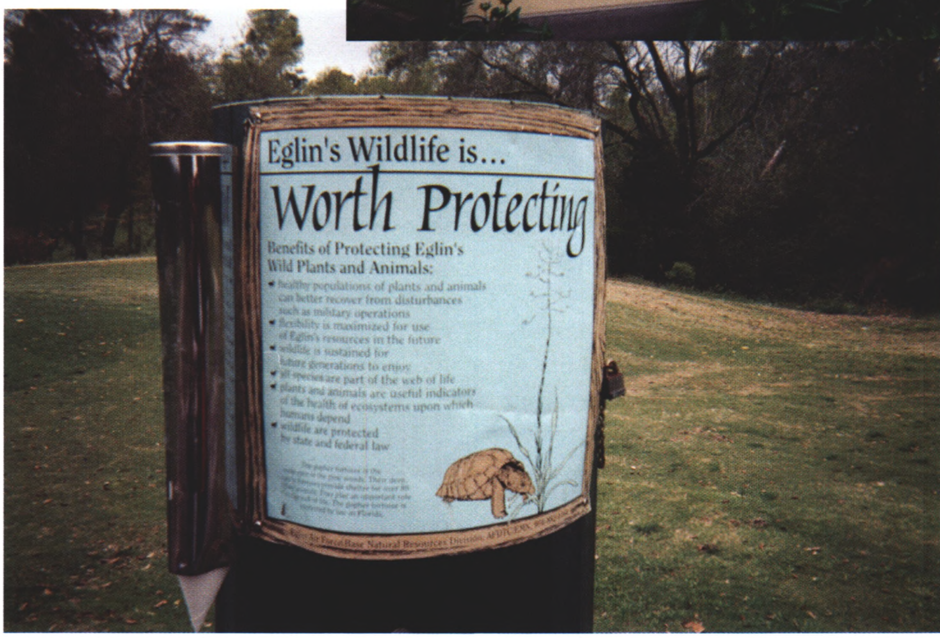
- **Know Your Target Audience:** Determine who the sign is intended for, e.g., the public or employees. Your audience may influence the design and wording of the sign.
- **Determine the Sign's Purpose:** Why is the sign being posted? Is it to educate, call attention to something, or offer instruction?
- **Include Key Words:** Use words that convey your message quickly and easily.
- **Avoid Wordiness:** Keep wording simple and to the point. Too much text is often counterproductive. People won't read signs that have too much information.
- **Make It Legible:** Keep the font simple and be sure that the font size is large enough to be read at a distance.
- **Choose Contrasting Colors:** Choose colors that can be differentiated easily from one another.
- **Include Graphics:** Even simple graphics can make signs more eye catching.

Stone Creek Golf Club, Oregon City, Oregon: The inclusion of a logo can make signs look more official and distinct. Combined with a few choice words, this one highlights the importance of the course's wetlands.

Glendoveer Golf Course, Portland, Oregon: A great location and the combination of key words and simple images make this a highly effective educational sign. Plus, it's made of recycled materials.

- **Consider Weatherproofing:** Protect signs from the elements to increase life expectancy and maintain attractiveness.
- **Choose the Best Location:** Post signs in locations that are well trafficked and where people are likely to pause and read them.
- **Limit the Number of Signs:** Don't litter your property with signage. A few well-placed signs are best.

JEAN MACKAY *formerly served as director of education at Audubon International and is the current director of communications and outreach for the Erie Canalway National Historic Corridor in New York State.* SHAWN WILLIAMS, *staff ecologist, assists golf courses in enhancing and protecting their natural assets through the Audubon Cooperative Sanctuary Program for Golf Courses. To find out more, visit www.auduboninternational.org.*



Eglin A.F.B., Eagle and Falcon Courses, Niceville, Florida: The creative placement of this sign gives golfers something to think about as they pause for a drink, and it's easily changed to offer new information throughout the golf season.

