TROUBLESHOOTING PROBLEM GREENS

USGA Green Section Collection

This USGA Green Section Collection – assembled to supplement the July 3, 2015 issue of the *Green Section Record* (vol. 53 issue 13) – provides useful resources to help turf practitioners identify and manage problem putting greens. The materials contained in this collection are not all-inclusive but intended to offer additional information about managing the many factors that affecting putting green turf health.

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For the good of the game®

Introduction

In 1920, E.J. Marshall, a Toledo, Ohio attorney and then Green Committee chairman for the Inverness Club, was in charge of course preparations for the U.S. Open Championship. Marshall sought, but could not find, impartial and authoritative agronomic information. His efforts led him to the USGA and the United States Department of Agriculture. The two organizations agreed to collaborate in the development of scientific information relating to golf course turf. Thus, on November 30, 1920, the Executive Committee of the United States Golf Association formally created the USGA Green Section.

This not-for-profit agency, free from commercial connections, was a pioneer and remains today a chief authority in turfgrass management for golf. The USGA Green Section is directly involved in every phase of golf course maintenance and management from the control of diseases, insects, and weeds to the breeding and release of improved strains of turfgrass. Furthermore, the USGA supports the largest, private turfgrass and environmental research effort in the history of golf focusing on resource conservation, cultural practices, soils, fertilizers, irrigation, and other aspects of turfgrass management.

Since 1921, the USGA Green Section has published information on the proper maintenance and upkeep of golf courses. Published under various titles, the *Green Section Record* magazine debuted in May 1963. In July 2010, the print publication changed to a bimonthly digital magazine offering the latest information on golf course management, turfgrass culture, environmental issues, research and economic sustainability.

By supporting research and offering sound, experienced, unbiased agronomic advice about the scientific and practical aspects of golf course turf management, the USGA *Green Section Record* provides ever greater value and better golf turf to the golf facilities and course officials it services.

Photo: Deep roots from a healthy putting green growing in an aeration channel ©USGA

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Troubleshooting Problem Greens

A number of factors determine the quality of a putting green, but golfer expectations define what makes a desirable green.

BY DARIN S. BEVARD AND BRIAN WHITLARK

Excessive shade is not good for any turfgrass, but it is especially detrimental on putting greens. Shade often discourages healthy growth of desirable grasses and promotes weed species and moss. Ample sunlight during the active growing season is important, but fall and winter shade also must be considered. Winter shade will subject grass to longer periods of snow and ice cover, increasing the potential for damage. Note the green in the background in full sun with no snow or ice accumulation.

Every golf course has at least one putting green that never seems to perform as well as the others. In other instances, many greens on a golf course may fail to meet the expectations of the golfers. Regardless of the number of greens involved, frustration and even anger boil over when putting green quality does not live up to golfer expectations. Fortunately, options are available to improve problem greens, and although they will not be perfect overnight, improvements can be made to improve putting green performance over time.

Multiple factors contribute to poor putting green conditions, including shade, poor air movement, concentrated traffic, and poor drainage. Furthermore, poor putting quality may be the result of inherent problems on a given putting green that cannot be overcome through daily maintenance. Troubleshooting problem greens starts with identifying the factors that can limit putting green performance. This should be followed by evaluating each

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green to determine whether one or more factors are affecting playing conditions. It is then time to determine the changes that are needed to produce greens that consistently meet golfer expectations.

GROWING ENVIRONMENT

The growing environment may have the greatest impact on putting green performance. To maintain healthy turfgrass and smooth, true putting conditions, it is critical that putting greens receive adequate sunlight and air movement. If either component is lacking, putting green quality will be compromised. In fact, many of the factors that affect putting green performance may be overcome on greens with good growing environments. Conversely, a well-constructed putting green with the best new grasses will struggle in a poor growing environment.

SUNLIGHT PENETRATION

Trees limiting sunlight penetration should be removed for the benefit of the grass. Persistent shade leads to weaker grass that is less able to tolerate daily stresses from maintenance and golfers. Shade also favors weaker grasses like *Poa annua* — not because weaker grasses thrive in the shade, but because they tolerate shade better than desirable grasses like creeping bentgrass and ultradwarf bermudagrass. Shade patterns need to be evaluated throughout the year. Fall and winter shade are often overlooked but can increase the potential for winter damage on greens. In addition to shading, the roots of trees planted too close to greens rob water, fertilizer, and other inputs from turfgrass and are often overlooked as a source of turfgrass problems.

AIR MOVEMENT

Underbrush and other vegetation should be removed where air movement is restricted. Air flow helps cool the turfgrass canopy and is especially important for cool-season grasses during summer heat. Adequate air flow discourages humid, stagnant conditions that favor disease development, thus reducing disease incidence. Keep in mind that a green that receives very good sunlight but poor air movement may perform poorly. Sunlight penetration *and* air movement are critical.

Tree removal is often controversial. However, if there is a general feeling that trees surrounding a green are more important than the health of the grass, expect maintenance challenges and reduced putting quality. When regulatory or property line issues prevent tree and underbrush removal, fans can be installed to improve air movement. Regardless of grass type, a putting green in a poor growing environment will be inferior to a putting green located in a good growing environment.

DRAINAGE

Drainage (both internal and surface) is a major component of turfgrass performance and putting green playability. Poor drainage promotes soft, wet conditions and increases the likelihood of scalping and other forms of mechanical damage from maintenance practices. Additionally, foot traffic and pitch marks from golfers cause severe damage when greens are soft. Standing water on greens also is problematic for putting green turf at any time of the year. Drainage problems in the winter can lead to increased winter kill; during the summer, grass can suffer from scald, wet wilt, and direct mechanical damage.

Greens designed with excellent surface drainage generally perform well, even when internal drainage is limited or nonexistent. Surface drainage problems are easy to diagnose. Observe a green during a heavy rain event or a heavy irrigation cycle to determine the areas where water accumulates. In some instances, low-lying areas that impound water may be improved over time with sand top-

Water accumulates in this area during rain events because the collar prevents water from flowing off of the green. The resulting wet, soft conditions promote stress and lead to mechanical damage from golfer traffic and maintenance practices.

Collar dams are often overlooked as a significant impediment to surface drainage. Regrading affected areas to promote positive surface drainage can eliminate a problem that affects playability and turfgrass quality.

dressing, but in more severe cases regrading may be required. Collar dams are a common cause of surface drainage problems. Collar dams can develop over time as topdressing sand used during aeration accumulates around the edges of the greens. Collar dams can be fixed by removing sod from the collar and immediate green surrounds then carefully regrading the affected area to provide positive surface drainage. Where bermudagrass is grown, sod replacement following regrading may not be necessary. If regrading is done during the active growing season and the area of interest is healthy, bermudagrass will recover from stolons and rhizomes in 3-4 weeks. Even when collar dams do not lead to direct turfgrass decline, they contribute to soft conditions that affect playability around green perimeters. Collar dams are often overlooked as a barrier to surface drainage and ultimately contribute to poor playing conditions.

The first concern related to internal drainage is whether or not a putting green has an internal drainage system. The majority of greens constructed during the past 30 years have some form of internal drainage installed; however, it is important to be sure that internal drainage is properly functioning. On older greens, internal drainage may be limited or nonexistent. In the absence of internal drainage, frequent rainfall will saturate greens, and they can remain wet for extended periods of time. Severe drainage problems can force temporary course closure.

Retrofitting older greens with sand-channel drains can benefit overall performance. Sand-channel drains can be installed in-house, but most utilize outside contractors. Fiberglass rope drainage also has been installed in greens to improve drainage in recent years, with reports of success. Surface drainage and internal drainage both contribute to successful putting green management. Remember, if either is less than ideal, problems can develop.

Limited entrance and exit points can affect putting green conditions. Golfers are forced to walk around this bunker to and from the cart path, leading to increased traffic on the back left of this green.

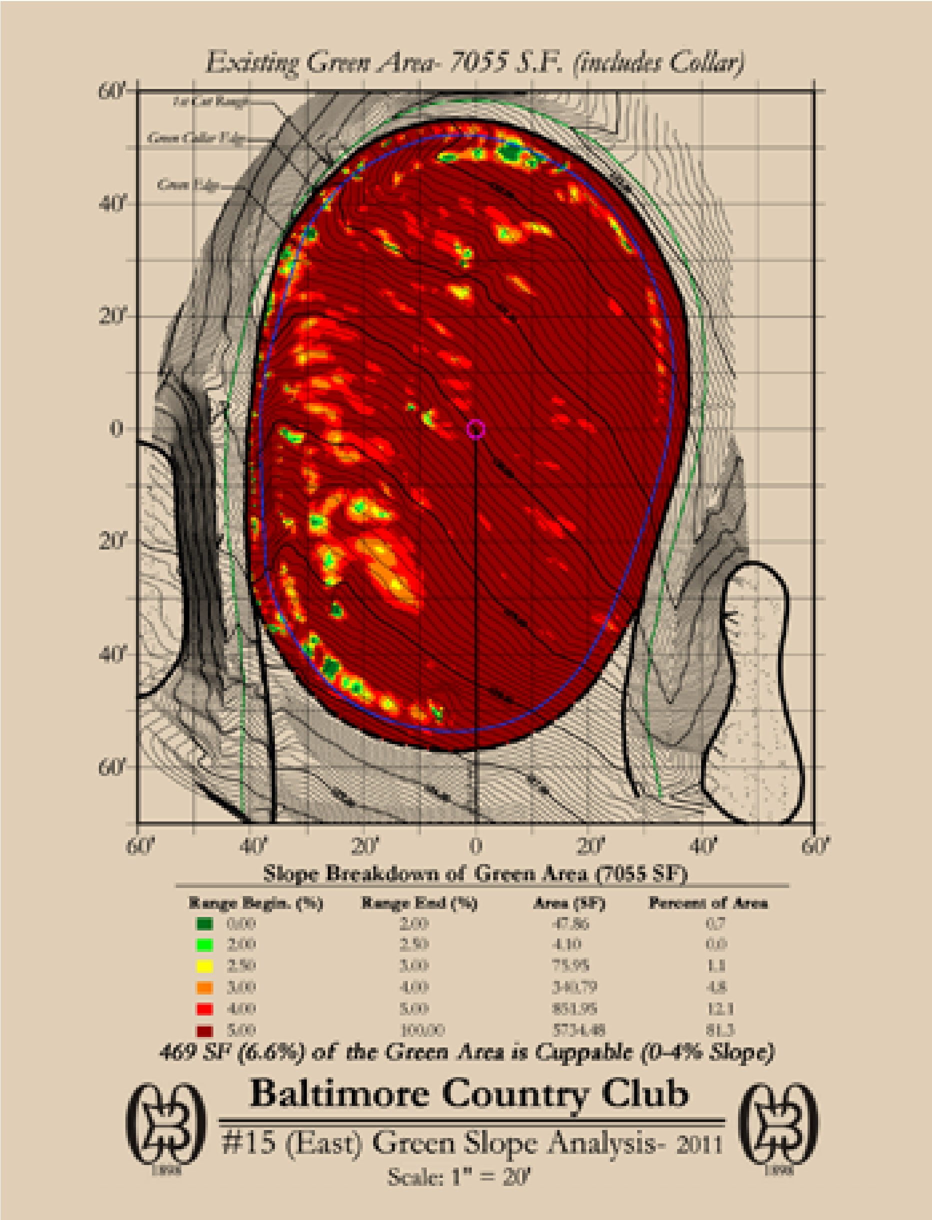
SIZE, AVAILABLE HOLE LOCATIONS, AND TRAFFIC

Putting green size affects putting green performance. An average-sized putting green is around 6,000 square feet. However, many older golf courses, and some new ones, have much smaller putting greens that can have significant problems depending upon the number of rounds played. Small greens can be difficult to manage because golfer traffic is more concentrated. Damage from foot traffic can be problematic on any green when conditions are soft, but small greens can be especially susceptible to traffic damage because of limited options for moving hole locations away from wet or damaged areas. Larger greens provide more room to disperse golfer traffic, which generally means healthier turf and better playability. Putting green size is not the only factor to consider regarding traffic distribution. Available hole locations and the number of available entrance/exit points also affect putting green conditions.

Hole locations may be limited at modern green speeds if greens have severe contours and significant surface area with greater than 4-percent slope. Fewer available areas for hole locations means the same areas must frequently be used, leading to increased wear and reduced playability. Furthermore, areas that are suitable for hole locations are often flatter areas with reduced surface drainage; they tend to be wetter, which makes them more susceptible to damage from golfer and maintenance traffic. Reduced surface drainage has a compounding effect, and the areas that are most important to playability on a green with limited hole locations are most likely susceptible to turf problems.

3-D green scans are helpful to identify the areas of a putting green that are suitable for hole locations at modern putting green speeds. Sloped putting greens that have excellent surface drainage often have fewer hole locations. While a sloped green may perform well with respect to turf health, the small, localized areas suitable for hole locations may suffer because of concentrated traffic. Ultimately, excessively sloped greens may be perceived to be in bad condition because there simply are not enough distinct hole locations to disperse daily traffic.

The number of putting green entrance and exit points also affects traffic patterns and turfgrass health. Architectural features like bunkers, water features, and even steep slopes constantly force golfers to use the same areas to enter and exit greens.



Putting green scans accurately depict total square footage within a variety of slope ranges. Generally, hole locations should be placed on slopes below 4 percent at modern green speeds. On this green, less than 7 percent of the total surface area is below 4 percent slope. (Used with permission from Baltimore Country Club and McDonald & Sons Design Group, Inc.)

Limited entrance and exit points concentrate traffic and can contribute to poor putting green performance.

GRASS SELECTION

Many different turfgrasses are managed on putting greens. In many instances, golf course superintendents are not managing the best type of grass on their putting greens; rather, they are "playing the hand they have been dealt" and managing a grass, or combination of grasses, that has been in place for many years. In other cases, cool-season grasses, like creeping bentgrass, may have been established where climatic conditions clearly favor warm-season grasses because it is often presumed that cool-season grasses have enhanced performance when compared to warm-season grasses like bermudagrass.

Over time, golfer expectations for putting green conditions have increased, especially with respect to green speed. Meeting golfer expectations with older varieties of grass can be very challenging, especially with a limited maintenance budget. *Poa annua* encroachment can compromise putting quality because of prolific seedhead production and differences in life cycle and growth rate. Older creeping bentgrass varieties also may develop a patchy appearance that can impact putting quality at certain times of the year. Although newer creeping bentgrass varieties currently seem less inclined to develop patchy growth, time will tell as these greens age. Off-type bermudagrasses in warm-season putting greens also can negatively affect playability. Off-type bermudagrasses can respond negatively to aggressive cultivation or changes in weather, causing turf to thin out at certain times of the year. Off-type grasses in putting greens often result in using increased resources to meet golfer expectations (e.g., labor, fertilizer, plant protectants, and plant growth regulators). Producing and maintaining high-quality playing conditions often is more difficult on older greens with Tifgreen 328 and Tifdwarf bermudagrass than on greens with newer varieties of ultradwarf bermudagrasses. Furthermore, because of enhanced characteristics like traffic tolerance, ultradwarf bermudagrasses are becoming more popular as the golf industry continues to adopt more sustainable maintenance practices such as eliminating overseeding.

Maintenance practices that are used to achieve golfer-desired green speeds, such as low mowing heights, double cutting, and repeated rolling, are stressful for all grasses, but they are especially stressful for older grasses. Fortunately, plant breeders have developed grasses for use on putting greens that more consistently meet golfer expectations. The first high-density creeping bentgrasses were released in the mid-90s and have created a new standard for cool-season putting greens. Similarly, the first ultradwarf bermudagrasses were introduced in the mid-90s, establishing a new standard for putting green quality in hotter climates. Since their release, ultradwarf bermudagrasses have replaced creeping bentgrasses on greens in areas where creeping bentgrasses required

The development of ultradwarf bermudagrass has prompted many golf courses in search of better playing conditions to regrass older bermudagrass greens and many creeping bentgrass greens as far north as Richmond, Virginia. Replacing older varieties of grass with new ones can be a dramatic, long-term upgrade that can also reduce the resources used to achieve acceptable playing quality.

substantial resources to maintain but older bermudagrasses failed to produce acceptable playing quality. Turfgrass breeders continue to improve the characteristics of grasses used on golf courses. The USGA has provided funding for turfgrass breeding projects at several universities in the U.S., resulting in improved turfgrasses that produce excellent playing quality while more efficiently using resources and better tolerating stresses than earlier grass types.

