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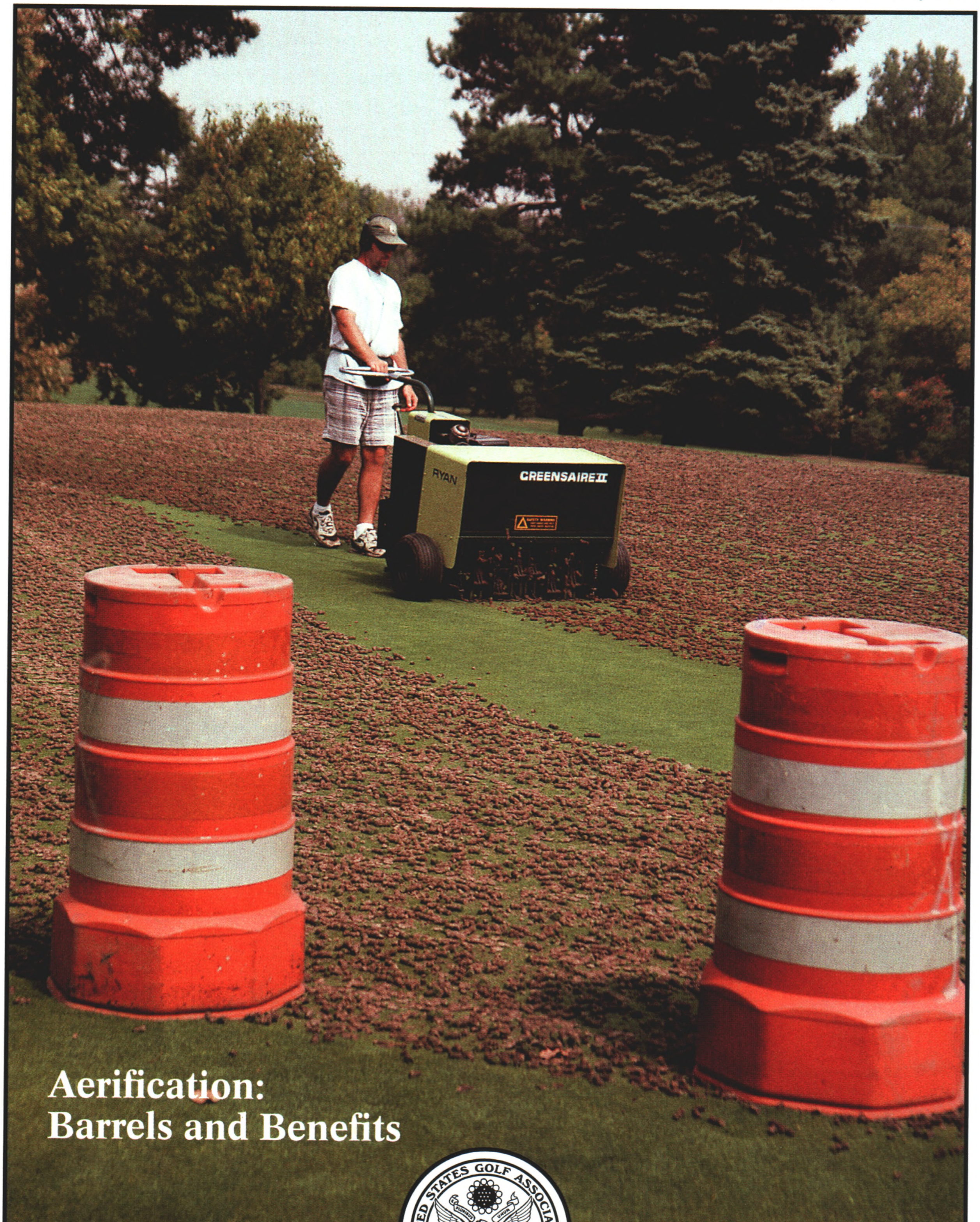

Aerification: Barrels and Benefits

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Cover Photo: While orange barrels draw contempt on our highways, it is conceded that progress has a price. In a like manner, putting green aerification will cause some short-term disruption, but that price is worth the long-term benefits.

Even though these trees are low-growing, the view to the green of this par-3 hole is extremely limited due to their presence. See page 8.

PHOTO COURTESY AURORA C.C., ILLINOIS

Using the best quality irrigation water is good for the golf course and good for nature. See page 15.

Orange Barrels and Putting Green Aerification

Progress has a price.

by R. A. (BOB) BRAME

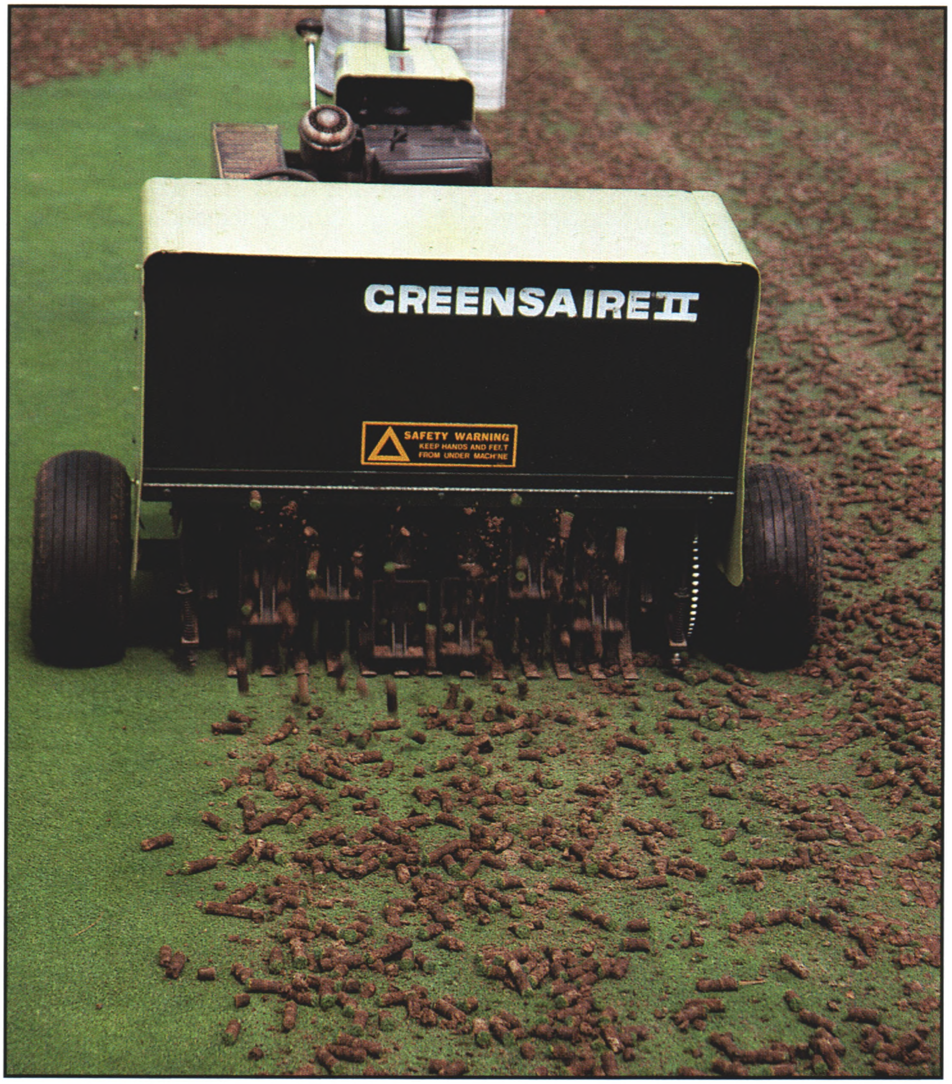
WHILE THE SIGHT of orange barrels draws contempt on our highways, it is conceded that progress has a price. In a like manner, properly timed putting green aerification will cause some short-term disruption to play. Putting green aerification is one of the most important, yet hated and ultimately compromised components of golf course maintenance. Aerification is rarely given enough credit for being an essential component in putting green maintenance. As a result, its purpose often is not defined, dates are not locked in and guarded, technique and the use of the best equipment are often ignored, and with this lack of resolve whining golfers have their way.

Golf turf management might be said to involve four essential/foundational agronomic building blocks. They are:

- **Fertilization**
- **Growing Environment** (sunlight and air movement)
- **Mowing** (type of mower being used, bench setting, and sharp blades)
- **Water Management** (drainage/aerification plus irrigation)

How greens are watered and aerified (water management) directly affects turf health and playability. This is especially true over the intermediate (3 to 10 years) and long haul. Limitations in one or more of these essential building blocks cannot be countered effectively with any conceivable combination of fine-tuning strategies. Although the reasons and techniques will vary, it is difficult to imagine a maintenance program that has been successful for any length of time (10+ years) that does not include aerification.

This article discusses key reasons for putting green aerification, considers general equipment categories, provides some guidelines for developing the right program at your course (customizing), and discusses how to minimize the disruption aerification causes (easing the impact of orange barrels). The



Root zone modification programs normally target the top few inches of the soil profile with shallow-tine aerification. A key benefit of machines like the Verti-Drain or Soil Reliever is fracturing in the lower soil profile.

focus is bentgrass or bentgrass-*Poa annua* putting surface maintenance in or north of the transition zone.

Key Reasons for Aerifying Greens

There are four primary reasons for putting green aerification in routine maintenance (interseeding or regrassing would fall more towards renovation). The list includes: (1) soil compaction relief (porosity enhancement; air, water, and root movement), (2) root zone modification, (3) thatch management, and (4) surface smoothing.

(1) Root zone compaction caused by equipment, cart, and/or player traffic will compromise turf health and the resulting playability. Compaction reduces porosity, which adversely affects the free exchange of air, water movement, and root system development.

(2) The accumulation of organic matter (thatch) and fine particles (silt and/or clay) can, over time, produce a surface layer that reduces porosity. Aerification can modify the profile, improving oxygen, water, and root movement, especially when the use of hollow tines is combined with core removal and backfilling channels with high-quality topdressing sand.

(3) Thatch management, while accomplished with root zone modification, is often needed even if the root zone profile does not need to be modified. A properly built USGA specification green is an example of where thatch management via aerification may be necessary while profile modification would not.

(4) The process of punching holes and either reincorporating the plugs brought up or removing the plugs and filling channels can offer some surface smoothing. Surface topdressing alone will fill/smooth low spots. The combination of aerifying and the follow-up topdressing will, over time, both fill low spots and soften high spots, resulting in more efficient surface smoothing than topdressing alone.

Overview of Equipment Categories

In today's golf turf industry there is a wide variety of aerification equipment available. Yet, with more options often comes more confusion in determining the best equipment to utilize. To sort through the equipment available and its usage, there are three principal categories to consider. These are: (1) conventional shallow-tine aerifiers, (2) deep-tine aerifiers, and (3) machines and/or tines used for summer management.

The first category includes a number of manufacturers with machines possessing various options. Basically, these aerifiers must be maneuverable, capable of producing reasonable tine penetration (+/– 3.5"), and offer good hole spacing (the most common standard has been 2" × 2"). Some machines offer adjustable hole spacing and/or bracket attachments to vary spacing. Speed, while often a marketing tool, is not as important as quality. The definition of "quality" is: a machine that enters and exits the playing surface without causing excessive disruption (punches straight into the surface). The second category includes aerifiers that penetrate much like the first group, only deeper. Straight entry of the tine into the surface is not as important in this category. In fact, certain deep aerifiers offer a beneficial kicking or fracturing action that is tied to an angled entry and/or exit of tines from the root zone. Water injection aerifiers and deep-drill machines would also fit into this category.

The third category, machines and/or tines utilized for summer management, is most often used to improve oxygen and/or water movement. Root zone modification, while often a goal of fall and spring conventional aerification, is not a primary objective with this category. The target is to create open channels in the soil profile with minimal putting surface disruption and turf trauma. Typically, the equipment used overlaps with the first two categories, with adjustments made in tines, spacing, and/or speed. While the equipment falling into the first two categories is normally used with reoccurring repetition, summer opening and venting is weather and traffic dependent and may not be needed every year.