It's Not the Tool — It's the Toolee!

Ball mark repair in the 21st century.

BY LARRY GILHULY

In the early '90s, a revolution hit the golf industry that changed how a golf ball rolled on putting greens — the introduction of spikeless alternatives that replaced "traditional" metal spikes. While ridiculed early by many players who assumed that metal spikes must be retained for traction, this slow-to-catch-on idea began to snowball as players found the combination of comfort and improving traction with various models made a real difference on creeping bentgrass, bermudagrass, and *Poa annua* dominated surfaces. The idea was simple — just remove "traditional" metal spikes from golf shoes, replace them with a good spikeless alternative, institute a metal spikes ban, and presto — your greens were significantly improved. There were no spike marks and not nearly the amount of wear noted around the holes due to foot traffic. Not perfect, but good enough to produce surfaces so much better that today the vast majority of players wear spikeless alternatives, and this issue is now virtually non-existent.

Enter the 21st century, and another way golfers negatively impact greens (ball marks) is undergoing a potential revolution with a myriad of manufacturers making claims that golf tees and "traditional" two-pronged tools need to be eliminated and only their type of new tool is the "answer" for all ball marks. While some of these tools have potential or have improved greens and are being marketed as *the only* answer, is it really the tool or simply the toolee?

As opposed to the spikeless alternative tsunami that washed over golf in the '90s, when golfers simply walked on the greens and improvement occurred, ball mark repair involves actual human thought — of which most players are either not educated or untrainable! The second problem is that all ball marks are not the same and all grasses are not the same when repaired. Let's look at the first problem — most golfers simply do not know how to fix ball marks properly.

Other than the new types of ball mark repair tools that either have shortened prongs or use a pinching action, the real problem with tees and two-pronged ball mark repair tools is that they are simply too long. When extended into the ground and lifted or twisted harshly, exposed soil is left behind with damaged plants on the ball mark perimeter. If nothing else, please remember this — **push your ball marks back toward the center; do not lift or twist harshly**. Ball marks can be fixed just as expertly with a two-pronged tool or tee by following these three simple rules:

1. Shorten the tee/prong length to no more than ½" to ¾". This can be accomplished easily where the forefinger acts as a base, with the thumb providing the pushing action.

2. Push the ball mark from the back side first. As a golf ball lands on a green, the "back" side of the ball mark will have the most turf displacement. This is where the most pushing should occur, and with some ball marks this is all that is needed.

3. Push the ball mark from the sides. The two sides of the ball mark can also be slightly displaced, so the second and third areas to push back are the sides. In some cases a small amount of twisting may be necessary, but under no circumstances should the turf be ripped toward the center. Also, the leading edge of the ball mark generally requires no pushing, as the turf has not been affected.

The second problem with some of the new ball mark repair tools is their short prongs or pinching action that simply cannot get to the center of deep *Poa annua* and creeping bentgrass ball marks, which can occur on many golf courses in cooler climates. This is especially true where *Poa annua* dominates, such as the Pacific Northwest, the California coast, and much of the northern Midwest and Northeast. These deep ball marks cannot be fixed with anything but a longer pronged device, and *Poa annua* does not respond as negatively as creeping bentgrass and hybrid bermudagrass when it is slightly twisted in an effort to level the ball marks in a cooler climate.

Bottom line — any player can fix *every* ball mark properly with a tee or two-pronged device, just as he or she can with some of the new repair tools, with the exception of deep ball marks. It is not the tool, but the toolee that truly determines how well a ball mark is repaired!