Growing the ideal grass is not a requirement for good greens, but more resources will be required or expectations must be lowered to maintain older grasses. Genetic limitations of older, existing grasses may prevent expectations from being met, regardless of available maintenance resources. Regrassing to a newer grass can allow better conditions to be maintained on a daily basis while reducing the use of resources like labor, fertilizer, water, and plant protectants, potentially allowing operating dollars to be allocated elsewhere. When expectations cannot consistently be met and turfgrass decline on putting greens regularly occurs, regrassing should be considered.

IRRIGATION AND WATER QUALITY

The irrigation system plays a huge role in putting green quality. Applying water when and where it is needed is critical. Ideally, putting green complexes have two sets of irrigation heads: one set of heads dedicated to watering the putting greens while a second set of heads applies water to only green surrounds. Generally, putting green surrounds require more water than putting greens, and water management on greens should not be compromised in the interest of the surrounds. Having dedicated heads allows water to be applied only where it is needed.

Also, individual-head control for putting greens is desirable. Control of individual irrigation heads allows specific areas of a green to be irrigated separately from areas that do not need additional water. An irrigation system that only provides the ability to activate multiple putting green heads at one time limits the superintendent's ability to target specific areas with overhead irrigation, further increasing reliance on hand watering.

Water quality plays a critical role in successful putting green management, water infiltration rate and internal drainage become very important when regular leaching is required. Managing a combination of factors, including water quality, grass selection, and drainage, is critical to maintain acceptable putting green quality.

Core aeration and topdressing provide short-term surface disruption, but these programs are very important to season-long putting green health. Golf courses considered to have the best greens generally implement aggressive aeration and topdressing strategies on a consistent basis.

and it is important to test the quality of irrigation water. As the quality of water available to golf courses decreases and golf courses throughout the country use more reclaimed water, the increased salt load associated with the water source must be accounted for in grass selection and management practices. For example, in a climate like southern Nevada, turf managers can successfully grow cool- or warm-season grasses, but warm-season grasses like bermudagrass or seashore paspalum are better adapted if the irrigation water contains high concentrations of salts.

Leaching is an important practice when irrigation water contains elevated salinity and sodium levels. An effective leaching event typically involves applying 3 inches or more of water to a putting green over the span of 8 to 12 hours. During flushing, water must not be applied at a rate exceeding the infiltration rate of the green. Thus,

MAINTENANCE PROGRAMS

Ongoing maintenance programs have the greatest impact on daily and long-term putting green conditions. However, maintenance cannot overcome inherent limitations of putting greens, especially if expectations are not in line with limitations and available resources. However, if proper maintenance is not employed, even a green with no limitations will underperform. Maintenance programs that minimize surface thatch accumulation while yielding adequate oxygen exchange and water infiltration are critical to putting green performance.

Inadequate aeration and topdressing lead to surface organic matter accumulation that can dramatically slow water infiltration. If not properly managed, organic layers will hold water and lead to soft conditions. Oftentimes drainage problems in putting greens are caused by layers of organic matter in the upper portion of the soil profile that prevent water infiltration. The best internal drainage is ineffective if water infiltration is limited.

Deep aeration programs like deep-tine, drill-and-fill, and deep sand injection are among the most disruptive programs used to manage putting greens. However, when implemented repeatedly over time, deep aeration programs can improve water infiltration, allowing water to move more rapidly into internal drainage systems. Deep aeration can both improve older, poorly draining greens and help maintain infiltration rates on newer greens.

Although budget heavily impacts daily maintenance, long-term programs like core aeration, topdressing, and deep aeration help provide a foundation for healthy turfgrass and should be used to some degree on golf courses regardless of budgets. Aggressive aeration may be all that is needed to improve putting green performance. Greens will perform better when proper soil profile management practices are implemented as needed.

CONCLUSION

Rarely do the factors mentioned in this article independently affect putting greens. Generally, several factors combine to make a good green or a problem green. However, one exception to this rule may be growing environment. Even a putting green with suitable drainage, adequate size, and multiple hole locations will struggle in a poor growing environment. There is no substitute for adequate sunlight penetration and air movement. The interaction of the factors discussed in this article will dictate whether small changes can be made to improve putting green conditions or whether complete renovation is required. Golfer expectations also play an important role in determining the appropriate path to improving putting green performance. How often are golfers satisfied by putting green playing conditions?

A putting green with several problems may be perfectly fine at a facility where golfers are simply satisfied to have good turf cover and accept slower green speeds that allow the turf to stay healthy. The same putting green could be considered completely inadequate at a facility where fast green speeds are expected or demanded on a daily basis.

Golfer expectations play a huge role in defining what is, and is not, a problem green. Golfer expectations also make it very difficult to compare one golf course to another. If greens consistently fail to meet golfer expectations, changes should be made. The extent of changes — from adjusting management practices to complete renovation — will vary and should be determined by carefully evaluating the factors affecting putting green performance at your facility.

If your golf course has problem greens, the factors discussed above most definitely play a part. The USGA Green Section offers a specialized Course Consulting Service visit, the Putting Green Evaluation visit, to help golf facilities assess the factors affecting putting green performance and determine which options should be considered to improve problem greens. If changes are not made to mitigate limiting factors, problem greens will continue to underperform and fail to meet golfer expectations.

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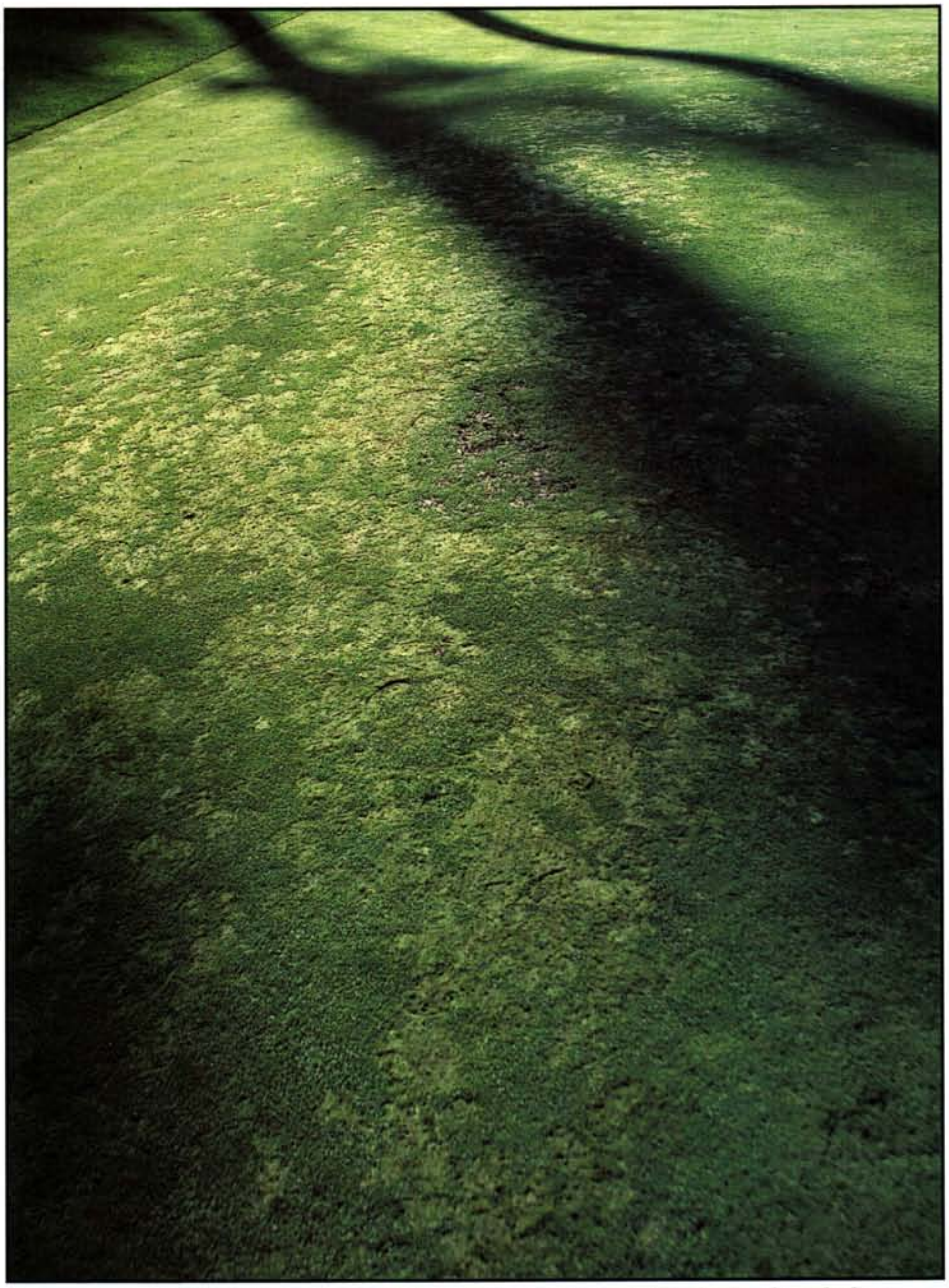
Total renovation of putting greens is an expensive proposition, but it offers the opportunity to address factors that limit putting green performance from the ground up and can provide dramatic long-term improvement.

Helping Your Greens Make the Grade

Here's a guide to help you evaluate the many factors that determine how your greens perform.

by JAMES FRANCIS MOORE



Reduced sunlight results in decreased photosynthesis and therefore reduced plant vigor. Problems are compounded by low-cut greens that have very small leaf area available to gather light. Moss invasion on a green is an indication that the proper environmental conditions aren't present to grow good turf.

GOLFERS and their greens have had a long and often tumultuous relationship. In fact, no area of the course has a stronger influence on the golfer's game, since between the approach shot and putting, the greens come into play on approximately 75% of the shots of a typical round of golf. Most golfers realize this and are quick to point their putters in disgust whenever the green does not act as they believe it should, and they brag to their neighbor when their club's greens are in top form.

Golf course superintendents and their greens have an even greater love/hate relationship. There is an old saying in the superintendent's world — "Your greens are your resume." True enough, since players overlook a great deal on the course when the greens are in good shape, but will call for the superintendent's head when the putting surfaces are less than perfect (regardless of how good the remainder of the course is). The golfer's perception of the role of the superintendent in providing perfect greens is reflected in the tendency of the weekend hacker to refer to the *superintendent* as the *greenkeeper* — a term poorly suited to describe the varied and often complex duties of today's professional golf course superintendent.

Since golfers and superintendents alike have such close relationships with their greens, it is beneficial for all concerned to have a better understanding of why greens perform the way they do. Truth be known, few golfers have any idea of the various factors that determine the overall performance of the green. They hear stories of mysterious turf diseases and bugs, and most know they should generally fear terms like *Poa annua*, goosegrass, and brown patch. But for the average golfer the *pest* most feared is the aerifier. And while superintendents spend many hours studying the agronomics of maintaining greens, they are occasionally guilty of putting the needs of the turf over those of the golfer. The best superintendents recognize the need to seek a middle ground — to establish a level of maintenance that results in a healthy stand of turf but still provides good putting quality. Obviously, the establishment of this *middle ground* should be the golfer's goal as well, since this is their best hope of playing greens that perform well day after day. Finding the middle ground is the purpose of this article.

Greens usually do not perform well or poorly because of a single factor. Instead, like most things, overall performance is the result of many influences. To identify these factors, it is suggested a *Report Card* be developed for each green. This Report Card will graphically illustrate where improvement is needed.

Quite simply, the Report Card is a *tool* to help golfer and superintendent alike evaluate the many factors that influence the overall performance of each green on their course. After the factors are identified and quantified, steps should be taken to improve each factor as much as possible. It probably will not be possible to bring each factor (or perhaps even any factor) up to a grade of "A." For example, on old or poorly built greens the factor for internal drainage may be graded as a "D." Through an aggressive aerification program the grade may be raised to "C," but only complete reconstruction would achieve the "A" rating. However, it may be possible to raise the grades for other factors as well. Perhaps entrance and exit points can be improved by rerouting a cart path or making greater use of ropes and signs. Air movement may be improved by removing brush or trees that block the wind. The relocation of misplaced sprinklers could improve the accuracy of irrigation. The overall impact of raising three or four factors will be a significant reduction in the influence of a factor that cannot be altered. In other words, the overall performance of the green can be expressed as a simple formula: The Average of Factors *A + B + C + D + E . . . = Overall Green Performance.*

Think of each green as a decathlon competitor. An athlete whose height may limit his or her ability to high jump will have to make up points on the 200-meter dash to remain competitive. There is another formula you should keep in mind regarding the changes that are made to improve the greens. This is a case where 1 + 1 + 1 +1 + 1 can actually add up to 6. In other words, by implementing multiple changes (each reducing the stress on the green), a synergism is likely to occur, reducing overall stress by more than the sum of the individual steps. This is due to the fact that so many of the stress factors are closely related. Improving one factor frequently results in improvement in one or more of the others.

To be the most useful and effective, the Report Card must be developed with the combined input of the golf course superintendent, course professional, and members of the course leadership (often the Green Committee). This group is referred to below as the *Rating Team*. There are three steps to completing this evaluation process.

Step 1

Assign an overall performance grade to each green. Before heading out to the course, the Report Card rating team should first gather in a comfortable and private area to discuss what lies ahead. This is also the time to complete the first phase of the Report Card — assigning a letter grade to each green's overall performance. Just like in school, a grade of "A" reflects superior performance, and "F" indicates failure. This overall grade is much like a college student's final GPA

Layers in the green profile severely restrict internal drainage and can even block it altogether. Conventional aerification may not be deep enough to fully penetrate a buried layer. Deep-tine aerification is the next step in solving the problem.

or grade point average over four years of education. Be sure not to base the overall grade on a single good or bad season. Base the grade on four or five years' worth of performance.

Step 2

Visit each green to complete the Report Card and identify where changes should be made. This is where the evaluation process gets more detailed. Listed on the accompanying rating sheet are many factors, each of which should be assigned a letter grade. Notice that the sheet has room to add additional factors. It also is possible that some of the factors listed are not applicable to your particular course. Since the grades are obviously subjective, it is important that the entire rating team participate in the evaluation process from start to finish. It is also advisable to complete the process in a single day. Based on personal experience with this rating concept, 18 greens should take approximately three hours to rate fairly.

Step 3

Implement the changes. The Report Card is useless unless changes are made to improve the overall growing conditions on the greens. Implement as many positive changes as possible, keeping in mind that no single change will have the impact of multiple changes.

Factors Influencing a Green's Performance

Listed below are the factors that have the greatest impact on the overall performance of a green. (Note that they are not listed in any particular order.) Also included are some criteria for determining a grade for each factor. It should be viewed as a starting point and not an inflexible guide that must be followed to the letter. Your rating team probably will find it helpful to modify the criteria to better fit your course.

Light

A basic agronomic fact that is overlooked far too often is that turfgrass requires light (lots of it) to flourish. As you rate each green for light, keep in mind what you probably learned back in the fourth grade. Light is necessary for photosynthesis. Photosynthesis is the process of turning the energy of light into energy the plant can use for growth. Growth is necessary for a plant to withstand and recover from wear and tear. Therefore, it stands to reason that when less light is available, the turfgrass is less able to withstand traffic.

The steps to improve the grade for light are obvious. Tree pruning, and in some cases complete removal, will be necessary to provide better growing conditions. It is easy to forget that trees grow larger every year and as a result block more light each season. Keep this physiological fact in mind when someone observes, "We never used to have problems with that green."

• "A" — given to greens that receive 8 hours or more of direct sunlight.

• "B" — given to greens that receive 6 to 8 hours of direct sunlight.

• "C" — given to greens that receive 4 to 6 hours of direct sunlight.

• "D" — given to greens that receive 2 to 4 hours of direct sunlight.

• "F" — given to greens receiving less than 2 hours of direct sunlight.

Air Movement

Air movement across the putting surface has a very strong influence on the overall health of the turf — particularly in terms of disease susceptibility and cooling of the plant. The pathogens responsible for the most devastating turfgrass diseases are far less active (and therefore less destructive) when air moves immediately over the turf. The air movement helps keep the turf and the surface of the soil dry. Wet, stagnant air provides excellent conditions for pathogens to proliferate. From a cooling standpoint, a good comparison can be made to our built-in air-conditioning system — perspiration. On a hot day, our skin is cooled as we perspire. The plant's perspiration system is called evapotranspiration (a combination of evaporation and the transpiration of water through the stomata or *pores* of the leaf). Air movement must be given high priority for all greens — particularly on golf courses located in climates that include high heat and humidity.