Customizing

Compaction

The need for aerification for compaction relief can develop on soil-based greens, sand-based greens, and everything in between. Although upper profile organic matter accumulation softens the impact of equipment and player traffic, the soil structure below eventually becomes compacted. Turf quality will then decline through the reduction of atmospheric gas movement, water penetration, and root system development. To alleviate these limitations, it is common to combine deep aerification with shallow-tine aerification. This is often done with a deep-tine aerifier like the Verti-Drain or Soil Reliever equipped with solid tines, followed immediately with a shallow-tine aerifier. Using this combination of aerifiers relieves compaction in both the upper and lower soil profile.

Water injection aerification is also used to reduce upper and lower profile compaction. However, the benefits have not been the same as conventional aerification and/or deep-tine aerification with regard to creating open channels in the root zone. This is likely because the channels do not last as long.

A well-built green will be, to some degree, compaction proof for the first few years. However, attempting to build a USGA green and missing the mark with too much silt and clay can result in compaction problems equivalent to those of poorly constructed and/or older soil root zones.

Root Zone Modification

The second issue is root zone modification. Do your greens have an organic matter/thatch accumulation in the upper root zone? Is water moving into the profile quickly? The goal of putting surface management is to keep the top few inches of the root zone as dry as reasonably possible. Factors like root depth, soil type, weather, irrigation system, and available staff impact the baseline goal of keeping the top few inches of the root zone dry. While most of a heavy rain will run off, the water that goes into the soil profile should drain away from the surface as quickly as possible. The use of shallow-tine aerifiers equipped with hollow tines, the removal of plugs, and backfilling channels with material of good porosity will create the best possible upper profile modification, short of rebuilding.

Root zone modification programs normally target the top few inches of the soil profile with shallow-tine aerification. Occasionally, however, a deep-drill or deep-tine aerifier with hollow tines is used to modify the lower profile. This is time-consuming, expensive, and, if needed on an ongoing basis, may indicate the need for green reconstruction.

Thatch Management

A program designed to modify the profile will also achieve some thatch control. A well-built green that has been consistently topdressed and aerified will likely not need upper profile modification. However, even a well-built green that has not been top-

Completely filled aerification channels achieve the quickest return to smooth putting surfaces (left). Care must be taken to use dry topdressing sand so that the channels can be completely filled. If the topdressing contains any moisture, a bridging action will occur, and while the holes may appear to be filled, the sand will eventually dry and then drop into the channels (right).

dressed consistently can develop a thatch problem. This requires pulling plugs, topdressing over them, and incorporating the mixture into the surface/holes, or completely removing plugs and filling channels. Tines only need to penetrate deeply enough for the thatch accumulation in the upper root zone to be removed. It is possible to minimize profile disruption and equipment tire depressions on the surface (often a problem with new greens) with short (cut off) coring tines. However, the tines do need to be long enough and penetrate far enough to pull a plug.

Smoothing

Smoothing is the key reason for aerifying a new well-built green, although integrating aerification with surface topdressing will maintain a homogeneous profile. Either topdressing over the plugs brought up when aerifying a well-built green and working the mixture in, or simply incorporating the plugs/root zone back into the surface/holes will offer a smoothing action. In smoothing, as with thatch management, tines can be shortened to reduce profile and surface disruption. Aerification offers a smoothing action on older and/or poorly constructed greens as well, although the smoothing action is typically a higher need on new greens.

Combination of Needs

In most cases, aerification is done for more than one reason. For instance, well-built greens are aerified to smooth the surface and dilute organic matter accumulation if not topdressed regularly. Soil and/or poorly constructed high-sand-content greens are often aerified to modify the upper profile, while also easing compaction and smoothing the surface. Deep aerification is often added to a maintenance program to open, loosen, and/or fracture the lower profile.

Easing the Impact of Orange Barrels

1. *Communicate the reasons for putting green aerification.* At times, it seems some golfers think the superintendent lies awake at night pondering ways of messing up their round of golf. The lack of communication may well be the primary reason for this mindset. There are times when politics may dictate the need for a superintendent to back down and accept the golfers' desires. However, when it comes to the four agronomic building blocks outlined in the introduction, a hard line should be maintained. Even though agronomics, economics, and politics are part of every maintenance decision, it is the agronomics that protects the intermediate and long-term performance and conditioning of the course. Make sure golfers understand why aerification is more important than, for example, edging bunkers or mowing around trees. Through newsletter articles, superintendents should explain why it is important to move water away from the surface as quickly as possible. Firm, dry surfaces equate to healthier turf and better playability — benefits that few golfers could argue with. Golfers would better understand the necessity of aerification if a hierarchy of goals were made known. For instance: (1) shallow-tine aerification targets upper profile modification, (2) deep aerification punches through the compaction zone at the bottom of shallow-tine penetration and enhances lower profile porosity, and (3) solid star tines and water injection are used in the summer to maintain positive atmospheric gas and water movement. Deep, plump, white roots growing down aerification channels dramatically communicate what "enhancing profile porosity" actually means.

A physical analysis of the soil profile by an accredited laboratory can scientifically quantify aerification requirements. This may help golfers understand why the greens are being shallow-tine aerified three or four times a year and deep aerified twice. The laboratory analysis may expose the fact that an aggressive aerification program is postponing the need to rebuild.

It is important for golfers, at least those who are interested, to understand all sides of the issue. That's what communication is all about. Don't assume anything.

2. *Equipment selection.* Golfers will be more tolerant and understanding of aerification work if surface disruption is held to a minimum. This means the greens must putt reasonably smoothly the day after aerification. To achieve this goal, use a quality machine and completely fill the holes produced by aerification.

A quality shallow-tine aerifier punches straight into the putting surface. If the tines enter at even a slight angle, the holes will be oblong. The raised or slight mounding behind the holes creates surface disruption that takes time to smooth. Even rolling the surface after using a poor-quality machine will not completely eliminate ball roll disruption. The sacrifice in speed to punch crisp round holes is worth the investment.

Completely filling aerification channels and using a quality machine will achieve the quickest possible return to smooth putting surfaces. The only way aerification holes can be completely filled is with the use of dry topdressing sand. If the topdressing contains too much moisture, a bridging action occurs and, while the holes may appear to be filled, the sand will eventually dry and then drop into the channels. The result is inefficient upper profile modification and partially open holes, producing bumpy putting surfaces. This also applies to a well-built green where upper profile modification is not a goal. It is for this reason that either topdressing (using the sand component of the construction mix that is completely dry) over plugs and incorporating the mixture into the surface/holes, or completely removing plugs and filling channels, is preferred to simply working in the plugs alone.

A key benefit of machines like the Verti-Drain or Soil Reliever is the fracturing that occurs in the lower profile. The kicking action generated by these machines usually results in some minor surface disruption. While the kicking action can be adjusted, some action is needed to provide the desired fracturing action. The soil moisture level is also important in achieving the desired fracturing. Too much root zone moisture virtually eliminates fracturing, while too little may result in significant surface damage. Following deep-tine aerification with a quality shallow-tine aerifier can aid in smoothing the surface, while blurring the holes from deep opening. This makes it possible to stay with the typical combination of removing shallow-tine aerification plugs and backfilling channels. Using both machines holds play disruption to one time frame, while receiving the combination of benefits.

Once the reasons for aerifying greens have been established, make sure the equipment complements the goals. While water injection aerifiers can be a tool, they allow neither profile modification nor the smoothing action possible when plugs are pulled. This is actually true of virtually all machines and/or tine combinations used for summer opening and venting. There is a tendency at some courses to move toward less disruptive and/or quicker aerification strategies at the expense of doing what is really needed for turf health.

3. *Schedule properly and stay the course.* Summer aeration, to open and vent the profile, is difficult or impossible to pre-schedule. The need will vary with weather conditions, traffic, and turf health. Some flexibility, like the course being closed for one-half day on Monday, should be factored in to allow this work some latitude. Conventional and deep aerification can and should be scheduled in advance.

The best approach is to take the course calendar and enter all aerification dates before golfing events are added. Ideally, place an alternate date two or three weeks after each target date. This ensures aerification will be done, even if a temporary postponement is necessary. Weather conditions and/or weak turf/roots may force a temporary postponement — golfing events should not. With target and alternate dates on the course calendar, golfing events can be added where appropriate. Advance scheduling protects aerification, while allowing golfers to be informed. The ongoing aerification of greens is more important than any one golfing event.

When greens are being aerified, either close the entire course, nine holes, or the applicable hole(s). The best policy is to either close nine holes at a time or close the entire course. The safety and efficiency of putting green aerification will be much better if play is not allowed during the process.

While the actual timing of the target dates will vary depending upon location, the late summer/early fall time slot is ideal. The more aggressive fall fertilization combines with the enhanced root zone porosity offered by aerification to strengthen root depth and mass. Mid-fall or mid-spring would be slot number two. Three conventional aerifications a year would normally target late summer/early fall, mid-fall, and mid-spring. Should four be needed, add late spring to the schedule. Deep aerification can be inserted just before any one or combination of the shallow-tine openings.

To achieve the quickest possible grow-over, all aerification work should be done when the turf is actively growing. Aerifying in late fall or early spring can expose the turf to more intense winter desiccation or overly wet root zones (open channels, even if completely filled as is the target, will allow more of a heavy rain to pass into the profile).

Once scheduling is completed, stay the course. Consistency is important to achieving maximum value.

Conclusion

Ultimately, the first step toward properly aerifying greens is to acknowledge its importance. The use of high quality, properly selected equipment can combine with ongoing communication and advance scheduling to minimize the presence of orange barrels. Yet, with progress comes orange barrels.

References

Callahan, Lloyd M. (1998). *Thatch control in bentgrass greens.* Turfgrass Trends. Volume 7, Issue 9, September 1998, pp. 1-9.

Mascaro, Tom (1988). *Greens Aerification.* Golf Course Management. Volume 56, No. 7, July 1988, pp. 16-20.

Murphy, J. A., Rieke, P. E., & Erickson, A. E. (1993). *Core Cultivation of a Putting Green with Hollow and Solid Tines.* Agronomy Journal. Volume 85, No. 1, January/February 1993, pp. 1-9.

Watson, James R. (1990). *Choosing Appropriate Aerification Methods for Greens.* Golden State Fairways — Second Quarter 1990. Volume 2, No. 2, May 1990, pp. 32-35.

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Confused About Weather Station ET? Perhaps You Should Be

ET and crop coefficient data from various weather stations are not interchangeable.

by DR. PAUL W. BROWN

USE OF evapotranspiration (ET) data has been touted as the means by which golf course superintendents can refine and optimize irrigation management. Today, most superintendents in the Desert Southwest can access local ET data from a public weather network or their own on-site weather station. In many cases, ET from on-site weather stations is integrated into sophisticated computer software that directly controls daily course irrigation schedules. While the use of ET data often leads to improved irrigation management, better turf quality, and lower operating costs, widespread proliferation and use of ET derived from weather stations does pose some problems that need to be addressed to make this data more reliable and useful to superintendents. The focus of this article will be on an important but rarely discussed problem: the procedure used by the weather station or its attendant software to compute ET. We begin with an exploration of the problem, then summarize results of a recently completed study designed to provide solutions to the problem.

