Diseases of Cool- and Warm-Season Putting Greens

History sheds light on where we are and a look at where we are headed.

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Everyone interested in diseases of fine turfgrasses should read the classic manuscript "Turf Diseases and Their Control" by John Monteith, Jr., and Arnold S. Dahl from *The Bulletin of The United States Golf Association Green Section*, Vol. 12, No. 4, August 1932. In the manuscript, Monteith and Dahl state:

> The constantly rising standard of excellence in the maintenance of golf turf continually confronts the greenkeeper with new problems . . . . The artificial conditions of growth to which turf has been subjected on golf courses have undoubtedly increased the damage caused by turf diseases. At the same time, the improvements in turf have tended to make the modern golfer far more critical and have increased the demand for turf of quality kept free at all times from any damage caused by disease or other agencies.

There is an amazing amount of knowledge available about what causes and controls many turfgrass diseases, but the success we have had in applying that knowledge certainly has not changed human nature. As turf pathologists, we have witnessed situations where superintendents have heroically battled to combat disease outbreaks that still can occur unexpectedly and cause severe damage. In almost all cases, disease outbreaks can be traced to changes in components of the classic Disease Triangle — diseases result from an interaction between susceptible hosts, favorable environments, and virulent pathogens. Disease epidemics happen in the context of time. Some diseases — like *Pythium* blight or rapid blight — literally can destroy stands of turf overnight, while other diseases become progressively worse as infestation levels of pathogenic organisms increase over time.

Fundamental stuff, right? While the concept of the Disease Triangle is simple, when one closely examines the detailed interactions that can occur and considers the demand for perfect playing conditions that many golfers have, complicated and often confounding factors result in situations where golf courses are managing turf on the edge of potential disease outbreaks. Riding the fine line between disease outbreaks and healthy turf, golf course superintendents do an amazing job managing playing surfaces. Fortunately, there is a lot of science behind the tools superintendents use to control diseases. However, a tremendous amount of knowledge and skill also plays a role in the art of managing turfgrass diseases and other pests, especially when golfers have high and, in some cases, unreasonable playing-quality demands. This was the case in Monteith and Dahl's time, and it remains the case today

In this article we will discuss diseases that continually challenge superintendents. We will discuss progress, areas where more research is needed to assist our understanding of diseases, and provide solutions or approaches to disease management. We will focus our discussion on putting greens, but readers also will surely be reminded of similar disease-management situations on tees and fairways. For the purposes of this article, we will discuss diseases on bentgrass, *Poa annua*, and bermudagrass greens.

COOL-SEASON PUTTING GREENS

Disease incidence and severity on putting greens is largely dictated by the species and even cultivar of turf. In the northern United States, creeping bentgrass (*Agrostis stolonifera*) and annual bluegrass (*Poa annua*) are the primary putting green turfgrasses. On many golf courses a mixture of the two species is common — spanning both ends of the spectrum. Each species has its own unique disease concerns, such as take-all patch in bentgrass and summer patch in annual bluegrass. However, turfgrass species also share in their susceptibility, albeit to varying degrees, to other diseases like dollar spot, brown patch, and *Pythium* blight.

Annual bluegrass is generally recognized to be more susceptible to most diseases, since it has not benefited from improvement in formal breeding programs. Conversely, creeping bentgrass has undergone breeding improvements since the early 1900s (Bonos and Huff, 2013). However, the disease tolerance of early creeping bentgrass selections was not much better than the South German bent and race seed mixtures commonly used on putting greens at the turn of the 19th century. It may be surprising to many today that disease tolerance was not the primary focus of early bentgrass improvement. A true emphasis on breeding disease-tolerant creeping bentgrasses only developed in the past 15-20 years (Bonos and Huff, 2013).

CREEPING BENTGRASS

Early bentgrass improvement was focused on developing uniform, dense turf that tolerated routine mowing (Bonos and Huff, 2013). As South German bent putting greens matured, spreading patches of dense, fine-textured turf different from the rest of the surface developed. The spreading clones grew from trace amounts of creeping bentgrass seed contained in the seed mixture. Selections from particularly high-quality patches on these putting greens eventually became the

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first "improved" creeping bentgrass cultivars (e.g., Arlington, Congressional, Toronto, etc.). The early "improved" bentgrasses were vegetatively propagated and readily formed uniform, dense turf by standards of the early 1900s. However, putting greens established with clonal sprigs of the early cultivars had extremely low genetic diversity, providing an opportunity for turf pathogens to rapidly spread under favorable conditions. For example, golf courses in the Midwestern U.S. with Toronto (C-15) and other vegetatively established creeping bentgrasses experienced rapid decline when bacterial wilt (caused by *Xanthamonas campestris*) devastated putting greens during the 1980s.