Steps to improve air movement include pruning and possibly removing trees and brush on the upwind and downwind sides of the green. When tree removal is considered to be impossible because of architectural or sentimental reasons, institute an effective pruning program. Even high mounding around a green can block air movement, so regrading the mounds can produce a significant improvement. In severe cases, fans are used to provide an artificial source of air movement.

• "A" — given to greens that receive unrestricted air movement across the turf surface.

• "B" — given to greens that are blocked from the predominant winds but open on other sides.

• "C" — given to greens that would receive very limited air movement without the use of fans.

• "D" — given to greens "open" on only one side.

• "F" — given to greens located in low areas that receive extremely limited air movement from any side.

Entrance and Exit Points

Codes for buildings call for a specific number of entrances and exits based on the capacity of the building. Perhaps greens should be given the same consideration. When the architecture of a greensite is such that entrance and exit points are severely limited, even a small annual number of rounds can be quite destructive to the turf. Greenside mounding, bunkering, trees, and other features can be as restrictive as cattle chutes. Predictably, such restrictions are far more important on heavily played courses than on the extremely private facility.

Steps for improvement include rerouting cart paths to encourage players to enter and exit from different sides of the green. Ropes and signs often are necessary evils (but be sure to move them frequently and keep them in good condition). In severe cases, bunkers may have to be removed or redesigned to provide greater access to the green. Mounding may have to be softened, since players instinctively avoid walking over hills to get to the green. Inconsiderate players might ignore all these efforts to spread traffic out over a large area. However, the majority of golfers realize they benefit the most from a course in good condition and will cooperate with properly placed and maintained traffic control devices.

• "A" — given to a green that has at least four readily usable entrance and exit points.

• "B" — given to a green that has three readily usable entrance and exit points.

• "C" — given to a green that has only two readily usable entrance and exit points. Other access points exist but will require extensive roping and/or signage to force players to use them.

• "D" — given to a green with only one readily usable entrance and exit point. Other access points may exist but require extensive roping and/or signage to force players to use them.

• "F" — given to a green with only one readily usable entrance and exit point and no other real options, regardless of roping, etc.

Size of Green

Golf has enjoyed tremendous growth over the past couple of decades. As a result, the greens on many courses must endure countless additional rounds. In many instances, the original architectural design that was appropriate in the early days of the course simply cannot support the twofold or even threefold increase in annual rounds that is not uncommon today. Just as many families start out driving a two-seater, these families often find themselves driving station wagons ten years later.

Steps for improvement are limited. Since greens sometimes grow smaller over time (as the workers on the mowers try to avoid scalping the edges), it is possible that the original boundaries of the green can be reestablished, providing additional square footage. A probe should be used to find the original edge of the rootzone

Often, something as simple as eliminating triplex mowing in favor of walk-behind can be enough to help a green through the rough times.

cavity. It should be noted that even if the green has grown it, enlarging the surface may take a lot of effort. For example, in areas of the country where bermudagrass fairways and banks surround bentgrass greens, simply enlarging the mowing pattern would likely introduce bermudagrass into the bentgrass green. In this situation, fumigation of the bermudagrass in the area to be recovered as green should be accomplished first.

• "A" — given to a green in excess of 7,000 square feet.

• "B" — given to a green 6,000 to 7,000 square feet in size.

Triplex mowers on sharp turns can result in severely worn turf. Simply changing to walk-behind mowers may be enough to return the turf to good health.

• "C" — given to a green 5,000 to 6,000 square feet in size.

• "D" — given to a green 4,000 to 5,000 square feet in size.

• "F" — given to a green less than 4,000 square feet in size.

Cupping Area

Another factor that has been strongly impacted by the increase in the popularity of the game (and therefore increased traffic on the greens) is cupping area, or the number of areas in which the hole can be *fairly* located. As a general rule, the hole should be located approximately five paces from the edge of the green, and the putting surface within three feet of the hole should be on the same plane.

Estimating the percentage of the green that is usable for hole locations takes a little practice. To develop a feel for this estimating process, try the following procedure on the first couple of greens rated. Using tees, roughly outline the portions of the green in which the hole can be reasonably placed. Next, estimate the square footage of each marked area. Add the square footage together and divide the sum by the total square footage of the green. For example, suppose there are three areas of the green that can be used for hole locations. The total square footage of these three areas is approximately 1,500 square feet. The entire green measures 6,000 square feet. 1,500 ÷ 6,000 = .25 or 25%.

Steps to increase cupping area include the restoring of original green boundaries (as discussed above in the "Size of Green" section) and selecting a speed for the greens that is appropriate to their contouring. For example, a green mowed at ⅛ of an inch and rolling 9 feet on the Stimpmeter may yield a rating of "D." Raising the cut to 5/32 inch might yield a speed of 8 feet and increase the percentage of usable cupping area to a "C" or even "B" rating.

Assuming greens are moderately sized to begin with, use the following grades to rate cupping area:

• "A" — given to greens with cupping areas in excess of 50%.

• "B" — given to greens with cupping areas between 40% and 50%.

• "C" — given to greens with cupping areas between 30% and 40%.

• "D" — given to greens with cupping areas between 20% and 40%.

• "F" — given to greens with less than 20% cupping area.

Surface Drainage

Surface drainage is extremely important to every green, including those with good internal drainage. Even the best-constructed rootzone will gradually drain more slowly. This is due to the production of organic matter by the plant and the introduction of soil *fines* (notably clay, silt, and very fine sand) into the rootzone over the years. These fines are introduced through topdressing, wind, and even during irrigation when the water supply contains suspended solids. It is even possible for some types of sand to be chemically weathered, causing a reduction in size.

Without good surface drainage, water collects in the low areas of the green, resulting in extremely poor growing conditions for the turf. The rootzone becomes saturated and can remain that way for extended periods of time. This results in anaerobic (without oxygen) conditions, which can lead to the death of the plant. Disease incidence also increases, as does the occurrence of algae and soured soil (often referred to as *black layer*).

Surface drainage occasionally can be improved by lifting the sod, adding additional rootzone mix to eliminate the water-collecting hollow, and replacing the sod. Obviously, this step is practical only in small areas and near the edges of the green. Sometimes surface drainage is blocked by the development of thick thatch in the turf immediately adjacent to the green. Removal of the sod and thatch, followed by replacement with a thatch-free sod, may be all that is necessary to allow water to once again flow off the green.

• "A" — given to greens with no water collecting hollows and surface drainage in at least three directions.

• "B" — given to greens with no water collecting hollows and surface drainage in two directions.

• "C" — given to greens with no water collecting hollows and surface drainage in one direction.

• "D" — given to greens with surface drainage to the center of the green and one surface exit point.

• "F" — given to greens with water collecting hollows.

Internal Drainage and Rootzone Porosity

Internal drainage and rootzone porosity are often the only factors considered when determining the need for the complete reconstruction of golf greens. The USGA provides specific guidelines regarding these factors (see the *USGA's Guidelines for a Method of Green Construction*). However, all too often greens will be rebuilt to meet these guidelines without consideration of the many other factors that contributed to the poor performance of the original green. Not surprisingly, in many instances the new green does not perform as well as expected. Internal drainage and porosity are extremely important, but they cannot compensate for the lack of light, poor air movement, poor traffic control, etc.

Good internal drainage is without question very influential to the overall performance of the green — particularly in adverse climates and in areas where water quality is less than ideal. The degree of internal drainage is measured as *saturated hydraulic conductivity.* Rootzone porosity represents the sum of two types of porosity — *capillary* and *non-capillary.* Capillary porosity is a measure of the percentage of pores in a rootzone mixture that are filled with water at field capacity, while non-capillary porosity refers to the percentage of pores filled with air. To determine these factors accurately, samples should be removed from the green and submitted to an accredited physical soil testing laboratory.

Short of complete reconstruction, the most effective means of improving internal drainage and porosity is to increase aerification. Often, a combination of deep-tine and conventional core aerification is necessary. Many courses now include water-ject aerification as a supplement to the mechanical aerification practices.

• "A" — given to greens built in accordance with USGA guidelines.

• "B" — given to non-USGA greens with hydraulic conductivity rates over 3 inches per hour and a functional subsurface drainage system.

• "C" — given to greens with hydraulic conductivity rates over 3 inches per hour but no subsurface drainage system.

• "D" — given to greens with hydraulic conductivity rates of 1 to 3 inches per hour.

• "F" — given to greens with hydraulic conductivity rates of less than 1 inch per hour.

Irrigation Control and Coverage

This is another area that frequently is overlooked when evaluating the overall performance of greens. Although proper irrigation has always been important, the lowering of cutting heights and the use of different grass species in the vicinity of the greens has enhanced the need for as much control and accuracy as possible. Common sense should make us wonder how full-circle, overhead sprinklers that cover the green, surrounds, and fairway approach areas, can possibly meet the specific needs of the turf in each area. For example, a bentgrass or bermudagrass green maintained at 3/16 inch or less does not conveniently have the same water requirements as the bermudagrass fairway cut at ½ inch or the bluegrass rough mowed at 2 inches. Different cutting heights and different turfgrasses demand different irrigation frequencies and volumes. As a result, even a well-designed and properly installed and operated system often must be supplemented with hand watering. And, obviously, a system with poor spacing, improper nozzles, or improper pressure adjustments will cause nothing but problems.

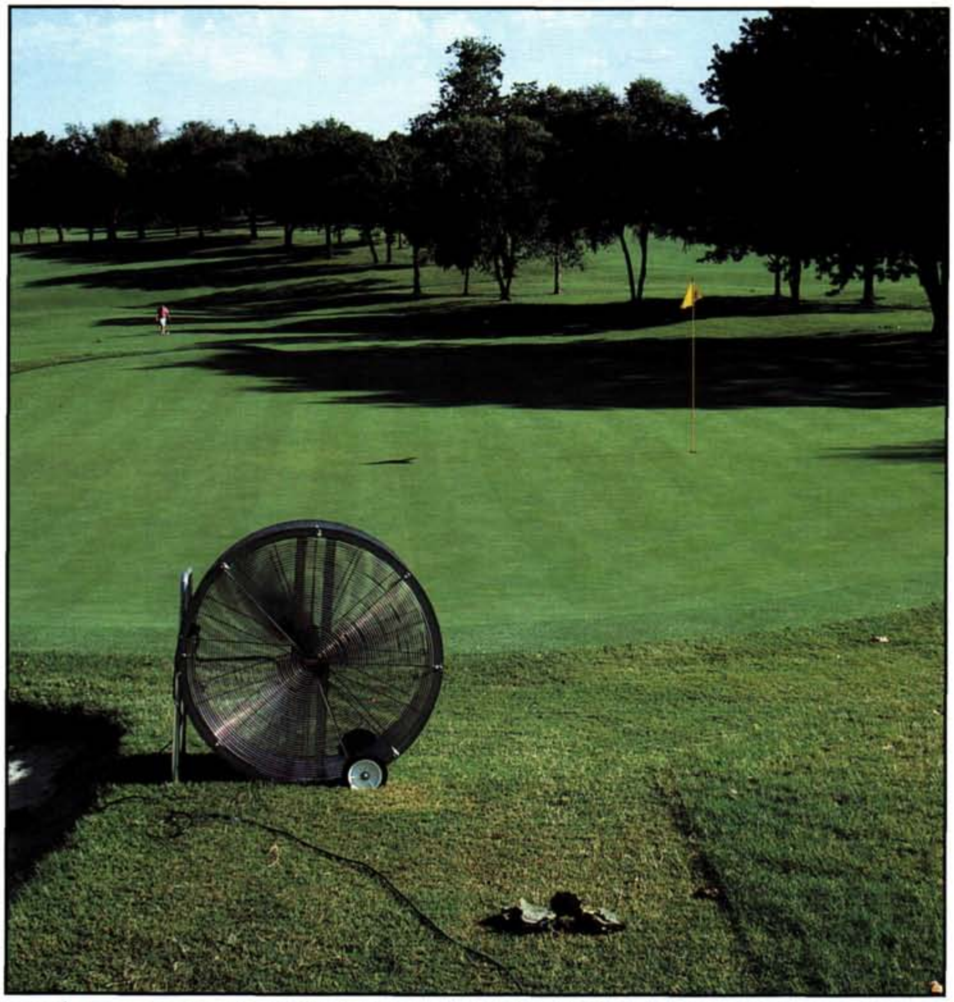
Steps for improvement include upgrading the irrigation system to provide single head control, installing a perimeter system to water the surrounding turf separately from the greens, relocating heads to provide even coverage, and altering nozzle sizes to achieve better coverage and proper pressure regulation. Hand watering can also be increased to help compensate for a substandard irrigation system.

• "A" — given to greens irrigated with a combination of full-circle and adjustable part-circle heads facing outward. Such a system is often referred to as a *perimeter* system. Each of the heads should be able to be controlled independently through the automatic irrigation system.

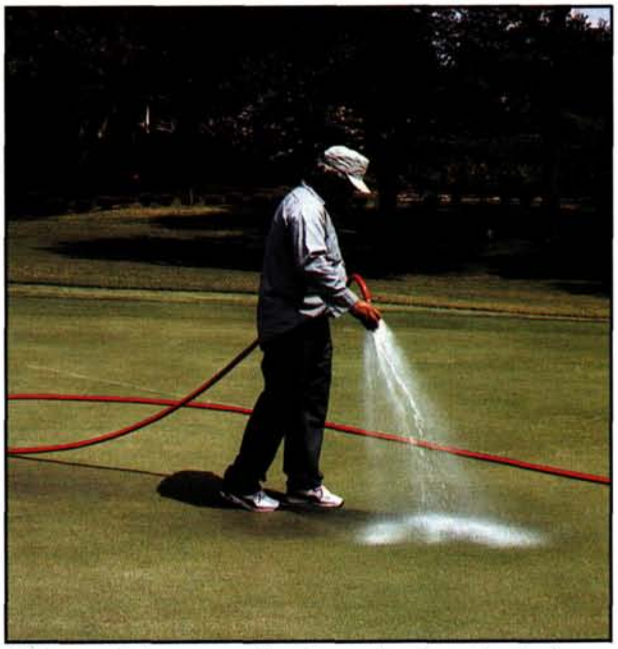
• "B" — given to greens without a perimeter irrigation system but with single head control of sprinklers that are correctly spaced.

• "C" — given to greens without a perimeter irrigation system and without single head control.

• "D" — given to greens with no perimeter system, no single head control, and the satellite that controls the greens is located on the same irrigation cycle as other areas of the course.



Good air movement across the putting surface is vital for disease suppression and plant cooling. If tree pruning or removal is not possible, fans are the next best option.



Good employee tenure usually results in a better-trained crew. Knowing the difference between cooling the turf and spot watering, and when each technique is needed, can result in better-managed turf during stress periods.

• "F" — given to greens with a manual irrigation system.

Purity of Turf Stand

Older greens are often composed of more than one species of turfgrass and even various biotypes of the same grass. For example, older bentgrass greens often have large percentages of *Poa annua* intermixed with the bent. Biotypes of both bentgrass and bermudagrass in greens begin to segregate over time, resulting in many patches of distinctly different grasses in the same green. Each of these different grasses and biotypes has a particular set of vulnerabilities to insects, disease, climatic stresses, and, particularly, cutting heights. As a result, the more varied the makeup of the putting surface, the more difficult it is to manage.

With the exception of very minor outbreaks of *Poa annua* and/or off-type grasses, there is little that can be done to restore the purity of the stand of grass other than completely replant. Until then, raising cutting heights to suit the type of grass in the green that is least able to tolerate low cutting heights will help provide uniformity in terms of putting quality.

• "A" — given to greens composed of a pure stand of turf.

• "B" — given to greens with less than 20% "off" types.

• "C" — given to greens with less than 30% "off" types.

• "D" — given to greens with less than 40% "off" types.

• "F" — given to greens with less than 50% "off" types.

Amount of Play

No agronomic mysteries here — the less you use your greens, the healthier the turf will be. When golfers make their inevitable comparisons from one course to the next, the amount of traffic the greens must endure often is the most overlooked factor.