Misconceptions About ET

A common misconception among many in the turf industry is that a weather station actually measures turf ET. This is not the case. Weather stations monitor meteorological variables that impact turf ET, including solar radiation, wind speed, humidity, and temperature. The resulting weather data are then input into meteorological models that estimate *reference evapotranspiration*, which is commonly abbreviated ETo. ETo is defined as the water lost from a well-irrigated, tall (3-6"), cool-season grass (ryegrass or fescue) by the combined processes of transpiration and soil evaporation. Factors ranging from turf species to mowing height cause the ET from golf turf to differ from that of ETo. For example, a bermudagrass fairway turf maintained at a height of ½" would likely use less water than the much taller cool-season reference grass that supports a higher leaf area and interacts more readily with wind. We commonly employ a simple multiplicative adjustment factor known as the crop coefficient (Kc) to adjust or convert ETo to actual turf ET (ETa):

ETa = Kc × ETo (Equation 1)

The key to optimizing the use of weather stations on a golf course is the selection of appropriate crop coefficients. Crop coefficients often differ for tees, greens, fairways, and roughs; therefore, availability of the appropriate Kc is required to tailor irrigation for each type of turf. Crop coefficients are usually developed in controlled research studies where actual turf water use (ETa) is compared with values of ETo computed from meteorological parameters. Rearrangement of Equation 1 provides the mathematical basis for developing Kcs, and reveals that Kcs are dependent on *both* the measured value of turf water use (ETa) and the computed value of ETo:

KC = ETa/ETo (Equation 2)

It is at this point where the problems and confusion develop with use of ETo derived from weather stations. The procedure for computing ETo is not standardized. While there are two general models used to estimate ETo — the modified Penman Equation and the Penman-Montieth Equation — the scientific community has developed and recommended numerous modifications to each general model to provide *better fits* to local data sets or local environmental conditions. Unfortunately, this scientific refinement has led to the publication of numerous procedures for estimating ETo, many of which generate different values of ETo when supplied with the same meteorological data.

The ETo computation problem is depicted in Figure 1, where data from a single meteorological station were used to compute ETo using modified Penman Equations employed by the public weather networks in Arizona (2), California (5), and New Mexico (4). Our experience with the ETo procedures provided by private vendors of

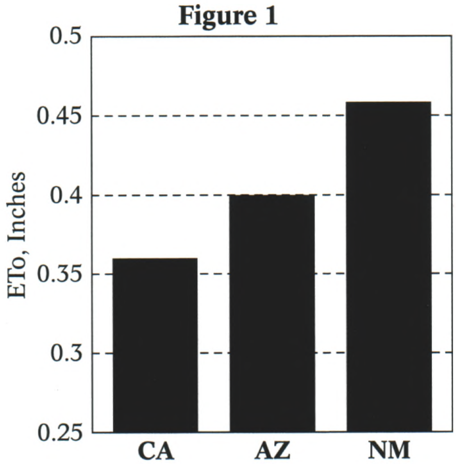
Weighing lysimeters are accurate to within 0.01" per day in measuring actual water use of the turfgrass (ETa) maintained under fairway management conditions.

weather stations and irrigation management software suggests ETo computation also is a problem with weather stations provided by the private sector.

ET Computation

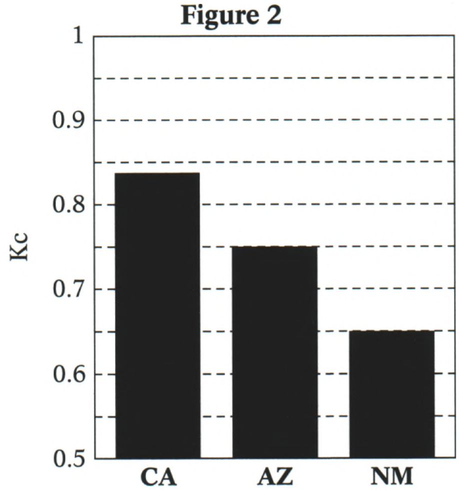
While the ETo computational problem may seem trivial or academic to some, the problem does generate negative consequences on at least two fronts. The most imporant consequence is practical in nature and relates to our ability to effectively transfer and use Kcs developed in regional research studies. Suppose, for example, that on the day depicted in Figure 1, Arizona researchers also measured an actual turf water use (ETa) of 0.30". From Equation 2, the crop coefficient appropriate for the Arizona procedure would be 0.30"/0.40" or 0.75. However, if a golf course in New Mexico takes the Kc of 0.75 and applies it to the ETo available from the New Mexico Climate Center, one would seriously overestimate fairway water use. The appropriate Kc for New Mexico needs to take into account their ETo procedure and thus would be 0.30"/0.46" or 0.65.

Figure 1



Reference evapotranspiration (ETo) for 19 June 1996 at Tucson, Arizona, computed using the modified Penman Equations used by CIMIS (CA), AZMET (AZ), and New Mexico Climate Center (NM).

Figure 2



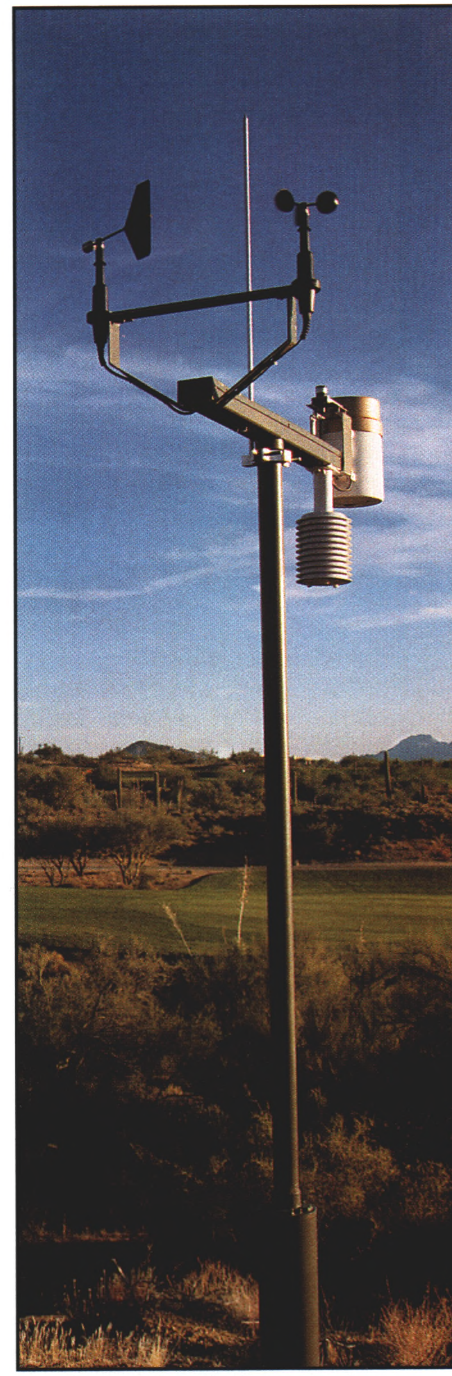
Bermudagrass crop coefficients (Kcs) developed for 19 June 1996 at Tucson, Arizona, using lysimeter measurements of actual water use and ETo values computed using the modified Penman Equations used by CIMIS (CA), AZMET (AZ), and New Mexico Climate Center (NM).

The bottom line on Kcs: they must be paired with the ETo procedure utilized during their development. We feel that much of the bad press given to Kcs results from the failure to recognize the need to adjust/modify Kcs for the method of ETo computation.

A second negative consequence of differing procedures for estimating ETo rests in the realm of regulation. Governmental agencies charged with regulating water use are beginning to use ETo as a means of assessing and regulating water use and allocation, especially in water-short regions such as the Desert Southwest. If in the future water allocations to golf courses are set based on ETo and Kcs, then it will be in everyone's interest that the problems and procedures required to deal with the ETo computation problem be resolved in a sound, scientific manner. Failure to do so will produce additional and unnecessary legal and political wrangling over the issue of golf course water requirements.

Solutions on the Horizon

At this point we have only addressed the problem of ETo computation, not the solutions. Fortunately, solutions to the problem are beginning to emerge. An obvious solution would be to develop a standard procedure for computing ETo. The scientific community is presently moving forward with such a proposal that would utilize a standard form of the Penman-Montieth Equation to estimate ETo (1). Development of a standard procedure should minimize future problems with ETo computation, provided both the scientific community and the commercial suppliers of weather stations and irrigation management software accept the procedure. However, in the interim, we need some means of interpreting and normalizing the numerous ETo procedures in existence at this time so superintendents and the regulatory community can make better use of ETo data.



On-site weather stations are often integrated with computer software that can automatically adjust operating times of irrigation sprinklers.

A research study presently underway at the University of Arizona Karsten Desert Turf Facility is focused on providing this needed interim assistance to golf courses that utilize ETo data from public or private weather stations. Two large weighing lysimeters, each planted to Tifway bermudagrass and maintained in accordance with fairway standards, provide daily values of ETa.

The lysimeters are overseeded in October with an intermediate ryegrass that serves as the winter turf surface. Automated weather stations are located adjacent to the lysimeter facility and provide the necessary meteorological data for computation of ETo.

Appropriate crop coefficients have been developed for ETo procedures used by the California Irrigation Management Information System (CIMIS) (5), the Arizona Meteorological Network (AZMET) (2), the New Mexico Climate Center (4), and the ET Feedback System used in Las Vegas (3) during the early 1990s. A fifth procedure for computing ETo, a version of the Penman-Montieth Equation recommended as an international standard, also is included in the study. Results from this study clearly drive home the point that crop coefficients must be matched to the ETo computation procedure.

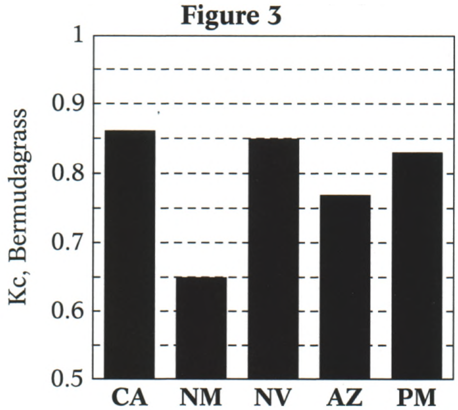
Figure 3 presents the appropriate seasonal crop coefficients for bermudagrass fairways during the summer months of May through September for each of the five aforementioned methods of computing ETo. It is important to remember that the turf water use data used to compute the Kc and the weather data used to compute ETo are the same for all five methods presented in Figure 3. The variation in seasonal Kc is totally a function of the procedure used to compute ETo.

Figure 4 presents a similar picture for winter Kcs when the bermudagrass is overseeded with ryegrass. The data in Figures 3 and 4 show the danger of using a Kc provided by another scientist or superintendent without first identifying the ETo procedure that was used to produce the Kcs. In the extreme case presented in Figure 3, if a Kc appropriate for New Mexico's ETo were used in California with CIMIS ETo, we should expect significant under-irrigation to result. In contrast, if one applies the Kc appropriate for California to ETo in New Mexico, one would likely over-irrigate the turf by nearly 30%.

The Arizona study also is working to find a solution for superintendents who operate their own weather stations. The large number of commercial suppliers of weather stations/irrigation management software and a reluctance on the part of some suppliers to release trade secrets precluded us from directly developing Kc values and correction factors for commercial equipment. Instead, we chose to develop a data set that contains both weather data and actual values of turf ET. This data set is presently being finalized for publication and release via the University of Arizona and the USGA. The availability of such a data set allows the manufacturers of weather stations and/or irrigation management software to 1) compare their ETo computations with those procedures evaluated in the Arizona study, and 2) develop Kc values for a common fairway turf system in the Desert Southwest. We anticipate that many of the commercial suppliers of weather stations and irrigation management software will utilize this data set to provide Kcs and ETo translation factors for existing owners of their products.