LARRY GILHULY *is director of the Green Section's Northwest Region.*

USGA

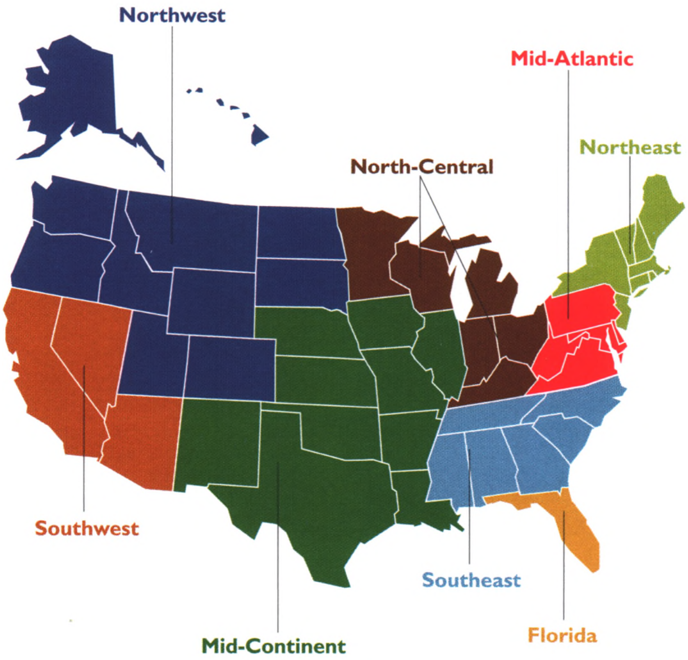
GREEN SECTION NATIONAL OFFICES

United States Golf Association, Golf House
P.O. Box 708
Far Hills, NJ 07931
(908) 234-2300 Fax (908) 781-1736
James T. Snow, *National Director*
jsnow@usga.org
Kimberly S. Erusha, Ph.D., *Director of Education*
kerusha@usga.org

Green Section Research
P.O. Box 2227
Stillwater, OK 74076
(405) 743-3900 Fax (405) 743-3910
Michael P. Kenna, Ph.D., *Director*
mkenna@usga.org

1032 Rogers Place
Lawrence, KS 66049
785-832-2300
Jeff Nus, Ph.D., *Manager*
jnus@usga.org

Construction Education Program
770 Sam Bass Road
McGregor, TX 76657
(254) 848-2202 Fax (254) 848-2606
James F. Moore, *Director*
jmoore@usga.org



REGIONAL OFFICES

●Northeast Region
David A. Oatis, *Director*
doatis@usga.org
James H. Baird, Ph.D., *Agronomist*
jbaird@usga.org
P.O. Box 4717
Easton, PA 18043
(610) 515-1660 Fax (610) 515-1663

James E. Skorulski, *Senior Agronomist*
jskorulski@usga.org
1500 North Main Street
Palmer, MA 01069
(413) 283-2237 Fax (413) 283-7741

●Mid-Atlantic Region
Stanley J. Zontek, *Director*
szontek@usga.org
Darin S. Bevard, *Senior Agronomist*
dbevard@usga.org
485 Baltimore Pike, Suite 203
Glen Mills, PA 19342
(610) 558-9066 Fax (610) 558-1135

Keith A. Happ, *Senior Agronomist*
khapp@usga.org
Manor Oak One, Suite 410,
1910 Cochran Road
Pittsburgh, PA 15220
(412) 341-5922 Fax (412) 341-5954

●Southeast Region
Patrick M. O'Brien, *Director*
patobrien@usga.org
P.O. Box 95
Griffin, GA 30224-0095
(770) 229-8125 Fax (770) 229-5974

Christopher E. Hartwiger, *Senior Agronomist*
chartwiger@usga.org
1097 Highlands Drive
Birmingham, AL 35244
(205) 444-5079 Fax (205) 444-9561

●Florida Region
John H. Foy, *Director*
jfoy@usga.org
P.O. Box 1087
Hobe Sound, FL 33475-1087
(772) 546-2620 Fax (772) 546-4653

Todd Lowe, *Agronomist*
tlowe@usga.org
127 Naomi Place
Rotonda West, FL 33947
(941) 828-2625 Fax (941) 828-2629