To deal effectively with traffic, it is vital the greens be established to the best turf for the climate in which the course is maintained. What is agronomically possible does not mean it is agronomically sensible. Bentgrass greens maintained in hot and humid climates cannot tolerate the same amount of play as bermudagrass greens in the same climate. The superintendent also should be sure that adequately high cutting heights are maintained to *cushion* the turf from heavy traffic loads. Topdressing, fertilizing, and grooming practices must be adjusted to maintain a pad or thin layer of organic matter between the crown of the plant and the underlying (usually abrasive) rootzone mixture. Potassium levels should be kept at recommended levels to provide a stronger plant that is better able to withstand stress. Spikeless shoes should be encouraged to reduce injury to the turf.

• "A" — given to greens that receive fewer than 20,000 rounds per year.

• "B" — given to greens that receive fewer than 30,000 rounds per year.

• "C" — given to greens that receive fewer than 40,000 rounds per year.

• "D" — given to greens that receive fewer than 50,000 rounds per year.

• "F" — given to greens that receive more than 50,000 rounds per year.

Water Quality

The water used to irrigate the greens can make the difference between success and failure of the turf. Greens maintained with water high in salts or bicarbonates are predisposed to a wide variety of problems. Establishing a grade system for water quality is impossible, since so many factors interact. If you have questionable water quality, it is best to solicit the input of a qualified agronomist to determine the impact of the water on the turf, as well as steps for improvement. The ratings listed below are therefore highly generalized.

• "A" — excellent water quality.

• "B" — good water quality.

• "C" — marginally acceptable water quality.

• "D" — poor water quality.

• "F" — very poor water quality.

Other Rating Factors

There are many other factors that may need to be considered by the rating team. These could include the following:

• Nematode levels.

• Experience and skill of maintenance crew.

• Availability of proper maintenance equipment.

• Tenure and skill of the superintendent.

• Tree root competition.

• Cutting height.

Rating the skill of the superintendent is perhaps the most subjective process of all. Without question, a skilled superintendent who has been given time to learn the nuances of a particular set of greens can have a very positive impact on the overall performance of those greens. However, no superintendent, regardless of skill, can completely overcome stresses resulting from the many factors discussed earlier. The superintendent cannot independently provide light, air movement, adequate size, drainage, or good water quality. Assuming your course has a superintendent of at least average ability, the team would be wise first to correct the many other factors that are holding back the greens. It is amazing how often a superintendent considered by the golfers to be without talent suddenly develops a green thumb when given the opportunity to manage properly constructed greens. By the way, there are steps to take to help the superintendent improve as well. The leadership of the course should support the superintendent's efforts to learn by providing the opportunity to attend educational sessions on national, state, and local levels. The science and art of greens management changes rapidly with the introduction of new technologies and the ever-increasing stresses today's greens must endure.

Conclusion

Developing the Report Card can identify where work is needed to improve the greens. It can also help determine whether or not reconstruction is necessary. Finally, completing the Report Card before building or rebuilding greens can help ensure that, when the construction is finished, the greens will be both agronomically sound and capable of providing top-quality putting conditions.

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Table 1

Report Card for ____________________ Date Completed ____________

FACTOR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Light																		
Air movement																		
Entrance and exit points																		
Size of green																		
Cupping area																		
Surface drainage																		
Internal drainage																		
Irrigation control/coverage																		
Purity of turf stand																		
Amount of play																		
Water quality																		
Historical Performance																		

The Evolution of a Putting Green

Learn more about what happens as a putting green ages.

BY DAVID A. OATIS

Golf courses are living, breathing entities that, once built, take on a life of their own. A golf course, or any of its many components, can eventually evolve into something very different from what was originally designed or envisioned. In some cases, the course or component may become much better than what was originally designed; in other cases, the evolutionary process may take the course or component in the opposite direction. It may deteriorate structurally, aesthetically, and/or architecturally. This is especially true of putting greens.

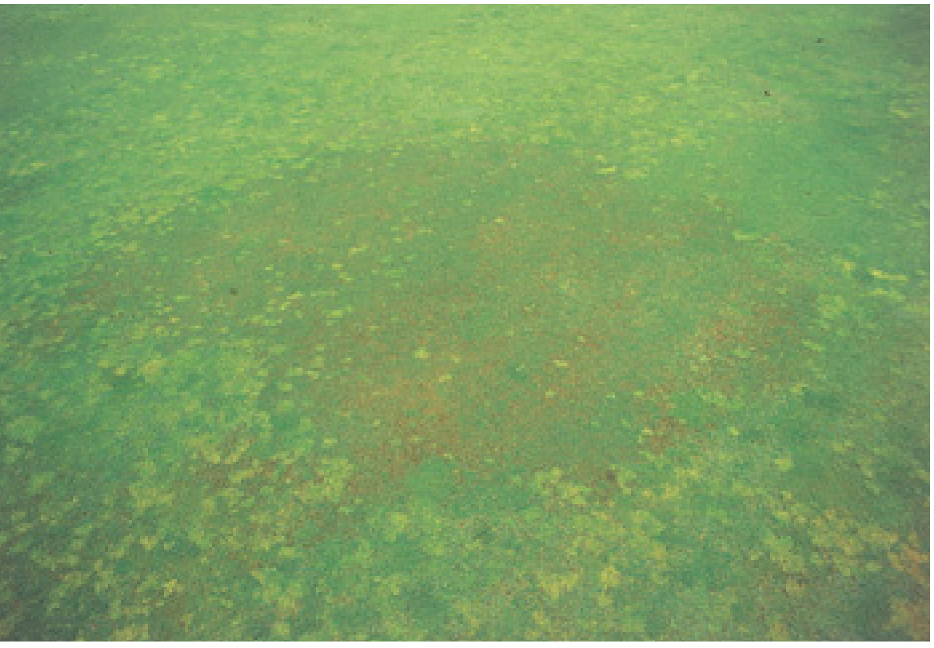
So why is this significant? Building a golf course, or even just a putting green, really just starts the process of evolution. In many respects, the golf course superintendent's primary job is to try to manage or steward the evolutionary process, hopefully ensuring that the changes are desirable in the long run. Understanding these evolutionary processes is especially important today, given the high demands being placed on our putting green turf.

Given the complexity of golf courses and the many changes that can occur to the different parts of a course, this article will concentrate only on the more common changes that occur to putting greens as a result of play, management practices, the passage of time, and the effects of natural selection. Be assured that the changes occurring to bunkers, tees, fairways, and tree plantings, etc. may be even more drastic.

An improperly built or managed putting green often will require extensive and involved management practices to help it perform adequately. In this case, a poorly drained mix was utilized, and deep soil modification was necessary to improve internal drainage.

SHORT- AND LONG-TERM GOALS

The number-one short-term goal for most golf courses usually is to produce good playability, but aesthetics and reliability also play a role. Without a reliable stand of turf, achieving good playability is not of much value. A green that performs well during mild weather, but fails when stress levels increase, is little more than a house of cards. In most areas of the country, weather extremes occur periodically to threaten turf, and new and different turf-threatening pests and diseases arise. Having a reliable stand of turf to go along with the good playability is of paramount importance. Thus, the short-term value of providing good playability today must be measured against the value of maintaining reliability through long-term change.



New bentgrass plantings look very uniform initially. Over time, the individual clones will segregate, creating a patchy appearance that is most evident in the fall, winter, and spring.

COMPLETION OF CONSTRUCTION

So, you just carefully built a brand-new putting green using the best materials and procedures, and you seeded it to the best new creeping bentgrass cultivar currently available. Now all you have to do is play golf, right? The greens should just stay like that forever, right? Nothing could be further from the truth. The process of evolution has just begun.

THATCH DEVELOPMENT AND MANAGEMENT

Thatch development is a normal and much-needed process; the key is to manage it. Seeded greens initially have no thatch, and although excessive thatch is a significant and common problem, some thatch is essential to hold soil particles (primarily sand) together to create a smooth, firm, stable, and resilient surface. Without any thatch, traffic from golfers and maintenance equipment would compress the tender turf into the abrasive sandy soil. This would cause the soil to shift and produce surface imperfections (light footprints, ruts, etc.) and significant injury to the turfgrass plants. The turf would thin out (wear away) and the wounds would leave the plants prone to infection from numerous different turfgrass pathogens. Insufficient thatch creates a wear- and disease-prone turf that does not play well.

Once bentgrass greens have been planted and the seeds begin to germinate, topdressing should commence very soon. The goal is to intersperse sand particles in the thatch as it develops. As the green matures and the thatch/mat layer develops, the surface becomes increasingly firm and resilient. This thatch layer, with topdressing incorporated, allows the putting green to handle traffic without excessive injury. It also aids in drainage and moisture and nutrient retention. A thatch layer (with topdressing incorporated in it) must be developed before a green can be subjected to normal play.

On the other hand, excessive accumulation of organic matter (thatch) at the surface of a high-sand green and insufficient dilution of thatch with topdressing are the most common problems of new greens. Other problems also occur:

- Shortened root growth.
- A soft, spongy surface that is prone to footprinting and rutting.
- An excessive thatch layer functions much like a kitchen sponge. It may allow for the transmission of water, but it will retain too much at the surface. A wet surface creates a perfect environment for algae, moss, and annual bluegrass invasion. A wet surface can create a vicious cycle: moss and algae both produce more organic matter that contributes to more water retention at the surface. The problem can spiral out of control.
- Thatchy, wet surfaces result in deep, pitting ball marks.
- If the surface stays wet, gas exchange declines and roots die back.
- Wet surfaces increase disease pressure.

For these reasons and more, developing a sound cultivation and topdressing program is of critical importance to the long-term health and playability of the putting green. The thatch/mat layer must be developed, then kept open, oxygenated, and adequately diluted to ensure effective drainage, gas exchange, and root growth. There are many ways to manage thatch, and much research has been conducted and numerous articles have been written on this subject. Cultivation and topdressing programs vary widely, but the point is that an effective thatch management program is essential.

Greens established from sod present a different set of problems. They often can be opened sooner than seeded greens, but extra cultivation usually is necessary to alleviate the layering that typically results from establishment with sod. Close-center, hollow-core cultivation followed by core removal and topdressing (to fill the holes) may be needed as many as four to six times or more annually for the first few years of a sodded green's life. Note that the extra cultivation also can increase the potential for weed encroachment. Golfers obviously dislike the cultivation, but it is the long-term downside to establishing greens from sod rather than from seed.

Annual bluegrass is an opportunistic invader, and once an opening is made in a bentgrass green, it can quickly invade. Openings come from traffic, ball marks, and ill-timed cultivation practices.

MATURATION

Greens in the Northeast Region usually take several years to mature to a point that they can withstand the same type of wear and tear a mature green can. The maturation process depends on a variety of factors, including weather, length of growing season, species, cultivar, construction methods and materials, irrigation, fertility, growing environment, etc., and three to five years is fairly typical for greens in good growing environments. Greens in poor environments usually take longer (possibly four to seven years) due to their reduced vigor. New greens usually need to be managed conservatively in their first few years, so it is wise to reduce stressful maintenance practices (prolonged low mowing, excessive rolling, etc.) when the weather turns ugly or the green begins to show signs of stress. The health and playing qualities of a new putting green deteriorate quickly when subjected to too much stress, especially when the stress is combined with unfavorable weather (usually high temperatures and rainfall). Closing a young green for 24-48 hours in the event that high temperatures occur in concert with rain and heavy play can obviate damage that otherwise might take weeks or months to recover from.

SEGREGATION

Some golfers seem to like the uniform color and blemish-free appearance of a brand-new putting green, and these golfers may complain when the grasses begin to segregate. Segregation refers to the "sorting out" of individual clones or biotypes with which the grass cultivar was planted. So why does it happen?

Creeping bentgrass seed is the product of sexual reproduction, so the individual seeds are not identical. New plantings initially have a very uniform appearance (assuming the seed is pure and there are no preexisting weed seeds in the soil) because the various different biotypes are uniformly dispersed. After planting, certain better-adapated and more aggressive biotypes gradually begin to crowd out weaker, less well-adapted ones. As this occurs, different clones/biotypes segregate into patches, gradually becoming visible to golfers. Segregation can be especially noticeable on putting greens, where the variety used is more prone to segregation or where multiple cultivars have been used. It also is especially noticeable in the early spring and fall when temperatures are cool. During cool temperatures, different biotypes of creeping bentgrass change color and grow at somewhat different rates, thereby enhancing the patchwork appearance. Generally speaking, the older the green, the more noticeable the segregation is. Segregation begins as soon as a green is planted, but it usually is not apparent until the green is at least five to seven years old.

Although some golfers dislike the patchwork appearance, others argue that segregation is desirable. It is a natural attribute that almost all older greens have, and some claim that it makes putting easier because the different patches make great aiming points to align putts. What is the downside? During the spring and fall, when growth is initiating or slowing down, the growth rates of the different patches will be slightly different, and this can contribute to slight unevenness in the putting surfaces. However, segregation cannot be prevented, and any resulting unevenness would be more than matched by the overall lack of growth. In a nutshell, segregation is not worth worrying about!

WEED INVASION

In the Northeast, annual bluegrass (AB) or *Poa annua* is the most common weed to invade putting greens, and there are thousands of different biotypes of annual bluegrass. Newer courses often struggle valiantly to keep annual bluegrass out of their putting green turf, and currently a variety of materials and strategies can aid in "*Poa* control." Nonetheless, AB almost always invades and usually becomes a significant component of the putting green turf population. Given the fact that annual bluegrass is a significant component in the greens at most older courses, it's a wonder why anyone would want to keep it out in the first place. Plenty of golfers like to play on *Poa annua* greens (some wax on about the putting quality of *Poa* putting surfaces), so what is all the fuss about?

When *Poa annua* greens are good, they are great, but when they are bad, they are producing seedheads or they are dead. Annual bluegrass is very susceptible to many turfgrass diseases and to winter injury (common in the Northeast). AB can be kept alive during many years, but there are weather patterns that virtually guarantee widespread loss of AB. Anthracnose and summer patch are two of the most damaging and most common diseases of AB, and the annual bluegrass weevil is an insect pest that is nearly exclusive to AB.

Annual bluegrass has many disadvantages when compared to creeping bentgrass (CB), but it has two distinct advantages: annual bluegrass is more wear tolerant and is a more efficient user of light. Thus, in low-light and high-wear situations, annual bluegrass may actually be the better-adapted species when compared to CB.

There literally are thousands of different biotypes of AB, and some are very desirable because they have fine texture, excellent wear tolerance, and are tolerant of the stresses associated with prolonged low mowing. There also are many undesirable biotypes. These typically produce the most seedheads, are the least tolerant of stress and disease, and may be true annuals. These are the types that fail most often and are the types that typically invade putting greens first.

Annual bluegrass encroachment into a new bentgrass putting green has significant consequences. Initially, it may go unnoticed because at first just individual plants become established. These form small, dime-sized patches, but they become increasingly obvious and disruptive as they expand. AB patches are most noticeable in spring due to their prolific seedhead production, and this is when the effect on putting quality is greatest. AB also is more visible in fall when CB is more off color. During the prime playing months, AB usually blends in better with CB, and putting quality can be perfectly acceptable.

Natural selection works for courses that can keep AB alive. Over time, the weaker, less desirable biotypes are gradually replaced with finer-textured, more stress-tolerant biotypes that are more hardy and attractive. The appearance of a new green suffers when AB begins to colonize it, as the ever-increasing number and size of the AB patches cause them to become more obvious in the bentgrass background. The AB and CB eventually coalesce into a homogeneous blend of the two grasses, but this may take eight to ten years or more from the initial planting. Some courses, particularly older courses that are rebuilding one or two greens, purposely plant new greens to a mixture of CB and AB to maintain consistency with the older greens, and doing so eliminates the troublesome colonization phase. For some, AB is a noxious weed, but for others it is the species of choice.

It should be noted that a green is comprised of millions of individual plants, and when two species (or more) are present, there can be significant fluctuations in their populations. For instance, AB out-competes CB in the spring and fall, and CB out-competes AB during the sum-

Annual bluegrass first colonizes a putting green as individual plants that can be nearly invisible. The plants expand into small patches that can become very obvious and unattractive, and they can disrupt surface smoothness.

mer months. The vast majority of greens in the Northeast Region are two-grass systems.

ENVIRONMENT

The environment a putting green occupies has a greater impact on its performance than any other factor, bar none. Simply put: a perfectly built green with the best grasses will perform poorly in a poor grass-growing environment. Conversely, a marginally built green may perform adequately in a very good growing environment. So what constitutes a good or bad environment? Simple: sunlight and air circulation. There are products and practices that can help improve the performance of turf that is grown in a poor environment, but none can overcome the effects completely.