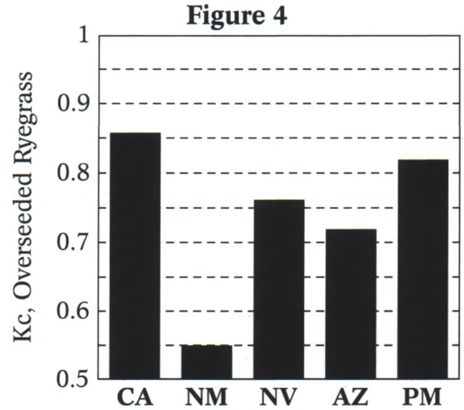
The concept of basing irrigations on ETo values derived from automatic weather stations is a proven technology. The problems associated with computation of ETo add to the difficulty of using and improving ET-based irrigation management systems; however, future efforts to standardize the computation of ETo should help eliminate this problem in the future. We encourage the turf industry to seriously consider adopting a standard ETo procedure to facilitate effective use of regional research on turf water management and to minimize potential problems with the regulatory community. We also suggest that future studies aimed at developing Kcs collect and provide access to meteorological data required for computation of ETo so public weather networks and commercial suppliers of irrigation management equipment can develop Kcs appropriate for their procedures of computing ETo. Simply using the Arizona data set will not provide Kcs appropriate for many temperate or humid regions, and using arid region climate data to compare ETo methods in humid regions may not provide legitimate translation factors.

Figure 3



Seasonal bermudagrass crop coefficients (Kcs) developed for five regional procedures used to estimate ETo. CA: California (CIMIS), NM: New Mexico, NV: Nevada (ET Feedback), AZ: Arizona (AZMET), PM: Penman-Montieth.

Figure 4



Seasonal crop coefficients (Kcs) for overseeded ryegrass developed for five regional procedures used to estimate ETo. CA: California (CIMIS), NM: New Mexico, NV: Nevada (ET Feedback), AZ: Arizona (AZMET), PM: Penman-Montieth.

References

Allen, R. G., M. Smith, L. S. Pereira, and A. Perrier. 1994. An update on the calculation of reference evapotranspiration. ICID Bulletin 43(2):35-92.

Brown, P. W. 1998. AZMET computation of reference crop evapotranspiration. AZMET Web Page: http://ag.arizona.edu/asmet.html.

Devitt, D. A., R. L. Morris, and D. C. Bowman. 1992. Evapotranspiration, crop coefficients, and leaching fractions of irrigated desert turfgrass systems. Agron. J. 84:717-723.

Sammis, T. 1996. Penman's Equation referenced to grass. New Mexico Climate Center Website: http://weather.nmsu.edu/math/penmans.html. New Mexico St. Univ.

Snyder, R., and W. Pruitt. 1985. Estimating reference evapotranspiration with hourly data. California Irrigation Management Information System Final Report. R. Snyder et al. (eds.). Land, Air, and Water Resources Papers 10013-A, Univ. of California-Davis. Chpt. VII:1-3.

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Play on this hole is compromised because of the tree on the left. Even from the back right portion of this tee, a large portion of the green is blocked. The bunker on the left is obscured, and the usable teeing area is reduced.

CHECK THE VIEW FROM THE BACK

Evaluation of a maturing golf course starts from the back tees.

by DARIN BEVARD

THE GOLFER steps up to the tee for his drive. He remembers years ago when a long, right-to-left shot would leave him a perfect approach to the green from the right center of the fairway. Now he must hit a short lay-up shot to avoid hitting the ball into the hazard on the left side of the landing area. "It was never meant to play this way," he thinks. What has happened?

* * *

At the time of construction, many golf courses have very few trees in their landscape. Often, trees are planted as an afterthought to make the course more difficult, more visually appealing, or to provide safety buffers and visual separation between adjacent holes. However, as the trees mature, the intended lines of play from tee to fairway and fairway to green can change greatly. Features such as bunkers and water hazards may also become less visible to the player, especially from the tee. It basically comes down to the effects of these additions on the original design or presentation of the hole, especially as viewed from the tee.

Oftentimes the golf course superintendent is the one person who provides continuity to the course maintenance and improvement program and can observe how the golf course changes as it evolves and matures. Green Committees change. The turf manager has the opportunity to monitor changes in golf holes over time by evaluating the golf course on an annual or semi-annual basis. One way to perform this evaluation is from the back tees of each hole, keeping the other tees in mind as well. This allows the hole to be evaluated from tee to fairway from much the same perspective as the golfer experiences it. In fact, it may even be beneficial to take pictures of each hole from the back tees to keep a record of how the course changes from year to year.

There are several different issues that can be evaluated during this process. These include alignment of tees, effects of trees and underbrush on visibility of hazards, effects on direction of play, and how this vegetation affects wear distribution on tees. There are other agronomic factors to consider as well. If these factors are evaluated on a regular basis, playability and fairness can be maintained without having to implement drastic changes. Oftentimes smaller trees can be moved to better locations where their impact on play is minimized, eliminating the need for the tough, emotional decisions that need to be made when a mature tree is involved.

Tee Alignment

This article will not address the issues of free-form, purposely unaligned tees vs. square-cornered tees. Rather, for this article it is assumed that the course wants tees aligned to the direction of play.

Through the planting of trees or through poor mowing practices, proper alignment between tees and fairways can be lost. Over time, a tee that once aimed to the centerline of the fairway may now be aligned off to one side of the golf hole. It has been my experience that if a tee is angled to the right, so is the golfer. If that golfer slices, as most do, the shot ends up in the rough or in the trees. This can add strokes, slow play, and frustrate the golfer.

One way to address this problem, in the worst case, is to rebuild and properly realign the tee, keeping in mind the changes that have occurred. However, another solution may be to simply alter mowing patterns. This is an inexpensive solution, but adds to the appearance and playability of the hole. By reshaping the mowed area of the tee to align in the proper direction, the player perceives the tee as being properly aligned even though the actual tee may not be. This can aid the player in preparing to play a shot more than most would suspect.

Hazard Issues

Another aspect that should be carefully evaluated from the tees is the effect maturing trees have on visibility and playability of hazards. Hazards can become obscured from view, and the player has no way of knowing a hazard is present except for local knowledge. The integrity of important features can be lost. Hazards, once positioned to challenge and even define a golf hole, can be hidden or lost. A lack of visibility can also present Rules of Golf problems. Questions some up, such as "Where did the ball last cross the margin of a water hazard? Did the ball, in fact, enter the hazard?" It is not imperative that the player sees the entire hazard. However, if the hazard is more visible, it can allow effects on playability to be known.

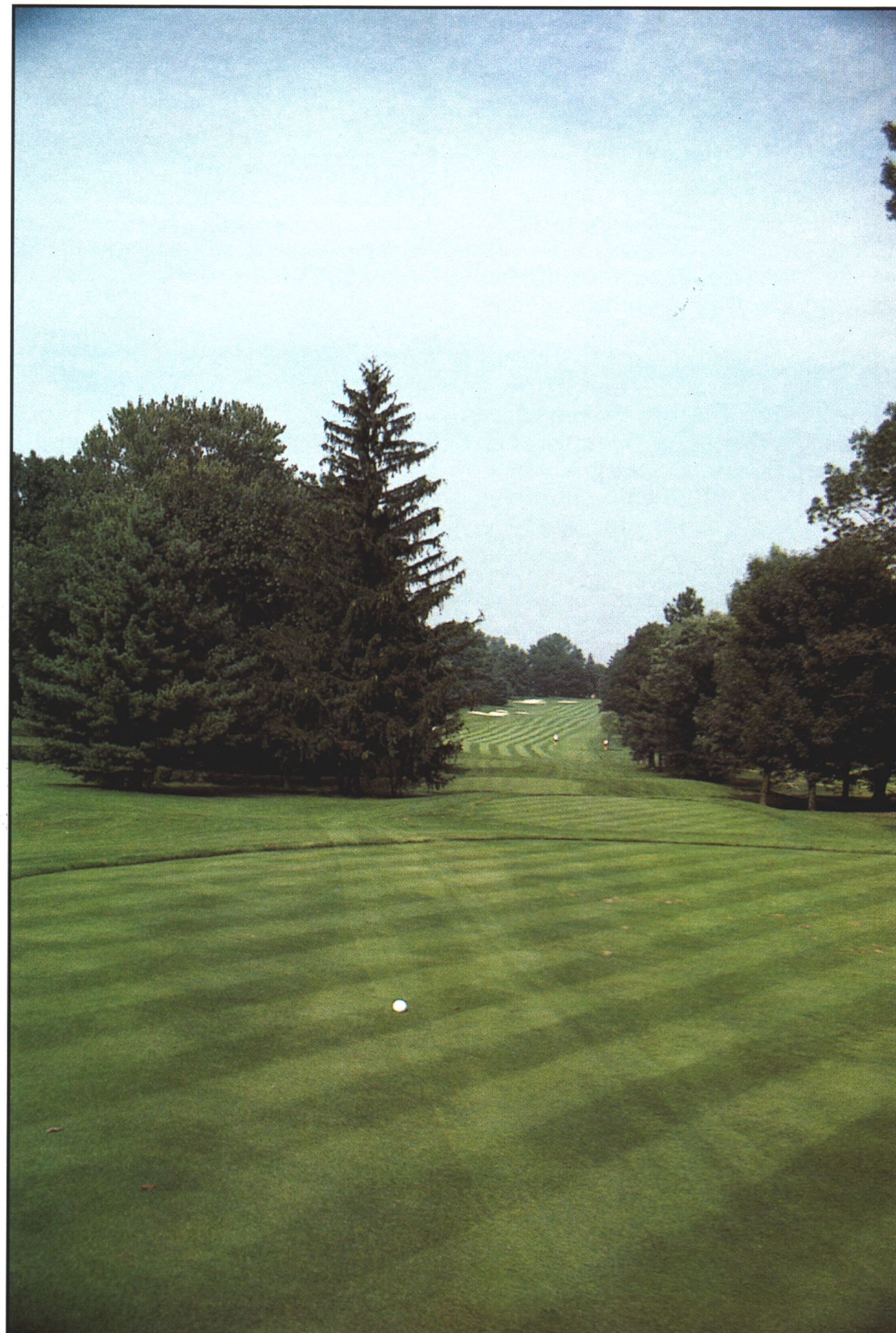
Planting trees can take hazards out of play altogether. Generally, where no trees were called for during the original construction, and a hazard is present, the architect intended for the hazard to provide the obstacle for the player. By planting trees, the trees can become the obstacle, and the hazard no longer is needed or, worse yet, creates a double hazard situation and the player is forced to negotiate both the trees and hazard.

The other problem with blocking the view of bunkers as well as water hazards is that the aesthetic value of the hole is often decreased. The contrast between the sand or water and the grass is no longer present.

Unfortunately, when these situations occur, there are no simple solutions. It is often a question of maintaining the hazard or removing the trees or vice versa. It makes little sense to continually provide maintenance for a bunker that rarely, if ever, comes into play, unless it defines direction.

Direction of Play

As they continue to mature, trees or other added obstacles can force a change in the direction of play for a



The left portion of this tee is virtually unusable due to the presence of the trees on the left. Wear is concentrated on the right side of the tee while the left side receives little traffic.

golf hole. For example, when trees are first planted, a shot can be played over them. As they grow, they force play to go around them. This forces the player to hit a lay-up shot or to manufacture a shot to avoid hitting into a bunker or water hazard that at one time was never even in the line of play for a properly played shot. Worse yet, these types of plantings can force play in the direction of adjacent holes, presenting a safety hazard for other players. Efforts should also be made to prevent weed trees growing in waste areas from becoming large enough to affect direction of play or the view of the hole.

This tree provides a double hazard situation. The location forces the player to hit out of the bunker and negotiate the tree as well. One or the other should be considered for removal.

Agronomic Considerations

The effects of maturing trees on the playability of a golf hole from tee to fairway are often obvious. However, the effects on wear distribution on the actual tee are often not noticed by the layperson.

Placing an obstacle of any kind in the line of play between tee and fairway will generally cause the player to select one side of the tee or the other. For example, if a tree blocks the line of sight to the left side of the hole, shots will generally be played from the right side of the tee box in an effort to avoid interference. This often leads to one side of the tee exhibiting poor turf quality due to high amounts of divots being taken in a very small portion of the tee. Usable teeing space can be greatly reduced when trees encroach on the line of sight from tee to fairway.