●Mid-Continent Region
Charles "Bud" White, *Director*
budwhite@usga.org
2601 Green Oak Drive
Carrollton, TX 75010
(972) 662-1138 Fax (972) 662-1168

Ty McClellan, *Agronomist*
tmcclellan@usga.org
165 LeGrande Boulevard
Aurora, IL 60506
(630) 340-5853 Fax (630) 340-5863

●North-Central Region
Robert A. Brame, *Director*
bobbrame@usga.org
P.O. Box 15249
Covington, KY 41015-0249
(859) 356-3272 Fax (859) 356-1847

Robert C. Vavrek, Jr., *Senior Agronomist*
rvavrek@usga.org
P.O. Box 5069
Elm Grove, WI 53122
(262) 797-8743 Fax (262) 797-8838

●Northwest Region
Larry W. Gilhuly, *Director*
lgilhuly@usga.org
5610 Old Stump Drive N.W.,
Gig Harbor, WA 98332
(253) 858-2266 Fax (253) 857-6698

Matthew C. Nelson, *Senior Agronomist*
mnelson@usga.org
P.O. Box 5844
Twin Falls, ID 83303
(208) 732-0280 Fax (208) 732-0282

●Southwest Region
Patrick J. Gross, *Director*
pgross@usga.org
505 North Tustin Avenue, Suite 121
Santa Ana, CA 92705
(714) 542-5766 Fax (714) 542-5777

Subscriptions $18 a year, Canada/Mexico $21 a year, and international $33 a year (air mail).

Subscriptions, articles, photographs, and correspondence relevant to published material should be addressed to: United States Golf Association, Green Section, Golf House, P.O. Box 708, Far Hills, NJ 07931.

Green Section Record (ISSN 0041-5502) is published six times a year in January, March, May, July, September, and November by the United States Golf Association®, Golf House, Far Hills, NJ 07931.

Postmaster: Address service requested — USGA Green Section Record, P.O. Box 708, Golf House, Far Hills, NJ 07931-0708.

Periodicals postage paid at Far Hills, NJ, and other locations. Office of Publication, Golf House, Far Hills, NJ 07931.

Printed on recycled paper

Turf *Twisters*

Q: Our putting greens were established with Penn G-2 creeping bentgrass in a semi-arid region of the West that typically has snow cover five months of the year. Would there be any advantage to overseeding Penn A-4 creeping bentgrass or another cultivar into the greens during aeration and topdressing operations to create a denser, more vigorous and heat- and cold-tolerant stand? (Utah)

A: Field observations generally suggest that interseeding of creeping bentgrass into an established stand of putting green turf is not very successful. Plant competition, traffic, daily mowing, irrigation regimes, and other routine maintenance practices to keep the greens in play are not conducive to seedling establishment. If the existing stand thins significantly, some success can be realized if adjustments are made to the maintenance programs that favor seedling establishment. Otherwise, regrassing via stripping and sodding or eliminating the existing turf with non-selective herbicide and planting a new cultivar are the best means to switch grasses.

Q: My Green Committee does not understand the impact of shade and overcast conditions on ultradwarf bermudagrass greens and the importance of the recommended eight hours of sunlight per day. We experience extended periods of overcast days, which can cause thinning in our greens, but golfers do not relate overcast to shade. Help! (Louisiana)

A: You are correct about the impact of overcast skies on bermudagrass. These conditions can simulate shade and are just as detrimental to ultradwarf bermudagrass greens. Fall and winter months can impose extended periods of cloudy skies and moisture in the South, which simulates the same conditions as shade exposure to greens and will reduce vigor and increase incidence of disease and algae. It is essential to educate your Green Committee about the consequences of shade and low light conditions on your ultradwarf greens.

Q: Should we strive to keep our golf course marked all year? (Alabama)

A: Absolutely. Course marking defines the boundaries of play, and if golfers expect to play according to The Rules of Golf, course marking is essential.