Shaded, pocketed environments produce weaker turf with reduced vigor and recuperative potential; also, disease pressure is greater as a result of the higher relative humidity. Poor environments produce weaker, more disease-prone turf that is more susceptible to stress, wear injury, and disease. Furthermore, when problems do occur, recovery is slower due to the lack of vigor. The growing environment also has a huge impact on natural selection. The advantages AB has over bentgrass already have been mentioned, but they are especially significant in a poor growing environment. CB has a high light requirement and does not perform as well in moist, low-light environments. AB is much better adapted to this type of environment and generally outperforms CB in shady, pocketed environments. It is virtually impossible to prevent AB encroachment in a bentgrass green that is located in a poor growing environment.

The comments regarding the significance of the growing environment are not made to discount the importance of proper construction; they are made to emphasize the importance of providing a good grass growing environment for the turf.

CONTOURS

The surface contours of a putting green, when initially constructed, sometimes are a bit too sharp, and this can make it difficult to mow without scalping the turf at the typical low heights of cut. Surface imperfections often limit how low a new green can be cut, and it may not be possible to lower cutting heights to the eventual target height until the green has been rolled, topdressed, and/or aerated repeatedly. Fortunately, the surfaces soften slightly by way of settling, combined with these practices.

On the other hand, sand blasted out of a heavily used bunker can build up the grade of a greenside bank. Initially, this may create more definition and interest, but a number of problems can occur if the buildup becomes extreme:

- The soil on the bunker bank becomes extremely droughty due to the sand buildup and is incapable of supporting healthy turf. This may eventually lead to turf failure and even to a structural breakdown of the bank.
- The buildup occurs primarily on the bunker banks, but when the bunker is close to the

Environmental conditions determine which grass will thrive. In this situation, *Poa annua* is more dominant on the lower portions of the green, which have inadequate drainage and greater traffic. The bentgrass is thriving around the perimeter areas of the green.

putting surface, the buildup can extend into the green, altering the surface contours on the putting green. The change can be minor or so severe that hole locations are lost. The buildup also may block surface drainage, increasing the potential for turf problems due to disease, winter injury, etc.

Some change in the contours of greens likely happens over time as a result of cultivation and topdressing practices, but the changes are so subtle that the human eye could not possibly notice it. Given the number of 100-year-old courses that still have severely contoured putting greens, the change must be very minor, indeed.

THE SHAPE OF THE GREEN

Greens often get smaller over time, and irregularly shaped greens frequently become more rounded. The amount of putting surface that can be lost over a long period of time can be tremendous. Unless extreme care is taken, greens on courses more than 10 to 20 years in age usually experience significant changes in their shape. It is rare to find an older course (50 years plus) that does not have significant loss of hole locations.

Loss of cupping area can have an enormous impact on a putting green from both the playability and turf management points of view. Smaller putting surfaces mean that more traffic is being concentrated on less area, and obviously that can cause wear problems. Shrunken greens also may play very differently than they were intended to play. Smaller putting surfaces mean they are farther from the hazards that were designed to guard them. Smaller greens also may not be as receptive to the type of shot called for in the original design of the hole. Perhaps most important of all, golfers are cheated out of playing to challenging hole locations envisioned by the architect in the original design, and this reduces options, strategy, and challenge. Most older courses can be improved significantly by expanding greens back to their original shape, and while this type of project may require plenty of labor and planning, it does not have to cost a lot of money.

DRAINAGE

Rigorous testing should be performed on the components a green is to be built from before construction begins in order to ensure the green will function properly. It is not enough just to make sure that the rootzone mix meets the USGA Putting Green Construction Guidelines. They also must be appropriate for your specific geographic area and project. The infiltration test is one of many that provide guidance in rootzone mix selection. According to the USGA Guidelines, a rootzone mix for a putting green should drain at least 6 inches per hour, but some mixes may drain in the range of 10 or 20 inches per hour or more. Regardless of what the initial infiltration number is, this number will drop by as much as 70% or 80% in the top few inches of the green, where the majority of the organic matter develops. While this may be surprising, it is not necessarily cause for concern. However, it does illustrate the importance of proper management of the thatch layer. If thatch is not managed properly, the infiltration rate at the surface of the green may drop dangerously low, thereby contributing to all of the problems previously described under thatch management.

Assuming the initial rootzone mix selected was appropriate and it is properly managed, its drainage properties should remain adequate indefinitely.

CONCLUSION

This article may spur many questions regarding the different subjects covered. A number of related articles are listed in the bibliography, and these will be appropriate reading for anyone interested in delving deeper into some of the topics touched on here.

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DAVE OATIS *has evolved into the director of the Green Section's Northeast Region.*

Although few sand greens still exist in the United States, they were much more prevalent in the early years of golf (Sag Harbor Golf Club, New York).

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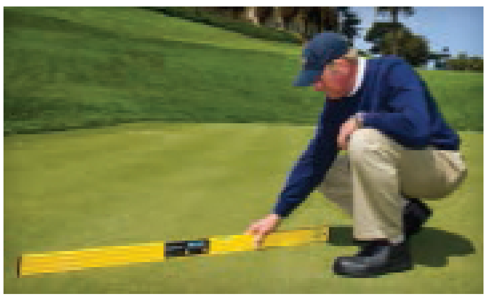

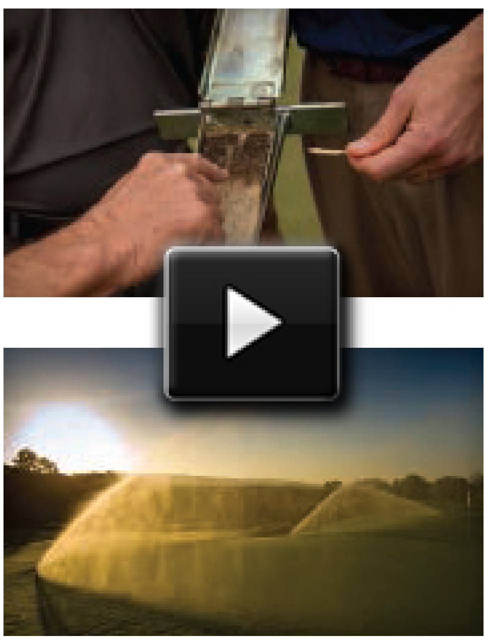

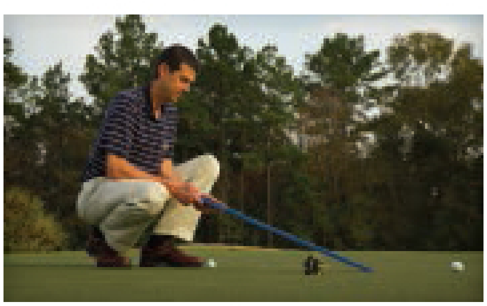

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Rebuild or Resurface

Greens must be rebuilt every 15 to 20 years, even those of USGA method construction – or do they?

BY BUD WHITE

The architect has completed the green complex reconstruction plans, including the long-range plan for the entire golf course. The grass variety has been chosen for the putting surfaces. A high-quality sand has been identified and the rootzone mix has been evaluated by an accredited lab. Bids have been put out and returned, and a contractor has been selected. Rebuilding the greens will cost $655,000, and they will be closed for about nine to ten months.

Many courses have undergone this process, but in this case, did the course officials consider resurfacing instead of rebuilding? This is a fair question, and resurfacing may be a feasible alternative.

Nearly all golf courses eventually face the decision of renovating greens to improve playability and agronomic performance. Many courses today are confronted with this dilemma, even with 10- to 20-year-old greens built to USGA guidelines. A resurfacing option may be available for these courses, costing as little as 20% of the cost of total rebuilding. Although total reconstruction is often the mindset, it is not always necessary.

Research has shown that greens built to the USGA method maintain their original integrity below about the 4-inch depth many years after construction. It is the upper 3- to 4-inch zone that undergoes a drastic change in composition in the field with age. An increase in silt and clay from topdressing, wind movement, or sometimes through dissolved solids in irrigation water, creates this change in the upper zone. Organic matter (OM) buildup, however, is the primary effect that leads to poor infiltration, a tendency for black layer, increased algae on the surface,

Careful observation and testing are needed to determine whether a green must be rebuilt or only resurfaced.

poor rooting, an affinity for localized dry spot (LDS), and soft playing surfaces. This zone also can remain quite wet because organic matter increases water-holding capacity. This problem is located in the top 4 inches of the green and is not a profile/drainage system problem. If the greens were originally built to USGA specifications and were properly managed over the years, the surface layer can be replaced or modified to put the putting green system back into as-good-as-new working order.

How is the "rebuild vs. resurface" decision made? This step-by-step decision-making process includes:

- Digging test holes in greens to evaluate the integrity of the drainage system and profile.
- Correctly taking undisturbed soil cores.
- Sending sand samples from several sources to the lab along with the cores.
- Utilizing lab services to evaluate undisturbed soil cores.
- Deciding on a surface renovation procedure.

WHERE TO START

Resurfacing is a very effective option for courses that have older greens built to either USGA or California specifications. A scientific and systematic testing process is essential to ensure that your greens are candidates for successful resurfacing with long-term benefits. For poorly built greens, resurfacing alone is a temporary or *Band-Aid* approach, but it can improve performance for three to five years. Some courses have utilized this approach to improve the greens temporarily and optimize time to raise money and develop a long-range plan before spending reconstruction dollars.

As mentioned earlier, many golf courses with well-built older greens find that the rootzone mix below the 3- to 4-inch upper zone still functions the same as when it was installed, but that upper 3 to 4 inches becomes unacceptable over time. When the lower portion of the rootzone is tested by an accredited lab and found to be within specifications and when the drainage system is

Deciding whether to rebuild or resurface a green should be based on several steps. One is to evaluate the integrity of the drainage system. Here, a test hole was dug on the high side of the putting green and water was added directly to the gravel blanket.

intact, the club can choose the option of green resurfacing instead of full renovation to restore the greens back to their original condition.

This explains why rigorous aerification and topdressing is so vital to the health and life of turf and greens. Properly done, aerification can lengthen the *useful* life and performance of a green. The newer bentgrass and bermudagrass putting green grasses produce substantially more thatch and require more aeration. When organic matter accumulation becomes unmanageable, resurfacing or reconstruction is necessary.

During the renovation decision process, it is important that greens be evaluated for external growing conditions, because reconstruction alone will not solve a problem such as poor air circulation or excessive shade. The *Green Section Record* article "Helping Your Greens Make the Grade," by Jim Moore, March/April 1998, which can be accessed online at http://www.usga.org/turf/-articles/construction/greens/make the grade.html, is an excellent scorecard that should be utilized on difficult green sites to make sure all external factors are addressed. An important factor is the adequacy of the greens' irrigation system, which often is lacking.

Detailed testing is an essential investment in time and lab costs to ensure successful renovation. This procedure monitors the aging process of the roootzone and evaluates the effectiveness of the aerification and topdressing program. Test holes dug in existing greens can measure the function of the gravel blanket and check water flow through the drainage system. This also helps locate the exhaust end of the drainage system if all outlets have not been found.

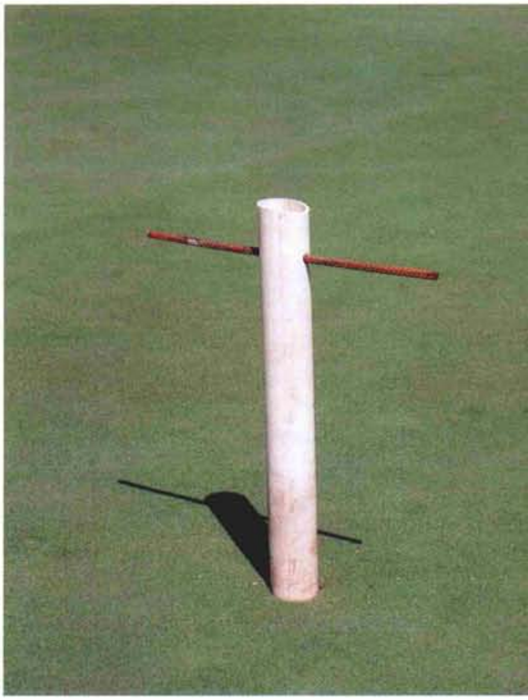
It is best to dig this test pit in the high side of a green so the cleanliness of the gravel blanket can be checked as water works its way through the gravel blanket, into the drain system, and eventually out of the drain outfall pipe.

LAB WORKS

Undisturbed soil core samples are taken by driving a 3-inch PVC pipe through the green profile and gravel blanket and into the subgrade. To remove the core, drill holes in the top of the pipe, put a piece of rebar through the holes, and pull the pipe out of the green. The pipe is then sealed on both ends and sent to an accredited lab for an undisturbed core evaluation. The lab will test the profile as it exists in the field, as well as the upper 3 to 4 inches and the lower 4 to 12 inches. The results help determine if the green profile is functioning properly and if it still meets guidelines below a certain depth. This is an excellent test for tracking the aging process of greens.

Along with the undisturbed core samples, the superintendent must send a sample of the sand expected to be used for the resurfacing. Ideally, the sand source will be the same one used when the greens were constructed, but this is often not the case. If there are questions about sand quality, or if a course is shopping for different sand sources for price, then multiple samples can be sent to the lab for evaluation. A gallon of each sand should be sent, along with a letter of explanation regarding your resurfacing plan. Contact the lab director prior to sending the samples so he/she is aware of your project, and provide some history and background to assist with the evaluation process. The lab will also provide sampling recommendations and shipping details.

The proper procedure for sampling sand, as for any rootzone or topdressing material, is detailed in the "Quality Control Sampling" brochure, available through your USGA Green Section office. Good quality control is essential for establishing the initial sand quality, and regular monitoring must be carried out as loads are delivered throughout the renovation process.



Undisturbed soil core samples help determine 1) if the green profile is functioning properly, 2) if it still meets guidelines below a certain depth, and 3) effects of the aging process. Cores are taken by driving a 3" PVC pipe through the green profile and gravel blanket and into the subgrade. The undisturbed core is sent to a lab for analysis.

GREEN REDESIGN

In the past, it was common for architects to utilize the rootzone mix instead of the sub-base for surface contour design. This practice does not adhere to the USGA method for construction, which requires that the sub-base mirror the finish grade contour and the rootzone be a consistent 12" ± 1" in depth. Therefore, rootzone depth validation should be conducted with probes to ensure a uniform rootzone depth. Only very minor modifications, if any, can be made to soften contours when resurfacing. If the golfers are happy with the existing contouring, then the upper 3 to 4 inches of the rootzone mix can be removed and a sand or mixture should be applied, making sure it is compatible with the existing rootzone mix. Rototilling may or may not be utilized (discussed

Over time, golf course greens change composition in the upper profile. The new profile (above) is from an eight-month-old green that was rototilled and resurfaced. The aged profile (right) shows the aeration history in the profile of a 12-year-old green.

later). The surface is then firmed, floated (smoothed), sterilized, and replanted.

The recommended standard today is a maximum of 3% slope on putting surfaces that will be maintained at a green speed approaching 10 feet as measured by the Stimpmeter.® A high percentage of older greens are too severe in slope and contouring for the increased speed demands of today's golfers. Existing slopes must be carefully evaluated and measured to stay within this guideline if at all possible. Severe slopes and faster greens are a recipe for disaster.

DECIDING ON A PROCEDURE

There are several ways to proceed with a resurfacing project.

- Thoroughly core aerate prior to sod removal and fill the holes with the replacement sand. Many superintendents double or triple aerate. Then, remove the sod to the 2- to 2½-inch depth, fill the void with the replacement sand, and float the green. Sterilization, final smoothing, and replanting complete the resurfacing. Deep-tine aeration or drill-and-fill can be utilized to penetrate the entire zone to more thoroughly eliminate deep layering. Sand is introduced 8 to 10 inches into the profile, versus 3 to 4 inches by conventional aeration only.

- The above procedure has also been utilized when resodding greens. Ideally, the sod is cut as thick as possible to remove more of the organic mat layer. Coordination with the sod producer is essential to ensure that the new sod is cut at the same depth as the sod being removed. After sod removal, the surface is lightly raked for smoothness, sterilized, and the new sod is installed.
- Remove the organic layer 2 to 4 inches deep, depending on the depth of the OM accumulation, and fill the created void with the replacement sand. The profile is tilled 6 inches deep to eliminate any layering that may still exist. This can be done quite effectively and uniformly by removing the upper 4 inches, followed by installing the replacement sand, rototilling the green in multiple directions approximately 6 inches deep, refloating, and firming. The new surface can then be inspected by the architect before planting to insure that the original contours are maintained.