One other agronomic factor that should be examined on championship tees is not related to trees at all. Thatch accumulations on back tees are often extreme. This can be a result of these tees being ignored to some degree from a maintenance standpoint. However, thatch accumulations generally result from the lack of traffic these tees receive. It's ironic that thatch accumulations are usually the worst on the back tees. The golfers who play from these areas are the ones who find the spongy surface most objectionable and can actually tell the difference while playing the game. Evaluating this aspect of the championship tees can also be important.

Summary

Evaluating your golf course on a regular basis and correcting small problems as they occur can prevent major changes from occurring with regard to tree encroachment and other factors. The architectural integrity of individual golf holes and their associated hazards can also be protected. Trees or other obstructions can add to the character of a golf hole when they are properly placed. Remember that trees grow, and as they do, they can have a profound effect on the golf course.

As a suggestion, take some time and evaluate the appearance and playability of individual golf holes from the back tees, and don't forget the more forward tees. As a turf manager, it is easy to be consumed by agronomics and forget what the golf course is really for. To the golfer, it's how the hole looks and plays!

A slight altering of the mowing pattern on the tee can provide much better alignment to the fairway and eliminate the need for costly renovations.

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FOR RICHER, FOR *POA*

Cultivar development of greens-type Poa annua.

by DR. DAVID R. HUFF

"FOR RICHER, for poorer. In sickness and health . . . ." These simple words underscore one of life's greatest commitments. It also describes the golf course superintendent's daily commitment to maintaining golf greens that are comprised of *Poa annua*.

Poa annua has been part of the golf industry for a long time, probably ever since the inception of the game. Sometime around the early 1900s, bentgrass became the chosen or preferred grass to grow and maintain on golf course putting greens. Yet, *Poa annua* continues to be a major component, and in many cases a dominant component of golf course putting greens.

By virtue of its prolific seed head production, occurring under even the closest of mowing heights, *Poa annua* has been able to evolve a competitive edge against creeping bentgrass in terms of shoot density, verdure biomass, and photosynthetic surface area. Moreover, under shady, moist, cool temperature conditions, *Poa annua* thrives and continues to gain a competitive edge against bentgrass until it ultimately dominates many golf green putting surfaces.

Observations such as these have played a key role in initiating Penn State's breeding program for developing commercial sources of *Poa annua* for use on golf greens. Yet some people view this idea as ridiculous; *Poa annua* is, after all, the enemy, isn't it? Nevertheless, an underlying truth is undeniable: superintendents who have *Poa annua* greens simply do not have a hope of obtaining a seed source for the types of *Poa annua* that are adapted to their golf green environments for use in routine overseeding, repair work, or new green construction. This industry need is the motivation and spirit that drives our breeding program towards what we hope will produce commercially available seed sources of greens-type *Poa annua*. Only time will tell if we will be successful.

Genetic diversity abounds in the multiple selections of Poa annua. *One goal of the Penn State University breeding program is to provide golf course superintendents with a commercially available seed source of greens-type* Poa annua.

Natural Selection

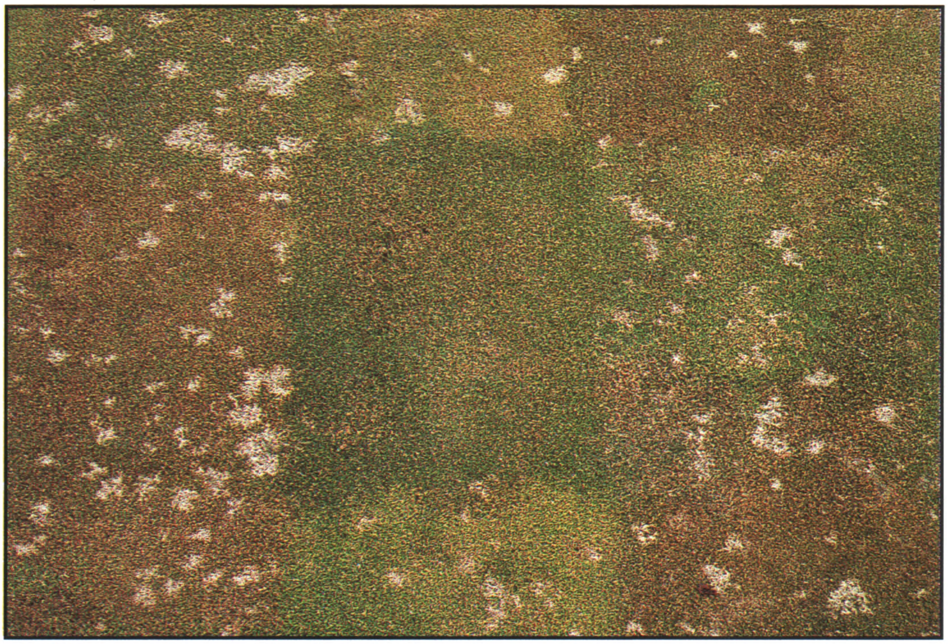
Nature, coupled with the intense selection pressure provided by superintendents and golfers, has performed a tremendous amount of evolutionary change in *Poa annua* during the past 100 years — from the wild and weedy annual bluegrasses that first invade a green, to the highly specialized, high-quality, greens-type *Poa annua* that we can find today. Our breeding program utilizes this *natural* evolutionary process by collecting and screening its products. We regularly collect samples from old, closely mowed greens from several regions of the U.S. and Canada.

Due to the reproductive biology of annual bluegrass, we believe this is a fruitful approach. *Poa annua* has a self-pollinating type of breeding system that results in true breeding strains through inbreeding. Eggs within the flowers (florets) are often fertilized before the florets ever open (cleistogamy). Such an inbreeding system of sexual reproduction is unique among the grasses we typically use for turf, and is most similar to that of wheat or soybeans. *Poa annua* also is a polyploid grass species, meaning that each of its cells carries multiple copies of its ancestors' chromosomes. Polyploidy is rare among animals and insects, but is common among plants. Among grasses, polyploidy is often the normal state of being.

Poa annua is believed to have had two ancestors, *Poa supina* and *Poa infirma*. Both of these species are considered to be diploid organisms, and each carries 14 chromosomes (denoted as 2n=2x=14 chromosomes). Because they are different species, the 14 chromosomes are very different between species and, upon hybridization, result in sterile offspring. A similar event happens when a donkey is mated with a horse to obtain a mule, which also is sterile. In plants, however, and probably due to their modularity, events may occur which restore fertility by doubling all of a cell's chromosomes. This is the situation with *Poa annua*. The two species, *Poa supina* and *Poa infirma*, mated to produce a sterile hybrid plant (1n=2x=14 chromosomes) whose chromosome number spontaneously doubled to yield *Poa annua* (2n=4x=28 chromosomes).

Such hybridization and doubling events generate extreme amounts of variability (i.e., 100%). The level of this variability is reduced by 50% within a particular strain after every generation of self-pollination. Thus, after the first generation of selfing, the amount of variability is reduced to 50%; the second reduces it to 25%; the third to 12.5%, and so on. A similar reduction in variability is necessary after making hybrids between distinct, true-breeding strains of greens-type *Poa annua*. Thus, after mating two different strains of *Poa annua*, it takes a minimum of six to eight generations before we regain strains that are uniform, stable, and true breeding. In producing one generation every two years, which includes some limited trial evaluation, it is easy to see that artificially breeding improved strains of *Poa annua* is a long-term process. However, much of this work has already occurred on old golf greens because of natural hybridizations, close mowing heights, the traffic provided by golfers, and the competition among all grasses for the limited resources of a golf green environment. With every generation, *Poa annua* has been evolving to tolerate low cutting heights and increased foot traffic. This evolutionary process has resulted in strains we call greens-type *Poa annua*.

Such greens-type *Poas* probably were not present back in the early 1900s when bentgrass was chosen as the grass to plant on golf course putting greens because it has taken the past 100 years of evolution and competition to produce them. In fact, the selection pressures of the green environment are so intense that we believe we are starting to observe a "reverse" evolutionary process that is resulting in the appearance of the original interspecific hybrid (1n=2x=14 chromosomes). These unique specimens have only half the amount of DNA of *Poa annua* and represent some of the densest, finest, highest quality strains we've observed to date. Like the mule, however, these unique strains are sterile, and our breeding program is investigating research avenues that may enable us to restore fertility while retaining their favorable attributes. Thus, in addition to simply collecting samples of *Poa annua* that have evolved naturally on golf greens, we also have begun the long-term process of actively breeding greens-type *Poa annuas* using traditional methods and some of the newer molecular genetic technologies.



Challenges such as seedhead production, disease and insect resistance, and rooting potential need to be resolved in the breeding program.

Growing Limitations

Just as the farmer who decided to grow dandelions for the natural food market discovered, when a weed is grown as a crop you find out your *indestructible weed* has a list of problems all its own that need to be overcome. One of the major limitations of growing *Poa annua* is its limited range of favorable growing temperatures. *Poa annua* tends to grow poorly when temperatures are either too hot or too cold. As part of our breeding program, we are actively investigating the variability within the species for tolerance to extreme temperatures. Working on temperature tolerance in plants is not as straightforward as it might seem. To simply plunge a grass plant into an extreme temperature does not allow the plant's natural defense mechanisms to incrementally adjust. In order to gain insight into *Poa annua*'s tolerance mechanisms, we first need to acclimatize the plants before exposing them to extreme temperatures. To evaluate for cold tolerance, the *Poa annuas* are pre-hardened at 2°C for one to two weeks, followed by -2°C for another two weeks. Temperatures are then lowered down to critically cold levels.

This cold-tolerance research is being performed as a collaborative research project with the Canadian Turfgrass Research Foundation (CTRF), Laval University at Quebec, and Agricultural Canada at St. Foy. At Laval University, co-investigator Julie Dionne's preliminary findings suggest that there are differences among greens-type *Poa annuas* in their ability to tolerate critically cold temperatures. The least cold-tolerant *Poa annua* showed a 50% survival rate at 1.4°F, while the most cold-tolerant *Poa annua* showed a 50% survival rate down to -8.3°F. These tolerances are far less than creeping bentgrass, which is capable of demonstrating 50% survival down to -18.4°F. Only by discovering differences among *Poa annuas* will we be able to discover the underlying genetic and physiological mechanisms responsible for these differences, which might enable us to improve *Poa annua*'s inherent cold-tolerance mechanisms.

Throughout our work, it has been helpful to look at other systems of cold tolerance. Fortunately, one of the only two plants known to grow in Antarctica happens to be a grass — Antarctic hairgrass (*Deschampsia antarctica*). Antarctic hairgrass has quite literally only a few hours each day during the middle of summer in which temperatures get above freezing, enabling photosynthesis to occur. The remarkable finding is that there seems to be no "silver bullet" cold-tolerance mechanism at work inside Antarctic hairgrass. Rather, cold tolerance is ascribed to a substantial ability to store naturally occurring carbohydrates called fructans.

We also have begun to observe differences in fructan levels among the *Poa annuas* and are currently correlating this information with our cold-tolerance studies. If it's discovered that fructan storage is a major component of cold tolerance in *Poa annua*, as it appears to be in Antarctic hairgrass, then we may be able to breed for the ability to store fructans and thereby begin to realize improved tolerance to cold temperatures in *Poa annua*.

Tolerance to Ice

Another important area of our cold-tolerance research is to determine *Poa annua*'s tolerance to ice coverage. Many factors may be related to *Poa*'s ability to tolerate ice coverage. Crown hydration, lack of oxygen, release and buildup of toxic gases, the frequency and modulation of freeze-thaw cycles, duration of coverage, and carbohydrate reserves are all potential factors that may work independently or may interact to yield the observation that, in general, ice coverage often kills *Poa annua*.

Our research to date has been inconclusive. During some experiments the *Poa annua* dies, in others it does not. Could other factors be responsible or interacting with those previously mentioned? What are the hydrodynamics at the interface between the soil and ice? Is it just ice or is it a combination of ice over a saturated soil that kills *Poa*? Are native soils more susceptible to ice damage than are sand-based greens?

Currently, we have more questions than answers. Even so, we know that visual differences in ice may appear. For example, warm water freezes slowly and is generally free of trapped air, making it appear clear or transparent (i.e., black ice); cold water freezes more quickly and often has pockets of trapped air which make it appear cloudy or white. Perhaps it is not whether ice is black or white that is important, but rather how quickly water freezes and what the potential is for soil drainage to occur before ice develops. We are only beginning to establish those conditions in which we are capable of killing *Poa annua* repeatedly with ice coverage at slightly freezing temperatures (approximately 27°F). Once these conditions are established, we will begin to screen the *Poa annua* collection for differential tolerances. After tolerant and susceptible strains are identified, we will begin to examine physiological differences to explore ways in which to enhance *Poa annua*'s tolerance to ice coverage.

Heat Tolerance

On one of my collection trips along coastal Virginia, a superintendent remarked that "*Poa annua* is the greatest grass . . . for nine months of the year." Heat tolerance and *Poa annua* may seem like contradictory terms, but the superintendent who made that statement had greens consisting of 80% *Poa annua*. Many northern regions where *Poa annua* dominates also experience some measure of summer heat stress during July and August. Thus, any improvement that might be made towards enhancing the heat tolerance of greens-type *Poa annua* would benefit those superintendents and golfers who have *Poa annua* greens.

Generation after generation, Poa annua *has continuously evolved to gain a competitive edge and improved shoot density.*

Like the above two projects, screening for differences in heat tolerance among the collections is our starting point. Heat benches containing sand root zones and adjustable heating units serve as our coliseum where *Poa annua* is forced to wage battle against high temperatures (approximately 113°F). Will *Poa annua* with deeper roots win out, being able to transpire and thus cool off more effectively, or do some *Poas* have root/crown proteins that function slightly better at elevated temperatures? Only time will tell.

Other Complicating Factors

Greens-type *Poa annua* has many additional problems that ultimately need to be resolved: seed head production, disease and insect resistance, rooting potential, and determining best management practices. Each of these areas, as well as extreme temperature tolerances, are beginning to be addressed in our breeding program. By screening the increasing number of collected strains, and through the eventual screening of new genetic combinations resulting from our hybridization breeding program, we hope to develop large enough supplies to offer turfgrass science colleagues around the country a chance to test and evaluate the elite strains of greens-type *Poa annua*. The ultimate goal of developing commercially available sources of greens-type *Poa annua* is not to replace bentgrass as a preferred grass for putting surfaces, but rather to offer an additional tool for superintendents to have at their ready, especially in regions and climates where *Poa annua* is simply a better choice of grass for use as a putting surface. For many, there is no other choice than to commit to "For richer, for *Poa*."

References

Beard, J. B. 1964. Effects of ice, snow, and water covers on Kentucky bluegrass, annual bluegrass, and creeping bentgrass. Crop Sci. 4:638-640.

Beard, J. B. 1970. An ecological study of annual bluegrass. USGA Green Section Record, March, pp. 13-18.

Beard, J. B. 1996. Low-temperature kill and ice sheets. Golf Course Management, May, pp. 60-64.

Beard, J. B., P. E. Rieke, A. J. Turgeon, and J. M. Vargas. 1978. Annual bluegrass (*Poa annua* L.) description, adaptation, culture, and control. Res. Rep. 352. Michigan State University, East Lansing. 31 p.

Bittenbender, H. C., and G. C. Howell, Jr. 1974. Adaptation of the Spearman-Käber method for estimating T_{50} of cold-stressed flower buds. J. Amer. Soc. Amer. Sci. 99:187-190.

Bjorkman, O., M. R. Badger, and P. A. Armond. 1980. Response and adaptation of photosynthesis to high temperatures. p. 233-249. *In* Adaptation of plants to water and high-temperature stress. John Wiley and Sons Publishers, Toronto.

Castonguay, Y., S. Laberge, and P. Nadeau. 1993. Freezing tolerance and alteration of translatable mRNAs in alfalfa hardened at subzero temperatures. Plant Cell Physiol. 34:31-38.

Cordukes, W. E. 1977. Growth habit and heat tolerance of a collection of *Poa annua* plants in Canada. Can. J. Plant Sci. 57:1201-03.

Dionne, J., and Y. Desjardins. 1996. What's happening under the blanket. Greenmaster, November.

Edwards, J. A., and R.I.L. Smith. 1988. Photosynthesis and respiration of *Colobanthus quitensis* and *Deschampsia antarctica* from the Antarctic. British Antarctic Survey Bulletin 81:43-63.

Fehr, W. R. 1991. Principles of Cultivar Development. Vol. 1. Theory and Technique. Iowa State University. Macmillan. p. 536.

Gibeault, V. A. 1970. Perenniality in *Poa annua* L. Ph.D. Dissertation. Oregon State University, p. 124.

Hetherington, P. R., B. D. McKersie, and A. Borochov. 1987. Ice encasement injury to microsomal membranes from winter wheat crowns. Plant Physiol. 85:1068-1072.

Huff, D. R. 1996a. *Poa annua* for golf course greens. Grounds Maintenance, January, pp. G2-G10.

Krause, G. H., and E. Weis. 1984. Chlorophyll fluorescence as a tool in plant physiology. II. Interpretation of fluorescence signals. Photosynth. Res. 5:139-157.

Krause, G. H., and S. Somersalo. 1989. Fluorescence as a tool in photosynthesis research: application in studies of photoinhibition, cold acclimation, and freezing stress. Phil. Trans. R. Soc. Lond. B 323:281-293.

Li, P. H. 1984. Subzero temperature stress physiology of herbaceous plants. Hort. Rev. 6:373-416.

Lush, W. M. 1988. Biology of *Poa annua* in a temperate zone golf putting green (*Agrostis stolonifera/Poa annua*). II. The seed bank. Journal of Applied Ecology 25:989-995.

McKersie, B. D., and Y. Y. Leshem. 1994. Anaerobic stress-flooding and ice-encasement. p. 15-54. *In* Stress and stress coping in cultivated plants. Kluwer Academic Publishers, Boston.

Meyer, W. A., J. A. Murphy, D. A. Smith. Response of cool-season turfgrass to a novel traffic simulator. 89th ASA-CSSA-SSSA. Anaheim, California. Agronomy Abstracts.

Minner, D. D., P. H. Dernoeden, D. J. Wehner, and M. S. McIntosh. 1983. Heat tolerance screening of field-grown cultivars of Kentucky bluegrass and perennial ryegrass. Agron. J. 75:772-775.

Mowforth, M. A., J. P. Grime. 1989. Intrapopulation variation in nuclear DNA amount, cell size, and growth rate in *Poa annua* L. Functional Ecology 3:289-294.

Osteryoung, K. W., and E. Vierling. 1994. Dynamics of small heat shock protein distribution within the chloroplasts of higher plants. Journal of Biological Chemistry 269:28676-28682.

Smillie, R. M., and S. E. Hetherington. 1983. Stress tolerance and stress-induced injury in crop plants measured by chlorophyll fluorescence in vivo. Plant Physiol. 72:1043-1050.

Tompkins, D., C. Bubar, E. Toews, and J. Ross. 1995. Physiology of low temperature injury with emphasis on crown hydration in *Poa annua* L. *In* Prairie turfgrass research centre annual report 1995.

Wallner, S. J., M. R. Becwar, and J. D. Butler. 1982. Measurement of turfgrass heat tolerance in vitro. J. Hortic. Sci. 107:608-613.

Warwick, S. I. 1979. The biology of Canadian weeds. *Poa annua* L. Can. J. Plant Sci. 59:1053-1066.

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Many thanks to the numerous golf course superintendents who have allowed collections of *Poa annua* from their greens and to the USGA Green Section agronomists who assisted with the collection trips.

Dr. David Huff has collected thousands of Poa annua *samples throughout the United States. A pile of* Poa annua *this large will make any plant breeder smile.*

Donating *Poa annua*

If you or someone you know has greens-type *Poa annua* and would like to have its merits examined, the PSU *Poa annua* breeding program would like to receive your samples. Begin by collecting one or two aerification tine cores from each "patch" you wish to sample (no limit here), wrap in a moist paper towel, enclose in a zip-lock bag, and label each bag with your course name and hole location (example: Oakmont 18G). Send by overnight mail to:

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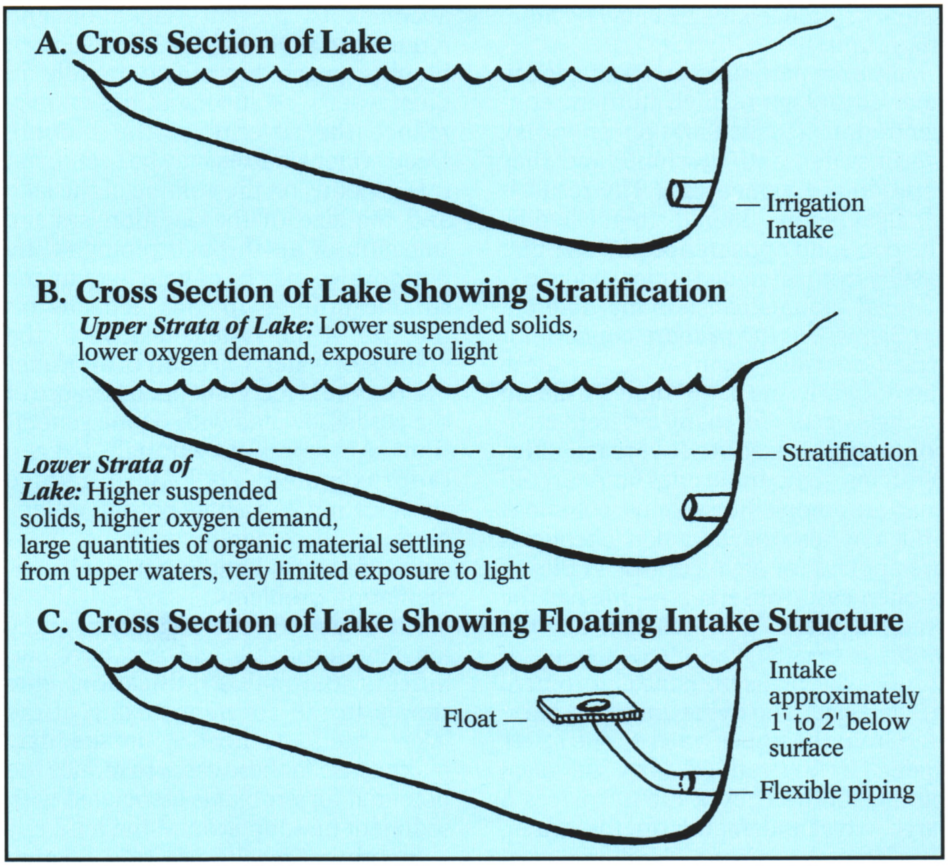
Poa annua *is a reality on most cool-season golf courses in America.* DR. DAVID HUFF, *assistant professor in turfgrass breeding and genetics at Pennsylvania State University, hopes to improve on what's available.*

Maintain The Best Irrigation Water Quality On The Golf Course

Consider the use of a floating intake structure.

by MILES M. (BUD) SMART, Ph.D.



WATER MANAGEMENT is one of the significant keys to the success of golf course management. Properly managed water resources provide good quality irrigation water, aesthetically pleasing ponds and streams, appropriate stormwater treatment, and no offsite surface- or ground-water pollution problems. Properly managed water resources also provide habitat for a variety of animal and plant inhabitants.