Special Note: The turf on the collar should also be removed as part of the renovation. Sterilizing the collar provides a buffer for keeping *Poa annua*, bermudagrass, or other offensive grasses out of the green. The collar is also used as a transition, or tie-in, to the green surrounds and should be as seamless as possible. This cannot be done at the green edge.

As noted earlier, not all greens need to be rototilled. Many green renovation projects have been successful with thorough aeration prior to sod removal, topdressing to fill the holes, removing the sod, and reinstalling the replacement sand or sod without any disturbance to the profile below the sod layer. Light hand raking prior to new sod installation is needed, of course. Aeration must be deep enough, however, to completely

The collar should be included with putting green resurfacing to maintain green purity and a seamless tie-in to the surrounds.

reach through the layer of OM buildup. The OM depth depends on the age of the green, cultural management practices, and the growing environment, all of which can affect the rate of accumulation.

When an area is rototilled, firming and floating procedures must be implemented to prepare the seedbed for planting. Green contours can be lost without careful rototilling procedures, and new surfaces should be inspected and approved by the architect prior to planting.

Consequently, the best method for preserving contours will have to be considered on an individual basis. Both of these methods, rototilling or not rototilling, can be successful. The lab can assist with recommendations about which method might be better for your greens based on the test performance of the undisturbed soil cores.

Firming and floating the finished product is a critical part of the renovation process, just as it is with new construction. Thorough applications of water are needed to maintain good soil moisture while firming and floating. Many courses contract this work out, as a quality golf course contractor is knowledgeable about the best procedures for firming and floating greens. If this work is done in-house, it is important for the superintendent to pay careful attention to preparing a firm and smooth seedbed.

A good rule of thumb is to firm and float the seedbed until the average-size person can walk across the green without leaving a footprint greater than ¼-inch deep. Again, watering must be included in the process to achieve appropriate firmness. To reiterate, collars must be included in the sterilization process. This also allows *Poa annua* and/or bermudagrass to be cleared from the collar to prolong a weed-free putting surface.

Total renovation is not the only alternative for improving green quality. Scientific and dependable methods are available to evaluate older, yet well built, greens to determine the quality of existing construction. Resurfacing has not been used frequently in the past, but many courses save 70% to 80% of what it would cost for complete reconstruction.

Moreover, the anticipated nine- to ten-month downtime is substantially reduced to four or five months, on average, due to the greatly reduced scope of work. This can significantly reduce revenue loss and golfer inconvenience. Your regional USGA Green Section staff agronomist can help any golf course work through this evaluation process and assist with quality control procedures during testing and renovation. Knowing the construction quality of your greens and researching renovation alternatives with an accredited lab could save your course money and downtime, and create much improved putting surfaces.

Green contours can be lost without careful rototilling procedures. One method is to leave sod strips during rototilling and sand replacement to help maintain the contour details.

BUD WHITE *is a senior agronomist in the Green Section's Mid-Continent Region.*

COMPLETE RECONSTRUCTION OR PARTIAL RENOVATION

How should you invest your money?

BY PAUL VERMEULEN AND CHARLES "BUD" WHITE

Once hidden in the shadowy recesses of densely planted trees, dozens of classic golf courses built during the early 1900s have undergone extensive restoration to regain their prominence with the American golfer. Notably, the North Course at Olympia Fields Country Club underwent a complete facelift and thus was able to successfully challenge the greatest players in the world during the 2003 United States Open.

In many cases, the restoration of an architectural masterpiece designed by the likes of Willie Park, Jr., requires rebuilding one or more of the greens, or, at a minimum, updating the putting surfaces with a new turf variety. This work acknowledges the fact that maintaining fast, firm putting surfaces expected by today's golfers requires large, well-drained greens established with turf capable of being continually mowed at an eighth of an inch.

To determine if the scope of a restoration project should include the complete reconstruction of all 18 greens or simply some sort of partial renovation requires in-depth design, rootzone, and site analyses. Without giving equal consideration to all three, it would be impossible for the ownership of an older course to make a sound investment in their future.

DESIGN ANALYSIS

As a starting point, the fundamental design of each individual green must be examined with a critical eye. And, as judging putting green design so often includes an overall evaluation of artistic merit, it is always best to solicit the assistance of a knowledgeable golf course architect.

Key elements of design that should be taken into account in the analysis of putting greens are traffic distribution, playability, and surface drainage. Combined, these elements can have a profound effect on both the enjoyment of a round of golf and a superintendent's ability to maintain high-quality turf conditions throughout an entire growing season.

To help determine the cause of a problem green, the rootzone and drainage should be thoroughly examined. Digging one or more inspection holes or removing deep soil cores with a soil probe allows you to look for signs of trouble in the soil profile.

To gain an appreciation for traffic distribution, or, more accurately, how well the wear and tear of normal golfing activities can be dispersed across the surface of a green, it is necessary to count the number of hole locations. Generally speaking, a hole location is a circular area of approximately 250 to 300 square feet with a slope of less than 3%. Courses with a high volume of play should have eight to ten hole locations per green, whereas those with a low volume of play need only six to eight. It is time to start thinking about complete reconstruction when the number of hole locations drops below five.

Judging a green's playability can be very complicated because it requires an interpretation of what is fair or equitable. Nonetheless, as anyone who plays golf knows, when a well-struck putt will not come to rest within a few feet of the hole because of severe contours in the putting surface, the game becomes a great source of frustration rather than fun. This point was certainly well illustrated during the 1998 United States Open at The Olympic Club when Payne Stewart's putt barely missed the hole on the 18th

Water standing in a hole for several hours after a heavy rainfall is a clear indication that a green is an excellent candidate for reconstruction or, at a minimum, new drainpipe installation. In this particular case, it also is noteworthy that the voids created by deep-tine aeration with large solid tines failed to improve subsurface drainage.

green and then rolled back in his direction an additional 20 feet. The fact that many older greens need to be redesigned with less severe contouring can be traced back to several technological advancements that have increased the average Stimpmeter reading during the last 25 years.

Surface drainage, it is said, can never be good enough. In an ideal sense, every green on the course should be designed to shed surface water in at least three directions during heavy rainfall. Due to the overall lay of the land at most sites, however, designing a course to meet this lofty goal is often impossible. The point at which surface drainage typically becomes a serious issue is when 1) the entire putting surface drains toward the front, 2) the putting surface has water-holding hollows, or 3) a large watershed in an adjacent rough area drains directly onto the putting surface.

ROOTZONE ANALYSIS

Analyzing the rootzone for problems should include testing the physical characteristics of the soil and reviewing exactly how a green was built. Testing the physical characteristics of the soil essentially requires submitting an intact core sample for laboratory analysis. Obtaining an intact core sample from a green is as easy as driving a short section of 2" plastic pipe all the way into the surface and then carefully removing it in a manner that prevents soil from falling out the open end. After the sample has been taken, it can be sent to one of several accredited physical soil testing laboratories located throughout the country.

Laboratory testing will determine a number of physical parameters, such as soil type, sand particle size distribution, organic matter content, and porosity. Caution should be exercised, however, when interpreting the test results from soil-based greens. Case in point, if the results from a soil-based green are judged using the specifications for a modern, sand-based green, one can falsely conclude that complete reconstruction is an absolute necessity due to low infiltration and porosity measurements. At most, test results should be used to support other evidence of a green's candidacy for complete reconstruction and not serve as the sole indicator of severe problems.

A visual examination of the rootzone should be performed by digging one or more inspection holes in the surface of a green or by removing several deep soil cores with a standard probe. Common signs of trouble would include such items as layering in the soil profile, inconsistent blending of soil amendments, uneven soil depth, black layer development, compaction, and poor root development.

A thorough visual examination should also include an inspection of the drainage system underneath the rootzone. For greens that were built with a gravel layer, the drainage system can be checked by running water through a ¾" hose into an inspection hole on the high side of a green. If water starts flowing out of the outlet pipe at the low side of the green after 20 to 30 minutes, it suggests that the drainage system is working properly. To be absolutely certain that all of the pipe underneath a green is still functioning, a fiber optic video camera can be used to check the drainage system.

SITE ANALYSIS

In the real estate business, the fundamental law of property value is location, location, location. In the golf course business, location is of equal importance to the laws of successful putting green management. In short, premium sites for putting green management all have two things in common — excellent sunlight exposure and unobstructed air circulation.

Sunlight exposure is pivotal to the management of low-cut turf because it is literally the driving force of photosynthesis. This biological process is responsible for converting carbon dioxide and water into life-sustaining complex carbohydrates. The take-home message regarding sunlight exposure is simply that, if an older green has sparse turf

While some critics of classical golf course restoration might disagree, updating older greens with modern restoration techniques is a great way to invest in the future of the game.

cover because it is in a shady location, there is no reason to consider either complete reconstruction or partial renovation because the result will simply be a disappointing reflection of the green's current condition.

The best approach for making an accurate evaluation of sunlight exposure on a problem green is to have the surrounding trees or other obstacles measured by a landscape surveyor. This information can then be entered into computer software and used to project the total hours of full sunlight exposure on any given day of the year.

The role of air circulation in turf management is admittedly more important in warmer regions of the country. This is because a current of air flowing across the surface of a green has a cooling effect. In warmer regions, this cooling effect can reduce the turf's canopy temperature on hot afternoons by as much as 15°F. If a problem green is situated in a stagnant location, restoring it without improving air circulation should not be attempted.

Based on the findings of design, rootzone, and site analyses, making the right financial decision regarding whether to completely reconstruct all 18 greens or opt for some degree of partial renovation should be much more straightforward. While some critics of classical golf course restoration might disagree, updating older greens with modern restoration techniques is a great way to invest in the future of the game.

PAUL VERMEULEN *and* BUD WHITE *are responsible for making Turf Advisory Service visits in the Mid-Continent Region. During the past few years, they have worked with multiple superintendents who have undertaken complete restorations.*

If the root cause of poor subsurface drainage in older greens is the malfunction or complete absence of drain tile, then the installation of new drainpipe by an experienced contractor can set the stage for making future improvements.

Made in the Shade or Mud in the Shade?

Sunlight assessment is a key to success with ultradwarf bermudagrasses.

BY CHRIS HARTWIGER

Trees and turfgrass are like brothers. Give them ample space to grow and they get along just fine. Put them together in a small bedroom and the bigger one is going to dominate. Just like finding a proper distance between brothers is a key to harmony, trees and turf must have adequate space, too. If they are too close together, the trees will out-compete turfgrass for growth-related resources like sunlight, water, and nutrients. Spaced appropriately, trees and turf will get along just fine, too. Ultimately, finding the proper distance to allow both trees and turf to flourish is an agronomic challenge on many golf courses.

In the Southeast Region, most golf courses have identified and corrected shade problems through trial and error. This could be called "after the fact" or "reactive" shade management. It typically works this way. Certain putting greens on a given course develop poor turf quality over a period of years. Shade is identified as a limiting factor. Protests about protecting the trees ensue. The protesters eventually capitulate under the weight of factual evidence and the desire to have acceptable turf quality on the putting greens. Trees are removed, and turf quality on the putting greens improves. All in all, this model has worked well, and today many golf courses have dealt with their shade issues.

The recent trend in the Southeast to replace creeping bentgrass on putting greens with an ultradwarf bermudagrass does not lend itself to an "after the fact" or "reactive" shade management program because ultradwarfs do not tolerate shade well. A "before the fact" or "proactive" shade management program is desired because officials at courses want to know if their putting greens receive enough sunlight to sustain an ultradwarf bermudagrass.

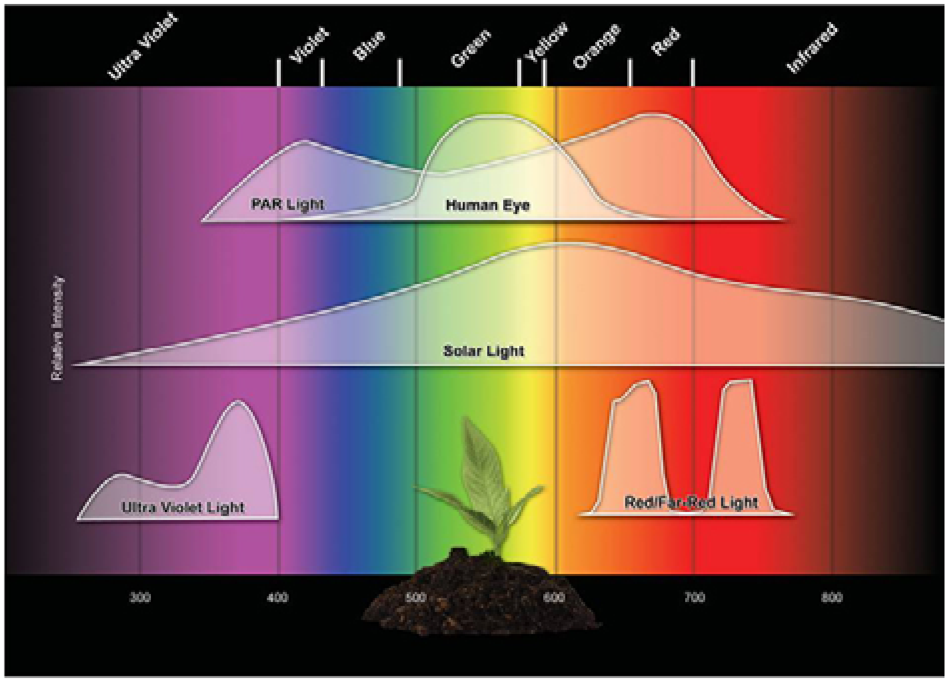


Figure 1: Ranges of light absorption for photosynthesis in plants. Note that the area where visible light for humans is greatest, it is of least value to plants. Therefore, light levels detected by the eye are not a good predictor of light levels used by plants for photosynthesis.

This article will help golf courses assess shade levels on their putting greens prior to a conversion from bentgrass to an ultradwarf. Golf courses with an ultradwarf presently will be able to use this information in case there is a need to address existing shade problems. In this article, some basics of plant physiology are reviewed, and important terms that will be used during site assessment are defined. Practical tips for proactively addressing shade will be presented.

HOW PLANTS GROW

Plant growth is a highly complex and ordered process. Plant growth requires energy, and the source of that energy is the sun. Light is the mechanism for energy transfer from the sun to the plant. The term irradiance (radiant energy) refers to the energy received on a specified surface, or, in our case, on the plant's leaf (Beard, 2002). Turfgrass plants receive the sun's energy via tiny particles called photons. The plant converts the radiant energy it receives into chemical energy through the process of photosynthesis.

Turfgrass plants are selective about the type of light (solar radiation) they require for plant growth. They absorb the bulk of their energy in the visible light range (400 to 700 nm) of the electromagnetic spectrum. This range is referred to as photosynthetically active radiation (PAR). Plant pigments such as chlorophyll molecules each

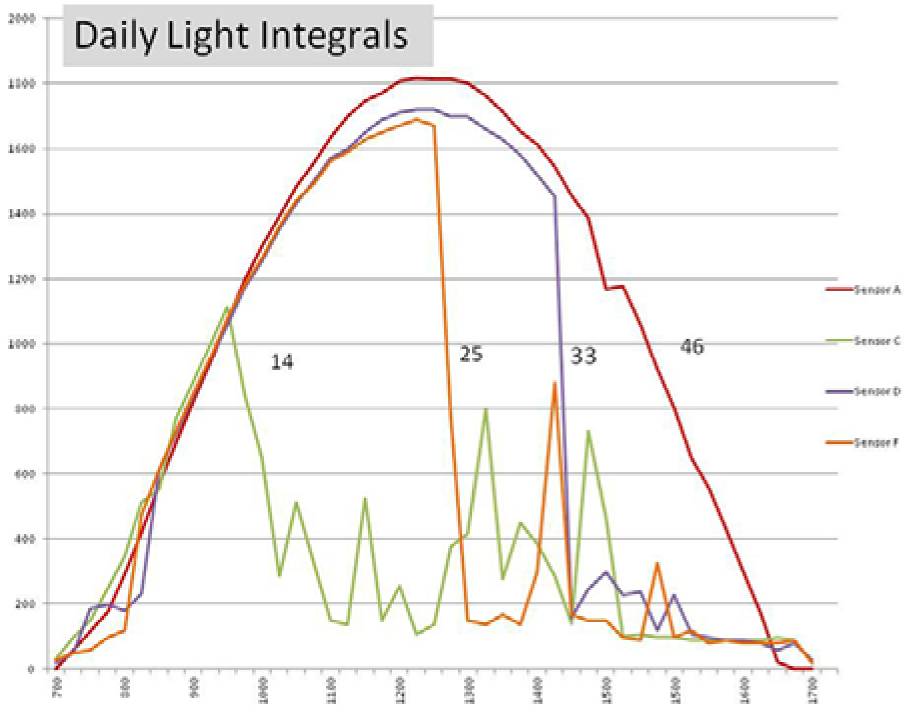


Figure 2: A DLI (daily light integral) is a measure of the total amount of photosynthetically active radiation (PAR) a given area receives in a single day. This graph shows the DLI measure by four different sensors. Note how each DLI curve changes throughout the day, with the highest levels achieved at solar noon. Sharp drop-offs or changes in the curve are caused by shade from trees.

have optimum absorption ranges. PAR in the ranges of 400-500 nm (blue light) and 600-700 nm (red light) is the most important for plant growth. PAR in the range of 500-600 nm (green light) is basically inactive for plant growth (Bell, Danneberger, and McMahon, 2000). The human eye detects light best at about 550 nm. Therefore, the light the human eye is good at detecting is the light that has no value for plant growth. For a graphical look at ranges of light absorption for plants, refer to Figure 1.