One technique used to maintain the best possible quality irrigation water is to install a floating intake structure for the irrigation system. Why does a floating intake structure, compared to a bottom structure, make sense? Because over the course of a year, an irrigation lake may go through several physical changes that result in the poorest water quality being located in the lower strata of the lake, right where the irrigation intake structure is located. Using poor quality irrigation water may result in turf damage or, at the least, difficult conditions for turf to thrive. This may, in turn, require the use of more fertilizers, pesticides, maintenance time, and equipment use, or even more water. Using the best quality irrigation water is good for the golf course and good for nature. Additionally, the intake structure is located one to two feet under the surface and is generally not even noticed.

Audubon International, working with members of the Cooperative Sanctuary and Signature programs, has observed many cases where an intake structure located near the bottom of a lake resulted in turf and aesthetic problems on golf courses. In one example, each time the irrigation system was used, a rotten-egg smell permeated the course, the sidewalks where irrigation spray drifted turned a mottled red, tree trunks that were sprayed turned slimy and black, and the greens were dying. These situations were the result of irrigating with less than desirable quality water.

The irrigation lake can be affected by many factors that impact the quality of water. Simply because irrigation lakes (ponds, streams, etc.) are at the bottom of drainage basins, and because water runs downhill to the lake, these water bodies are influenced by meteorologic, geologic, and biologic inputs, via the terrestrial watershed or directly from the atmosphere. In addition to these outside influences, there are several internal characteristics that are important to its overall health and stability, and thus important to good irrigation water quality. Characteristics include lake regions, light, heat (thermal stratification), and nutrients. Water quality also dictates the abundance of algae, which can further influence water quality.

Light: Light is the major energy source to aquatic ecosystems, and light is the major source of heat to a lake. Absorption of light and its dissipation as heat influence the thermal structure, water stratification, and circulation patterns of lakes. Ultimately, these factors also can impact the aquatic organisms that live in the water.

Upper layers of water bodies are generally warmer than the lower layers because of heating by solar radiation. During the summer (or summer-like temperatures in the southern tier of states), temperature differences between upper and lower waters can become great enough that these waters are effectively separated. Separation is due to density differences that are caused by differences in water temperature (called thermal stratification). The upper waters are warm and mixed by the wind to an approximately uniform temperature (called the epilimnion). Bottom waters are cool, heavier, and not affected by wind (called the hypolimnion). Separating the two regions is an intermediate zone, where temperature drops rapidly with increasing depth (called the metalimnion).

Thermal Stratification: Once a lake is thermally stratified, a number of changes take place in the lake. One of the most important is the dissolved oxygen levels. Oxygen and the levels present in an irrigation lake can have a dramatic effect on the life of a lake and its water quality. Aquatic organisms require oxygen to survive and, in its absence, organisms either move from the oxygen-poor area or die. Many studies have documented changes in biological communities with a shift in dissolved oxygen concentrations.

Dissolved oxygen in a lake comes from photosynthesis or from exchanges with the atmosphere at the water's surface. During thermal stratification, a delineation occurs between the oxygen-rich water at the top of the lake and the oxygen-poor water at the bottom. This reduction or lack of dissolved oxygen also can establish a series of chemical reactions that further reduce water quality. Examples, such as sulfate being converted to hydrogen sulfide, insoluble iron being converted to soluble forms, suspended material concentrations increasing, and decomposition of materials that settle from the surface to the bottom being slowed (algae, grass clippings, leaves), can make the bottom water an inappropriate medium for supporting aquatic life. It also makes a very poor source of irrigation water.

The irrigation intake, traditionally located in the bottom water region of the lake, generally provides your golf course with the poorest quality water. In our example from above, the rotten-egg smell is from the hydrogen sulfide, the red mottled sidewalks result from an increase in the reduced form of iron (ferrous) in the bottom water that is oxidized (ferric, red color) when the irrigation water comes in contact with the atmosphere, and the slimy black material on tree trunks is the partially decomposed organic material that was from both the drainage basin and the lake. The greens also are stressed by the partially decomposed organic matter as it competes with the turf for oxygen at the soil surface. On many of the greens, stress is so great that the turf can't survive and may have to be replaced.

An overabundance of algae also can become a hindrance to water quality and make a floating intake structure important. Water bodies have algae that occur naturally and are an important component of the aquatic food chain. However, at some point a healthy algal population may actually become an *algal bloom* that may impair the usefulness of a water body for irrigation. The cause of most algal problems is an abundance of phosphorus in the water of freshwater lakes (in marine or estuary systems, nitrogen may be more important).

Algae are particularly well adapted to take advantage of high nutrient concentrations (particularly phosphorus), warm water, and sunshine, and they reproduce exponentially. The result is an algal bloom, often distinguished by the pea-soup appearance of water that results from large quantities of algae.

Algal blooms cause many different problems, but the primary concern for irrigation water occurs when the algae die at nearly the same time. A die-off of algae occurs for many different environmental reasons (overcast skies reducing light intensities and a cold snap are among the two most common) and may also occur when chemicals are applied for algal control. A die-off is often easily observed — one day the water is green, and the next day the water is brown. The intense green of the algal bloom is from the chlorophyll in the algae. The dying and dead algae rain from the upper water to the lower water. In a stratified lake, an algal bloom followed by a die-off places a large oxygen demand on the water, increases the organic load and suspended solids load, and in general makes irrigation water unsuitable for use. Putting grass clippings in the irrigation lake also may cause symptoms similar to an abundance of algae — oxygen stress, organic loading, and increased suspended solids.

A floating intake structure is an economical way to get the best possible irrigation water for your golf course and maintain the ability to obtain water when water levels drop. A floating intake structure also reduces the possibilities of sediment problems that can occur with a bottom intake structure. A floating intake structure can be purchased or can be built and installed by a local machine shop.

There are two questions that are frequently asked by golf course superintendents concerning floating intake structures: 1) Can I use an aerator system instead of a floating intake? 2) My irrigation lake cycles every ten days (has a hydraulic retention time of ten days), so do I need to have a floating intake?

In answer to the first question, with the use of fountains, the objective is to circulate enough water to ensure mixing of the lake. Fountains generally do not have the depth or breadth of circulation to be effective as stand-alone systems for the irrigation lake. In smaller, shallower ponds they may be adequate to prevent stagnation and reduce the potential for massive algal blooms (algae reproduce rapidly in quiet waters, so stirring things up may reduce the severity of the bloom). Deep-water aerators may be useful, but this depends on the volume of the lake and the size of the aeration system. Injection of air through piping at the bottom also may be of help in reducing stratification; again, this depends on the size of the system relative to the volume of water. Injection of air rather than ozone is recommended because of the cost associated with ozone generation. Air contains enough oxygen (approximately 20.9%) to reduce stratification and aerate bottom waters. None of these aerator systems, however, effectively handle potential sedimentation problems.

An irrigation lake that cycles every ten days probably will not have significant thermal stratification, due simply to the constant mixing of the lake waters. A floating intake may make sense in these cases to reduce the potential for problems associated with sediment buildup around the intake.

Incorporating the use of a floating intake structure makes sense on many different levels. It can decrease the probabilities that your turfgrass will be negatively affected by poor water. Because the intake structure floats, it allows for continued availability of the best quality of water under many different situations and occurrences that a water source is subjected to seasonally. Using the best quality irrigation water is good for the golf course and good for nature.

DR. BUD SMART *is the Director of the Department of Environmental Planning at the Siena College-Audubon International Institute. The Institute conducts research on human-managed landscapes and provides technical assistance to members of Audubon International's Cooperative Sanctuary and Signature programs.*

1999 Turf Advisory Service Changes

Following four years of maintaining the same fee structure for our Turf Advisory Service, 1999 will bring a small increase. For those of you budgeting for the next season, our fee structure will be $1,300 for a half-day visit and $1,800 for a full day.

As an even better value, plan ahead to take advantage of the prepayment discounts. A $300 discount is offered for both half-day and full-day visits if the visit is paid before May 15, 1999. As always, visits can be scheduled to occur at any time during the season to meet your needs.

The USGA Green Section is the only agency in the country devoted solely to golf course turf, its playing conditions, and its management. The cost of a TAS visit is a flat fee that covers agronomic aspects of the visit, the preparation of a detailed written report, as well as *all* of the related expenses, such as transportation, food, and lodging. Whether dealing with diseases, soil problems, or day-to-day management of the golf course, the valuable experience offered to your golf course by our 16 agronomists cannot be matched by any individual or agency anywhere.

Contact your regional Green Section office to obtain more information about the Turf Advisory Service and to schedule your visit for 1999.

USGA Contributes $1 Million to Turfgrass Information Center

The USGA has announced that it will contribute $1 million over the next five years to help establish an endowment to support and expand the Turfgrass Information Center (TIC) located at Michigan State University.

"The USGA's Turfgrass and Environmental Research Committee decided to allocate $200,000 annually for the next five years from its research budget to support TIC," Joe England, Chairman of the USGA's Green Section Committee, said.

"TIC is simply the world's best library of turfgrass and golf course maintenance information. The USGA's support of this one-of-a-kind collection will help ensure the continued availability of this critical resource for generations to come," England concluded.

TIC contains a computerized database that has abstracts of more than 58,000 entries, including books, newsletters, periodicals, bulletins, and other publications. It is used by university faculty, golf course superintendents, turfgrass students, USGA Green Section staff, and others interested in the proper maintenance and management of golf courses.

"The World Wide Web now makes the delivery of the information within the Turfgrass Information Center immediately accessible throughout the world. This valuable gift from the USGA points to the day when the TIC will be universally available," said Clifford H. Haka, Director of Libraries, Michigan State University.

Since 1992, TIC has obtained most of its funding from Michigan State University (MSU), with a modest contribution from annual subscriptions from users. The Development Department at MSU will establish a campaign to raise $5 million for the TIC endowment, which includes the USGA's $1 million contribution.

If at least $2 million is raised, then the TIC database will be made available free of charge to all Internet users. Additional funds raised would be utilized to expand full-document availability of information from the database, provide video and photographic files, and expand other services to the turfgrass industry and the game of golf.

The USGA originally provided more than $700,000 to help establish and expand the TIC database from its inception in 1982 to 1992.

Individuals and organizations wishing to support the endowment can contact Clifford H. Haka at (517) 355-2341 or Michigan State University Library, 100 Library, East Lansing, MI 44824-1048.

Questions about the USGA's contributions to the Turfgrass Information Center may be directed to Jim Snow, National Director of the USGA Green Section, at (908) 234-2300.

Physical Soil Testing Laboratories*

The following laboratories are accredited by the American Association for Laboratory Accreditation (A2LA), having demonstrated ongoing competency in testing materials specified in the USGA's Recommendations for Putting Green Construction. The USGA recommends that only A2LA-accredited laboratories be used for testing and analyzing materials for building greens according to our guidelines.

BROOKSIDE LABORATORIES, INC.
308 S. Main Street
New Knoxville, OH 45871
Attn: Mark Flock
(419) 753-2448
(419) 753-2949 FAX

EUROPEAN TURFGRASS LABORATORIES LIMITED
3 Cunningham Road
Springkerse Industrial East
Stirling FK7 7SL Scotland
Attn: John Souter
(44) 1786-449195
(44) 1786-449688 FAX

N. W. HUMMEL & CO.
35 King Street, P.O. Box 606
Trumansburg, NY 14886
Attn: Norm Hummel
(607) 387-5694
(607) 387-9499 FAX

THOMAS TURF SERVICES, INC.
1501 FM 2818, Suite 302
College Station, TX 77840-5247
Attn: Bob Yzaguirre / Jim Thomas
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(409) 764-2152 FAX

TIFTON PHYSICAL SOIL TESTING LABORATORY, INC.
1412 Murray Avenue
Tifton, GA 31794
Attn: Powell Gaines
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(912) 382-7992 FAX

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310-A North Winchester Street
Olathe, KS 66062
Attn: Chuck Dixon
(913) 780-6725
(913) 780-6759 FAX

*Revised January 1998. Please contact the USGA Green Section (908-234-2300) for an updated list of accredited laboratories.

United States Golf Association
Green Section Educational Program

Sunday, February 14, 1999
Orlando Convention Center
Orlando, Florida

Experience Spoken Here

Moderator: James T. Snow, National Director, USGA Green Section

8:30 a.m. **Welcome**
Joe England, USGA Executive Committee

8:35 a.m. **The Best Turf Tips from the Green Section Staff**
Patrick O'Brien, Director, Southeast Region
Brian Maloy, Agronomist, Mid-Continent Region
Darin Bevard, Agronomist, Mid-Atlantic Region
Bob Brame, Director, North-Central Region
Matt Nelson, Agronomist, Northeast Region

8:55 a.m. **Organic Fact and Fallacies**
Dr. Noel Jackson, University of Rhode Island
The mystical world of biological controls contains a lot of fact and fiction. Dr. Jackson will discuss what to look for when making decisions regarding products available on the market.

9:25 a.m. **More of the Best Turf Tips**
Jim Skorulski, Agronomist, Northeast Region
Keith Happ, Agronomist, Mid-Atlantic Region
John Foy, Director, Florida Region
Mike Huck, Agronomist, Southwest Region
Chris Hartwiger, Agronomist, Southeast and Florida Regions
Paul Vermeulen, Director, Mid-Continent Region

9:50 a.m. **It's the Same Game, But How It's Changed!**
Frank Thomas, Director, USGA Test Center
Golf equipment issues have been a major discussion topic in the golf world. Hear about the true *impact of equipment from the head of the USGA Test Center.*

10:25 a.m. **Presentation of the USGA Green Section Award**
Dr. Noel Jackson, University of Rhode Island

10:35 a.m. **On To The Next Millennium**
Buzz Taylor, President, United States Golf Association
A look into the future of golf as we approach the year 2000.

10:50 a.m. **The Best Turf Tips Keep on Coming**
David Oatis, Director, Northeast Region
Pat Gross, Director, Southwest Region
Bob Vavrek, Agronomist, North-Central Region
Stan Zontek, Director, Mid-Atlantic Region
Larry Gilhuly, Director, Northwest Region

11:10 a.m. **Closing Remarks**

1999 GREEN SECTION NATIONAL & REGIONAL CONFERENCES

NATIONAL CONFERENCE		
February 14	Orange County Convention Center	Orlando, Florida
FLORIDA REGION		
April 27	Orlando Airport Marriott	Orlando, Florida
April 29	Palm Beach Gardens Marriott	Palm Beach, Florida
MID-ATLANTIC REGION		
March 16	Woodholme Country Club	Baltimore, Maryland
MID-CONTINENT REGION		
March 16	Old Warson Country Club	St. Louis, Missouri
March 17	Brookhollow Golf Club	Dallas, Texas
March 18	Lakeside Country Club	Houston, Texas
March 22	Embassy Club at Capital Square	Des Moines, Iowa
NORTH-CENTRAL REGION		
January 26	Indianapolis Convention Center	Indianapolis, Indiana
March 16	Wayzata Country Club	Wayzata, Minnesota
NORTHEAST REGION		
March 19	Wesleyan College	Middletown, Connecticut
March 23	Oak Hill Country Club	Rochester, New York
March 25	USGA Golf House	Far Hills, New Jersey
SOUTHEAST REGION		
March 9	Atlanta Athletic Club	Atlanta, Georgia
March 17	Pinehurst Country Club	Pinehurst, North Carolina
March 31	Richland Country Club	Nashville, Tennessee
NORTHWEST REGION		
March 22	Hillcrest Country Club	Boise, Idaho
March 29	Fircrest Country Club	Tacoma, Washington
April 12*	Waialae Country Club	Honolulu, Hawaii
SOUTHWEST REGION		
March 15	Spanish Trail Country Club	Las Vegas, Nevada
March 23	Orange Tree Resort	Phoenix, Arizona
March 24	Lakewood Country Club	Denver, Colorado
March 30	Industry Hills Golf Club	Industry Hills, California
March 31	Castlewood Country Club	Pleasanton, California

*Tentative

The Seven Dirty Words of Golf Course Maintenance

Watch your language!

by PATRICK GROSS

THERE ARE certain words that should never be mentioned in public, especially at a golf course. To do so would constitute a serious breach of decorum and good manners. Golf, being a game of etiquette and gentility, requires that certain social graces be observed. The following seven words are listed as a public service to golfers and superintendents to help you avoid social embarrassment.

Aerification: Does this sound familiar? "Just when the greens start getting good, they plug 'em and mess 'em up." You would think superintendents aerify on purpose just to upset golfers. The truth is, if you want healthy grass, you need to aerify. This process removes thatch, relieves compaction, stimulates root growth, and improves air and water movement within the soil. Aerification also helps prevent the discussion of some of the following dirty words.

Brown: Unfortunately, there is no room in the American golfer's vocabulary for the word *brown*. Grass must be green — perfectly, uniformly lush green, even if it means over-watering and plugged lies in fairways. There's nothing wrong with green grass, but there's nothing wrong with a little tinge of brown, either. It's a good sign that the course is not over-watered.

Ast: No matter how fast greens are, they are never fast enough. More time, energy, and money have been spent over the years to produce fast greens, but golfers want still more. Gradually, the pace of play grinds to a halt as golfers plum-bob their fourth putt. In the end, the quest for fast greens leaves in its wake dead grass and unemployed superintendents. Whatever happened to the goal of smooth greens with reasonable pace?

Bunkers: Golfers will tell you bunkers are always "too" something — too hard, too soft, too wet, too dry, too shallow, too deep, etc. All I can say is, "Too bad." Bunkers are *hazards*. Something is seriously wrong when courses are spending more time and money maintaining bunkers than greens.

Trees: People love to see trees on golf courses. Trees are beautiful, they are challenging obstacles, and they provide some degree of safety. But trees and turf just can't seem to get along. Excessive shade, root encroachment, interference with irrigation, and blocked air movement are just some of the problems caused by trees. When superintendents suggest removing trees to grow healthier turf, they are met with strong opposition. I have heard golfers say, "Do you know how long it took for that tree to reach that size and now you want to cut it down?" I think it is unfortunate that courses have suffered with terrible turf at the expense of trees. After all, the game of golf is played on grass.

Carts: The negative impact of golf carts on the playing quality of courses cannot be denied. Soil compaction, thin turf, abrasion, and wear injury directly affect turf quality. But if you suggest cart use rules or restricting carts to the paths, screams of protest can be heard throughout the course. Many golfers don't pay attention to the rules anyway and then wonder why there are *brown spots* (see dirty word #2). A significant amount of money is spent at courses each year for ropes, stakes, directional signs, and marking paint to restrain carts, not to mention the maintenance programs to correct the damage. Unfortunately, many courses are addicted to the revenue produced by the rental of carts, but I wonder if the revenue is enough to offset the damage caused to the golf course?

Rebuild: When all the agronomic alternatives have been exhausted and you still cannot grow healthy turf on the greens, many superintendents and green committees entertain the thought of rebuilding the greens. But be very careful about saying the "R" word. Golfers just don't want to hear it. To them it means change, it means disruption, and it means money. The thought of rebuilding greens becomes even more offensive if previous construction efforts failed to solve the problem. Before you consider rebuilding greens, make sure you are doing it for the right reasons. You may want to discuss some of the previous dirty words that led to the problem in the first place (*aerification, fast,* and *trees*). Then do your homework to ensure that the project is done properly and efficiently so that golfers can get back to playing the game they so dearly love in as short a time as possible.

In closing, I beg of you to please watch your language the next time you are at the golf course. Especially avoid these seven dirty words, because we don't want to have to bring you home and have mother wash your mouth out with soap.

PAT GROSS *is the Director of the Southwest Region. He politely discusses these seven dirty words and more with courses in California, Arizona, Nevada, Utah, and Colorado.*

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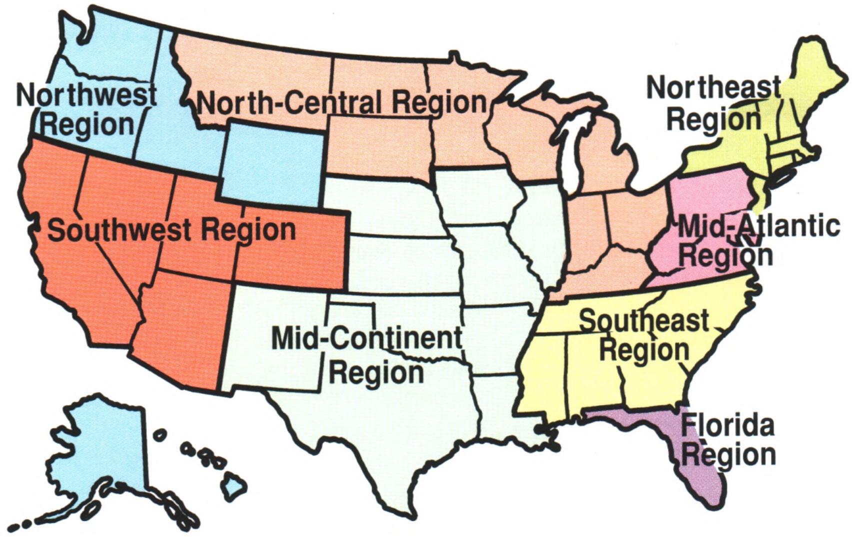

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TURF TWISTERS

HAZARD AHEAD —

Question: We use a variety of stakes to mark our water hazards. Unfortunately, the stakes can be difficult to maintain and keep in place. Are there better options for marking our hazards? (New Hampshire)

Answer: A painted line can be used to define the margin of a water hazard. Several indicator stakes would then be placed well inside the line to help players identify from a distance whether the body of water is a water hazard (yellow stakes) or lateral water hazard (red stakes). Wooden indicator stakes also can be equipped with a metal post or spike to ease their installation. Using a painted line to define water hazards reduces the number of stakes required, and those stakes that are used as indicators can be placed in areas where they are less likely to interfere with play and mowing activities. If you use both stakes and lines, be sure to clarify on the local rules sheet that the lines define the hazard margins and that the stakes only identify the hazard.

PUTTING GREEN

Question: Our golf course is located in the mountains and we only have a six-month golf season (May through October). Is the fall plugging of the putting greens absolutely necessary if our membership expects high quality surfaces at this time? (North Carolina)

Answer: With the shorter golf season in your area, it is perfectly understandable that the membership would desire smooth putting surfaces throughout the play season. *Double aerifying* the putting greens during the scheduled April aeration is one option. This operation will produce twice as many holes, but not twice the work or twice the recovery time. Use the largest size tines possible, preferably at least ½ inch. Obviously, remove the aeration plugs and backfill the holes with sand topdressing. The putting surfaces will be bumpier after this double aeration, but the course is closed and you can anticipate a satisfactory recovery by the May opening golf date.

RENOVATION

Question: We are considering replanting our greens. One question that is frequently asked is, How quickly can we open the greens after we plant them? (Missouri)

Answer: Opening dates vary widely depending on many factors, including climate, planting date, fertilization rates, type of grass, amount of play anticipated, type of rootzone mixture, etc. A good method to determine whether or not the green is ready for play is to examine the green's profile using a profile tool or cup changer. In order for the new turf to withstand traffic, there must be a pad or thin layer of organic matter between the crown of the turfgrass plant and the underlying rootzone material. This pad is developed as the green matures. When the pad has reached approximately ¼ inch in thickness, the green is usually ready. As a very general rule, bentgrass takes 14 to 16 weeks of good growing weather to develop such a pad. Bermudagrass is slightly faster and often develops the pad over 12 to 14 weeks of good growing weather. Please note the phrase *good growing weather.* This is weather that provides ideal growing conditions for the turfgrass selected.