LIGHT QUALITY

Light particles (photons) have different energy levels as determined by their individual wavelengths. Light quality refers to the spectral distribution of light, or the relative number of photons in each portion of the light spectrum (visible and invisible) emitted from a light source.

Outside, the different shade sources have different effects on light quality in terms of plant growth. Shade from clouds and shade cloths in research are considered to be spectrum-neutral. They filter out all wavelengths of light equally. Shade from trees is not spectrum-neutral, and it changes the ratio of blue light to red light, which can affect plant growth. There have been conflicting research data regarding differences to turfgrass growth between deciduous and conifer induced shade, but research on turfgrass at Ohio State University showed no difference in spectrum response between deciduous and coniferous trees (Bell, Danneberger, and McMahon, 2000). This article will not resolve this conflict, so for the purpose of this article, no distinction is made between different types of trees and their impact on light quality.

LIGHT QUANTITY

Given that trees are the most common means of shade on golf courses, the quantity of light becomes the most pressing question. It would be nice if shade could be evaluated strictly in terms of the number of hours of direct sunlight needed, but that would assume that in terms of plant growth, the PAR for one hour of sunlight is constant throughout the day. Practically speaking, this would imply that one hour of sunlight between 7 and 8 am is equivalent to an hour between 12 and 1 pm. Unfortunately, one hour of direct sun between 7 and 8 am has much less PAR than an hour of sun between 12 and 1 pm. Therefore, a method to measure PAR over the course of an entire day is needed rather than a method to measure PAR at any given moment.

Scientists measure PAR as the number of photons striking a square meter every second. This measurement is sometimes referred to as the Photosynthetic Photon Flux Density, and the units to express the intensity of PAR light are micromoles per square meter per second. For the purposes of measuring the total amount of PAR an area receives in a 24-hour period, scientists use the term Daily Light Integral (DLI). The DLI is expressed as the number of moles of PAR per square meter per day. Figure 2 shows an example of DLI for a clear summer day with no shade. Note how PAR peaks in the early afternoon and is substantially lower in the hours just after sunrise and just before sunset. PAR will peak at your location at solar noon, which is defined as the time when the sun reaches its highest point and crosses the meridian. Depending on the time of year, solar noon can occur before or after 12 noon. More details on solar noon can be found at http://www.sundials.co.uk/equation.htm.

Dr. Todd Bunnell and Dr. Bert McCarty identified in a research project at Clemson University that a Daily Light Integral of 32.6 was needed for TifEagle bermudagrass to provide an acceptable level of quality. Practically speaking, Bunnell and McCarty recommend eight to ten hours of sunlight for TifEagle bermudagrass in Clemson, S.C. (Bunnell and McCarty, 2004a). Four of those hours should be between approximately 11 am to 3 pm, when PAR levels are highest. This is excellent information to know when assessing sunlight levels.

Bunnell and McCarty continued shade-related research and examined the effect of the plant growth regulator Primo, mowing height, and nitrogen rate on TifEagle bermudagrass grown

Shade from trees surrounding a putting green vary throughout the year due to the changing angle of the sun. The quantity of light for plant growth not only changes based upon shade, but on the time of day.

under varying levels of shade. They found that plots with four hours of sun (12 noon to 4 pm), applications of Primo, and a 3/16" height of cut, produced acceptable turf quality at a DLI of 22.1. These researchers concluded, "Therefore, applying a plant growth regulator that inhibits gibberellic acid and raising mowing heights will improve the growth, quality, and performance of ultradwarf bermudagrass greens in shade (Bunnell and McCarty, 2004b)."

MEASURING DAILY LIGHT INTEGRALS

With a solid background now established in light terminology and more confidence in how much light an ultradwarf needs, attention can shift to measuring sunlight levels on a golf putting green.

Equipment Needed. The first step in assessing shade levels is to identify the Daily Light Integral on the area in question. This can be done through the acquisition of both a light sensor and a meter to read the light sensor. A popular sensor model contains a row of three to six sensors and comes with detailed instructions for use. Based on 2011 prices, the cost is approximately $600 - $650. Other less-expensive light sensors can be purchased for several hundred dollars, but these meters may only express DLI within a range, not as a specific number. Spectrum Technologies (Plainfield, Ill.) is a company with many available choices that would work well in determining the DLI on a putting green.

WHEN TO TAKE MEASUREMENTS

Summer: The Clemson studies were conducted over two years, and data were collected between late June and mid-August. During this time of year, bermudagrass is producing the greatest quantity of vegetative growth, so it makes sense to assess shade levels for the purpose of growing acceptable ultradwarf turf. Use the light sensor to take measurements sometime between mid June and early August. Because the light sensor will need to be at a given location all day long, there may be interference with play, even though the actual sensor is less than 18 inches long. Make plans to communicate where the sensor is, and make a local rule to deal with any interference.

Spring and Fall: Consider taking measurements in spring and fall, also. These are times of the year when metabolic changes are occurring within the plant in response to day length and temperature. Although plant physiologists have quantified that changes do occur in the plant at these times of year, there is minimal research that quantifies minimum levels of sunlight necessary for adequate long-term growth. We do know that as day-length decreases and temperatures decrease, the plant begins to store carbohydrates that ultimately will be used during greenup the following spring. Therefore, shade in the fall may have an effect on winter survival and spring green-up.

Conversely, sunlight levels in the spring will have an impact on soil temperature and spring green-up, too. It stands to reason that areas receiving less sunlight may be slower to green-up in the spring months. Superintendents have aided the green-up process by increasing canopy temperature through the application of turf paints or dyes and green or black topdressing.

Taking a few measurements during fall and spring will help identify shaded areas. Because we do not have a recommended minimum DLI for the fall, determining acceptable shade levels in the fall will be a judgment call.

Planting trees too close to a putting green can result, years later, in levels of shade that hinder turfgrass growth, particularly ultradwarf bermudagrasses.

WHERE TO TAKE MEASUREMENTS

A golf course superintendent can identify the putting greens that historically have battled issues caused by shade. It is common on some greens that there is only a small corner or area that may receive more shade than other parts of the green. It is a good idea to take two or three measurements on a putting green to assess both the highest and lowest levels of shade on a putting green.

If someone is interested in determining the percent shade that a putting green receives, it will be necessary to also take a DLI reading on any area in full sun. To determine the percentage of shade, use the following equation.

$$\% \text{ Sun} = \frac{\text{DLI of Shady Location}}{\text{DLI of Sunny Location}} \times 100$$

$$\% \text{ Shade} = 100 - \% \text{ Sun}$$

A word of caution is in order — when determining the percentage shade, be sure to take the DLI measurements for both areas on the same day. Try to pick a day with full sun and minimal clouds. Cloud cover can and does impact DLI, so if data were taken on two different days, results could be skewed.

How many measurements to take? This is a judgment call on the part of the end user. The Clemson study took data for almost two months and had the ability to take an average of all those days. At the local level, it would be a good idea to record data on several days that one would consider to be sunny or a typical summer day. A typical summer day in the Southeast would be one with clear skies in the morning and some isolated clouds in the afternoon. Please note that in the Bunnell and McCarty study the two-year DLI for plots in full sun was 41.6, with a maximum DLI reading of 52.1.

Is it necessary to measure every putting green? Probably not. Start first

Because shade levels vary throughout a putting green, it is important to measure light levels at different locations on a given putting green.

with the putting greens most influenced by shade. Generally, there are two or three greens that cause the most concern. Measure them first and make a determination if other less-shaded greens need to be measured. If the shaded greens have DLIs more than 33, it won't be necessary to evaluate less-shaded greens. Also, look for corners of greens that may have shade issues and measure them. The edge of the green with the cleanup lap has more mower traffic and turning, therefore solve the shade issues on the edges and the rest of the green should be okay.

DATA INTERPRETATION

After taking the Clemson studies into account, a superintendent or course official has solid information in hand to make an educated assessment to determine whether adequate sunlight for growing an ultradwarf exists or if additional action is warranted. Please note that the target of 32.6 is an indicator, not an absolute, and does not take into account additional stress factors, such as traffic, water quality, soil-borne pests, etc. Added stress will require higher DLI.

The initial measurements described above will yield several different outcomes.

- Summer DLI comfortably above 32.6; no action needed. Sunlight is adequate for an ultradwarf. There may be some minor tree issues to deal with, but even if no trees were removed, the ultradwarf will have enough sunlight to grow sustainably.
- Summer DLI at mid 20s-33; potential action needed. Are there trees that can be removed, or is the course able to manage this green differently? Primo use will be essential. A putting green in this scenario is going to require closer attention. Assess the percentage of the putting green that has a DLI below 32.6. A secondary issue for putting greens in this range is to look at DLI levels in the fall and spring, too. The lower a summer DLI level is, the more important it will be to have as much sun in the fall and spring as possible.
- Summer sunlight below DLI of 22-30; action needed or green will be deemed unsuitable for an ultradwarf. In this case, removing trees or moving the green is necessary.

Meters with multiple sensors are now financially affordable and can be used as a tool in assessing the quantity of photosynthetically active radiation (PAR) for turfgrass plants.

INCREASING SUNLIGHT LEVELS

On a shaded putting green, it may not be difficult to agree that trees need to be removed, but there may be disagreement on which ones need to be removed. The trees that need to be removed are the ones that will provide the greatest increase in DLI. Fortunately, there are several tools that are available to assist in this process.

- Commercial Services — Companies such as ArborCom Technologies use computer modeling technology to determine the shade impact of individual trees on a given putting green. Shade patterns on a putting green can be modeled for any day of the year and any time period during the day. Within the model, an almost unlimited number of scenarios can be run, examining the impact of the removal of a given tree or multiple trees on sunlight levels. This is a highly precise process.
- Applications on Handheld Devices (i.e., apps) — An app developed for the real estate industry has found a niche in shade management. This app is called SunSeeker and is available on iTunes for a nominal fee for owners of an iPhone or an iPad2. With the app running and the device in camera mode and facing the object(s) potentially causing shade, the user will see several lines across the screen. A blue line traces the path of the sun on the winter solstice, December 21. A red line traces the path of the sun on the summer solstice. A third line traces the path of the sun on the day of the user's choice, with the default being the current day.

During the summer months, this app is quite helpful in identifying trees that block sunlight and determining the duration of time that they block sunlight. This app is a good tool to assist in identifying the fewest trees to remove to achieve the largest increase in direct sunlight.

A WORD ABOUT WINTER SHADE

The angle of the sun decreases by about 36% over the course of a year, and, as a result, shade levels may increase dramatically during the winter months if there are trees along the western, southern, and eastern sides of a putting green. Questions involving whether to measure winter shade are common. A warm-season species, such as bermudagrass, moves from periods of rapid vegetative growth in the warmer summer months to periods of slower to no growth in winter months. The times and rates of growth change are dependent on upon temperature and day length.

In the fall and winter, changes in temperature and light intensity trigger changes in a bermudagrass plant. Dr. James Beard explains it this way, "High light intensities and low temperatures interact to cause winter discoloration of bermudagrass leaves. High light

Affordable technologies are available for in-field use to more effectively observe the path of the sun and identify trees that block sunlight. When only a few trees may be an issue, a superintendent using the Sun Seeker can identify the trees that block sunlight to a putting green and the approximate length of time these trees cause shade.

intensities cause degradation of the existing chlorophyll, while low temperatures impair chlorophyll synthesis. The result is typical winter discoloration since the chlorophyll degradation rate exceeds the rate of synthesis" (Beard, 1973).

The implication for the topic in this article is that sunlight levels in the winter do not contribute much to plant growth. Therefore, the key issue with winter shade relates to direct or indirect low temperature injury. Shaded putting greens or shaded areas on a putting green are going to have lower soil temperatures because they receive less solar radiation. The focus for superintendents then switches to monitoring air and soil temperatures and turfgrass covers as needed.

CONCLUSION

Trees and turf are an everyday occurrence on golf courses. The desire of all superintendents is to find the proper balance between the locations of trees in relation to areas of turf, particularly the putting greens. As new grasses are being used in the Southeast, the need for assessing sunlight levels has started anew. Fortunately, important research and a variety of tools are now available to every superintendent. Applied appropriately, these resources provide the most accurate measurement and assessment of shade on your golf course, setting the stage for sustainable turfgrass for many years.

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CHRIS HARTWIGER, *senior agronomist, enjoys his time in the shade during the hot summer months in the Southeast Region.*

Using Turf Fans in the Northeast

Limited air movement isn´t just a southeast or transition–zone problem.

BY ADAM MOELLER AND BRETT CHAPIN

Putting greens with poor air movement caused by dense tree or shrub plantings, high mounding, or being located in a low-lying area are prone to turf decline without the use of large oscillating fans.

Imagine yourself playing golf with friends or family on a warm summer day. Everyone is enjoying the game and then you get to that one green. Suddenly the air feels stagnant and hot, you start to sweat more, your clothes stick to your body, and you can't wait to get to the next hole, where there always seems to be a nice cooling breeze. Now imagine staying on that green the whole day, throughout the entire summer, with endless hot, humid days without any relief from a cool breeze. Pretty miserable, right? Well that's exactly what the putting green turf suffers through when it is located in a microclimate that has limited air movement.

The microclimates in which putting greens are located play a major role in the superintendent's ability to produce good golf conditions. Many articles have been published in the *Green Section Record* about the negative effects that shade have on putting greens, but only a few articles discuss the consequences of poor air movement.

Research and field observations are very clear that putting greens can be greatly improved with the use of fans because of the cooling effect on the turf canopy, soil temperature, and increased root development (Duff and Beard, 1966; Guertal et al., 2005). Fans also help to dry the soil and reduce turf leaf wetness duration, reducing pathogen pressure. Using a fan to dry the surface improves putting green wear tolerance, too. Oppressive heat and humidity make it next to impossible to grow healthy creeping bentgrass or *Poa annua* putting greens during the summer in the Southeast Region and transition zone if air movement is limited. As a result, most golf courses in the Southeast that have creeping bentgrass or *Poa annua* rely

Fans on portable trailers offer flexibility to improve air movement at many green sites.

on fans to keep putting greens healthy during the summer (O'Brien, 2009).

Farther north, the use of fans has slowly become more common in the past decade, but many facilities are still hesitant to install them. So why is there still resistance to the use of fans in the Northeast? Cost of fan installation and operation is one reason. The perceived disruption to the game of golf and their unattractiveness probably play a bigger role. Finally, many golfers still feel that fans are necessary only in the Southeast or transition zone and not important in the Northeast. This couldn't be further from the truth.

Obviously, the Northeast doesn't experience periods of heat and humidity for the same duration as the Southeast or transition zone, but that has no bearing on whether a fan is necessary. Instead, these conditions suggest that fans need not be operating for as long a period in the Northeast. For instance, fans run in the Southeast from May through October, while the Northeast may need fans only during June, July, and August. The bottom line is restricted air movement leads to poor putting greens in all parts of the country. It's not just a Southeast or transition zone problem.

EVALUATING AIR MOVEMENT ACROSS PUTTING GREENS

Some putting greens are obvious candidates for fans if they are encircled by dense vegetation, are pocketed, or are located in low-lying portions of the golf course. Evaluating air movement is easy to do with the use of hand-held wind meters that measure wind velocity. Next, determine air movement direction with a smoke bomb or similar device (Zontek, 1992). Correlate this information with past green performance and it should be easy to identify which microclimates are in most need for additional air movement. Turf canopy thinning, algae, disease, and excessive moisture retention are common maladies of putting greens with poor air movement to look for during the evaluation process. Keep in mind that fans are not a substitute for tree removal, but some microclimates could require the removal of hundreds of trees to improve air movement, which is why fans are so beneficial.

FAN PLACEMENT IS KEY

Fan technology has remarkably improved since their early use. Small, loud fans that improved air movement over a small area have been replaced with large, quiet fans that can improve turf conditions over a much larger area through slow oscillation. Fans work similarly to automatic irrigation heads.

Fans should be located close enough to the green that air movement is improved across the entire surface. The fan angle and height should be thoroughly evaluated so that air movement is adequate at the turf surface.

Surface temperature on a green with poor air movement (left) compared to a green located in an open environment with good air movement (right) can be very different, leading to poor turf performance in many instances.

Air movement is greatest near the fan and declines gradually farther away from the fan. Consequently, fans can be misused when poorly placed. Fans installed far away from putting greens to camouflage their existence usually benefit the rough near the green complex but provide little, if any, improvement to the green. Don't fall into this trap. Just because larger fans can improve air movement over a bigger area doesn't mean they should be placed farther away from the surface. If the fan is farther than 20 feet from the green surface, it's not likely to benefit the entire putting green. Also, fans should be placed in the area that is most in need of air movement. All too often, fans are hidden so players don't see the fan from drive zone. Sometimes this works, but in most situations a fan placed directly behind the green (in clear view) is most beneficial because the oscillation will allow for the entire green to benefit. Portable fans installed on easily moveable trailers are a relatively new method to use fans when and where necessary. Like permanent fans, though, they need to be close to the putting green to improve air movement significantly.

Fan height is usually 10 feet or less to maximize air movement across the surface of the green. The angle of the fan also should be considered to maximize the benefit. Seeing the moving flag on a flagstick is a good sign, but the air movement at the turf surface could still be stagnant. During installation, place irrigation flags throughout the green so that the miniature flags are three inches above the turf surface. Adjust the fan angle according to the movement of these flags. In most instances, this requires the angle of the fan to be pointed toward the turf more than you would have otherwise. The ultimate goal with fans is to increase air movement by 3-5 mph across the entire putting surface. If this isn't achieved, adjust the fan placement, height, or angle as needed.

FAN USE

Fan use is most needed during the summer months, but stressful weather in the spring has been common in the past few seasons, so don't wait to get them set up. Running fans 24 hours a day during periods of heat and humidity is common. If fans can't be used for 24 hours, operating them from evening to early morning hours may offer the most benefits with respect to alleviating heat stress and increased rooting (Haung et al., 2001).

CONCLUSION

The summer of 2010 was extreme and putting greens with poor air movement suffered throughout the Northeast. Many facilities learned the hard way that fans can make the difference between a good golf season and a terrible one. The agronomic benefits of fans cannot be disputed. The game of golf is played on grass, and fans may be necessary to produce healthy grass on golf courses, even in the Northeast. You might even play better golf on that green that used to make you uncomfortably hot and sticky in years past.

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A Case Study at Redding Country Club, Conn.

The putting green turf has improved greatly at Redding Country Club since the installation of fans.

The Redding Country Club in Redding, Conn., opened in 1973 with a challenging layout through dense woodlands and rolling hills. The dense woodlands that brought beauty to the property continued to mature and started to cause poor growing conditions for the putting surfaces. Air movement became minimal and turf was lost on a yearly basis. Brett Chapin became the superintendent in 2006 and quickly realized that it would be extremely difficult to meet his members' expectations without adjusting the microclimates around several putting greens.

DECISION TIME

USGA Green Section agronomists, Mr. Chapin, and key club officials evaluated all of the putting green microclimates during a Turf Advisory Service visit. It was very evident that the microclimates had reduced sunlight and air movement, and tree removals and fans were necessary to meet membership expectations and have reliable, healthy putting greens. In 2007, the decision was made to provide additional sunlight by way of tree removals and purchasing five turf fans. During the winter of 2007, hundreds of trees were removed and the search for the right fans began. A source of power on the western portion of the property was not available, and the cost to run electricity to this area of the golf course was very high. At that time, Turf Breeze was the only company in the market with a gas-powered fan. The fan was 50 inches in diameter, internally held a 16 hp engine, and was capable of pushing wind 3 mph over a 150-foot radius. It was determined that the coverage would be sufficient for the 5,000-square-foot-average putting surfaces. The fan came with a stand that would be secured in the ground, and the fan would have to be brought in and out each season with a large backhoe and stored inside for the winter.

THE FIRST TEST

During the spring of 2008 the fan bases were installed by maintenance staff employees. The bases were small, less than three square feet in size, and the fans were transported to the bases in early June. Immediately, questions were being asked and the fans were being talked about by the golfers. *Did we need to buy such large fans? Do we need five? Do we need more than five? How loud are the fans? What happens if my golf ball hits a fan?* The fans were started when the summer humidity and stagnant air arrived in late June. Golfers were excited to feel a breeze on a warm day and noticed that the quiet, constant sound didn't affect their concentration or conversation while putting. Suddenly, the membership was raving about the fans. Throughout the month of July the fans ran for up to 24 hours if it was determined necessary. Then the unexpected came — a trip from the local zoning enforcement officer and the Connecticut Department of Environmental Protection (DEP).

FAN CHALLENGES

Although relatively quiet, noise complaints from neighbors required some education and subtle adjustments in how the fans were used. The decision was made not to run the fans before 8 a.m. and have the fans off by 5 p.m. to minimize disturbance to the neighbors. Ideally, we'd like to run the fans for 24 hours, but making these concessions has allowed us to run them enough for our situation. Fans were also adjusted to keep the rear of the fan, where the engine is stored, from aiming toward neighborhood homes.

The next challenge came soon after, when a neighbor asked how the fans were permitted to stand alone as a "permanent structure," which violated a local regulation. A decision was made to purchase five fan trailers from Turf Breeze, a concept designed for mobile fans in sports arenas or practice fields. The five trailers arrived in May of 2009 and the maintenance staff worked quickly to put the fans on the golf course in the exact locations of the permanent bases.

THE RESULTS

The Redding Country Club utilizes the fans on a daily basis in the summer months. Removal of trees has reached more than 1,000 since the project began. Air movement has greatly increased and so has the turf quality. There has not been turf loss on a putting green since the fans have been purchased. The putting surfaces that struggled in the past, due to the microclimates, now thrive with the help of air movement, drier surfaces, and improved growing environments.

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One way to avoid overwatering is to have two sets of sprinklers in order to irrigate the green separately from the surrounding rough.

Putting Green Drainage, Drainage, Drainage

Just as location is important in real estate, drainage is the foundation of any good putting green.

BY JAMES H. BAIRD

Drainage has long been considered the single most important element of good quality putting greens, and more often than not, failure of putting green turf can be traced back to one or more factors related to excess moisture and the inability to get rid of it. Poor drainage creates softer conditions on putting greens, exacerbating ball marks, footprints, spike marks, and wear damage, especially around golf holes, all of which adversely affect ball roll and the ability to make a putt. Wet soil is more prone to compaction, which leads to weak, shallow-rooted turf and encroachment of algae, moss, and *Poa annua*. In the end, turf in poorly drained areas usually succumbs to diseases such as anthracnose or *Pythium*, or stress caused by traffic, mower scalping, or weather extremes. In northern climates, loss of turf from winter injury frequently occurs in poorly drained areas of putting greens.

Troubleshooting a drainage challenge is likely to start by examining the underlying soil. However, soil is just one of several factors that can contribute to wet greens. The objectives of this article are to outline the various causes of poor drainage in putting greens and to offer the best and most current solutions.

STEP ONE: LOOK AROUND

Before reaching for your soil probe, take a step back and look around the green. Pay particular attention to irrigation, trees, traffic patterns, side-hill seepage or runoff, and poor surface drainage.

IRRIGATION

Overwatering due to improper irrigation practices, poor irrigation design, or both, is one of the leading pitfalls of golf turf maintenance and can contribute to poor drainage. Unfortunately, some turf managers find it easier and safer to err on the side of applying too much water rather than barely enough, especially since most golfers view lush, green turf as good and anything less as problematic.

Besides reminding golfers that "green is not necessarily great," putting green irrigation systems of today should include properly spaced sprinklers that provide uniform water distribution and are controlled individually for site-specific water management. In addition, a second set of sprinklers should be installed to irrigate the green surrounds separately from the putting surface to account for differences in water use requirements relative to mowing height and turfgrass species. Irrigation scheduling should be based upon a combination of weather data and frequent monitoring of soil moisture to prevent excess irrigation. Finally, having a state-of-the-art irrigation system and employing proper irrigation scheduling methods will significantly reduce but not eliminate the need to hand water.

TREES

Trees contribute to poor drainage by blocking sunlight and air circulation, which reduces both evaporation and transpiration of moisture from the turf canopy. As a result, irrigation must be restricted accordingly to account for reduced water loss. Remove trees that block the direction of the prevailing wind and sunlight, especially during the morning hours when photosynthesis is optimal and in order to dry out the turf canopy to reduce disease incidence. If that is not possible, use fans. These will artificially elevate the evapotranspiration rate and help the turf pull more water from the soil, thereby aiding in drainage.

TRAFFIC

Wet turf is particularly susceptible to wear damage and soil compaction caused by concentrated traffic from equipment and golfers. Switching from triplex to walk-behind mowers, and from grooved to solid front rollers on the cutting units can help reduce turf wear, especially on poorly drained greens. Removal or repositioning of trees, bunkers, or other obstructions around the green can help to improve traffic distribution. Raising the height of cut is the easiest way to increase cupping area on sloped greens without having to level, add to, or rebuild putting greens. Finally, increasing cultivation practices such as aeration and sand topdressing will help reduce surface compaction and improve drainage.

SIDE-HILL SEEPAGE OR RUNOFF

Look for drainage challenges that may be caused by excess water from neighboring slopes. The best solution for side-hill seepage is to install an interceptor or curtain drain just above the wet area near the base of the slope. The bottom of the trench should be positioned just into the less-permeable subsoil and then back-filled with stone or highly permeable sand and drainage pipe. More than one interceptor drain may be necessary, depending upon the depth and volume of water entering the green.

Repeated applications of the deep drill or tine and sand fill procedure usually helps to improve wet greens short of drainage installation or total reconstruction.

SURFACE DRAINAGE

The presence of puddling in low areas of a green following irrigation or natural precipitation is a sign of poor surface drainage. This phenomenon can be caused by poor design and/or construction, or by settling over time. Poor surface drainage can be overcome by additional and selective topdressing of low areas. Broader low areas may require removal of the sod, regrading of and/or addition to the underlying soil, followed by replacement of the sod. Inadvertent topdressing applications to collars may create a "lip" that prevents positive surface drainage from the edge of the green. Extra aeration with core removal and rolling may solve this problem; however, for severe cases, regrading may be necessary.

In extreme cases, for example on a punch-bowl green, it may become necessary to install a surface inlet drain at the lowest point in the depression. Although this type of drain can obstruct playability, it will allow a large volume of water to leave the surface and enter the collector pipe. Be sure to use a large enough grate and pipe to handle the surface water and install a trap to capture sediment or debris before it enters the drainage system.

STEP TWO: LOOK DOWN

After looking around, next grab your soil probe or profiling tool to examine the soil profile. The initial evaluation can be subjective in nature, looking for clues such as color, hardness, root distribution and depth, presence of thatch, or any other visible layers. The most common causes of soil-related poor drainage are layering and impermeable soil.

LAYERING

Layering can be caused by excessive thatch accumulation, poor construction methods, inconsistent use of cultivation practices, including topdressing materials and the frequency of application, or continued use of the same cultivation

Installation of slit drainage is effective, but it is usually more disruptive than subsurface drainage.

practice whereby a "plow-pan" or compacted area develops underneath the penetration depth of the tine or implement. Most of the time, layering problems can be alleviated by aggressive conventional and/or deep-tine aeration combined with sand topdressing to maintain the integrity of the channels.

IMPERMEABLE SOIL

One of the most common causes of poor drainage is impermeable soil underneath the green. The desire to save a buck or two during construction can often lead to use of an improper or poorly drained rootzone mix. On the other hand, even an ideal rootzone mix can become poorly drained if cultivation practices such as aeration, verticutting, and topdressing are not performed as needed to minimize organic matter accumulation. Poor drainage is often associated with greens that were constructed using finer-textured native soils. Over time, drainage in these greens usually worsens due to organic matter accumulation, increased play and resultant compaction, and changes in equipment, irrigation, and other maintenance practices.

If the drainage problem is not too severe, then aggressive aeration and sand topdressing will likely improve the soil to a point where no further action is needed. In more severe cases, it would be best to have an accredited soil testing laboratory conduct a more objective analysis of the soil. The laboratory will provide instructions for submitting undisturbed soil profiles from the green(s) in question using PVC pipe. A complete physical analysis is usually conducted on two or more sections of the profile to determine particle size distribution, density, infiltration rate, porosity, and organic matter content. In most situations, recommendations for improving drainage in impermeable soil will involve either installation of drainage or complete reconstruction of the putting green. The two most common methods of drainage used today in the Northeast are slit drainage and subsurface drainage.

Subsurface drainage installation is tedious work that is often best left to the expertise of a drainage contractor.

Slit drainage can be installed using a customized vibratory plow, which injects coarse sand into veins that are approximately 1 inch wide, 12 inches deep, and on 1- or 2-foot spacing, depending upon subsoil composition, compaction, and surface pitch of the green. Veins are extended away from the green to a low point and then connected into a dry well or interceptor drain. Approximately two tons of material are injected per 1,000 linear feet of drainage installed, equaling about 12 tons for a 6,000-square-foot green. The top of the sand is made flush within a half inch of the putting surface, and then the green is blown, brushed, rolled, and smoothed with topdressing sand in preparation for play.

There are various procedures for installing subsurface drainage. The most critical components include: identification of outlet drain(s); arrangement of laterals, depending upon soil characteristics and perpendicular to the general slope of the green; excavation of narrow trenches by careful removal of sod and underlying soil where the drainage pipe will be placed; installation of 2- or 3-inch-diameter perforated drainage pipe surrounded by gravel or pea stone; backfilling of the trench with a rootzone mixture (something on the order of 60% sand, 20% soil, and 20% peat) using careful tamping along the way to prevent settling; and replacement of the original sod followed by more tamping and hand topdressing to smooth out the surface. Use of narrow trenches and pipe and a "dirty" rootzone mix is critical to prevent drought stress. Also, pipes should be extended out of the high end of the green cavity and marked with a metal tag so they can be located and flushed out if necessary.

The decision to install either type of drainage system is usually based upon several factors, including size and scope of the drainage problem, timing of the project, and availability of the contractor. While subsurface drainage can be installed in-house (see "Wet Greens: Let's Try This First"), the work is tedious and is best left to an experienced contractor who can complete the project on an average-sized green in one day with little or no disruption of the putting surface. Installation of slit drainage is equally or more rapid compared to subsurface; however, the putting surface will likely not be smooth afterwards, and repeated aeration and/or topdressing may be necessary to smooth it to an acceptable degree. Longevity is another consideration when choosing a drainage method, and it would be logical to assume that wider trenches that contain pipe will last longer than narrower veins of sand. The narrow slits may function well initially, but they will likely become silted in from the surrounding soil and eventually become non-functional. Nevertheless, the author has observed continued success of greens with slit drainage more than five years after installation.

FINAL STEP: RECONSTRUCTION

Unfortunately, many courses skip either or both of the two first steps in identifying and solving drainage problems and go straight to complete reconstruction of a green, only to be disappointed later when poor drainage is not solved and playability is far different from the remainder of the greens. In the event that all other measures have been exhausted and reconstruction is necessary, now is not the time to cut corners in the interest of saving money or time. Working together with your agronomist and a soil testing laboratory, it is possible to construct a green that closely matches the others in terms of playability without compromising drainage, drainage, drainage!

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