Further advances in turf characteristics were made when Penncross — the first improved, seeded creeping bentgrass variety — was released in 1954. Penncross had a broader range of adaptability, tolerating environmental stress and diseases better than earlier vegetative cultivars. When Penncross was developed, putting green mowing heights typically were 0.25 inch. Over time, as routine mowing heights decreased to meet golfer demand for faster green speeds, Penncross and other varieties of its era bottomed out at their physiological limit. Lower mowing heights reduce leaf tissue, photosynthesis, and root mass, particularly in the transition zone (Fagerness and Yelverton, 2001) and other regions with high summer temperatures. Fungicides can effectively control many routine bentgrass putting green diseases; however, putting green failures as early bentgrass varieties were maintained at lower mowing heights often were due to physiological summer bentgrass decline (Huang, 2001).

High-density bentgrass cultivars — like the Penn A and Penn G series and L93 — developed in the 1990s and still widely used today were selected for improved tolerance to low mowing heights — i.e., 0.09 to 0.125 inch. The newer, high-density cultivars also are better adapted to surviving Summer Bentgrass Decline. Furthermore, high shoot density provides excellent uniformity for ball roll and resists annual bluegrass invasion. One drawback to some of the newer bentgrass cultivars is that their high shoot density reduces surface hardness (Moeller et. al., 2008) and increases thatch accumulation compared to Penncross (Stier and Hollman, 2003). To address this and to attempt to enhance green speeds, increased sand topdressing to firm putting surfaces and dilute thatch accumulation, along with core cultivation practices, has become more common. Creeping bentgrass cultivars from the mid-1990s were clearly another leap forward in turf characteristics, but their disease tolerance was not much better than that of Penncross. Significant improvements in creeping bentgrass disease tolerance were finally achieved with the development of dollar spot-tolerant cultivars like Declaration in the early 2000s (Bonos and Huff, 2013).

ANNUAL BLUEGRASS

A highly competitive and adaptable "weed," annual bluegrass has been very successful at colonizing and persisting on putting greens throughout the temperate climates of the U.S. This species and its prevalence on putting greens was documented as early as 1921 by Piper and Oakley, who described the primary shortcomings of this grass as having tremendous seed set under low mowing and annual reduction in quality as mature tillers, having produced seed and completed their life cycle, turn chlorotic and senesce. In moderate climates of the West Coast, northern U.S., and Canada, annual bluegrass stands may recover as new tillers emerge from auxiliary buds during early summer. However, newly emerged tillers typically have low carbohydrate reserves and thus are inadequately prepared to survive the heat and drought of summer months. Particularly stressful summers in moderate climates can deplete annual bluegrass energy reserves, resulting in turf failure due to abiotic and/or biotic stresses. In areas of the transition zone and southern United States, summer stress routinely exceeds the species' physiological potential, resulting in its annual decline.

Interestingly, Piper and Oakley did not dismiss annual bluegrass as a weed to be eradicated from putting greens. Rather, they acknowledged that eliminating annual bluegrass would likely prove too costly, and its performance as a putting surface made it desirable, if only in certain regions. In the absence of truly effective means of controlling annual bluegrass, superintendents over the years have been resigned to managing this species much as Piper and Oakley suggested. Innovations in technology and better understanding of turfgrass stress management have improved our ability to maintain annual bluegrass on putting greens. However, catastrophic failures of annual bluegrass due to weather, disease, and other pests are still common.

BERMUDAGRASS PUTTING GREENS

There have been several significant changes in the use of bermudagrass for putting greens. The development of turf-type cultivars was the major change that resulted in the improved bermudagrass putting surface quality. The legendary Dr. Glenn Burton at the USDA in Tifton, Ga., was responsible for the release of several bermudagrasses that revolutionized golf around the world. Released by the USDA in 1956, Tifgreen bermudagrass became very common on many putting greens in the South. Nine years later, in 1965, the greatly improved Tifdwarf bermudagrass was released, replacing Tifgreen in many locations. In addition to the Tifton cultivars, many local bermudagrass ecotypes also have been selected and propagated. However, the Tifton cultivars were cultured over the most widespread geographic area. For many years the cultivar Tifdwarf remained the standard for bermudagrass putting greens, only being replaced by the selection and development of the ultradwarf bermudagrass cultivars in the late 1990s.

It can be argued that the development and adoption of ultradwarf bermudagrasses was the result of a "perfect storm" of circumstances. One factor — the occurrence of off-types in Tifdwarf greens — caused great discontent, especially as demands for better bermudagrass greens increased.

Figure 1. Relative rooting differences of ultradwarf cultivars compared to Tifdwarf. Photo by S. B. Martin.

An off-type could be caused by contamination, mutations (a natural phenomenon), or a combination of causes that results in a grass that is not true to type when compared with the original cultivar. Also, as golf in the U.S. boomed during the 1990s and early 2000s, the demand for improved putting conditions — i.e., speed and consistency — increased the need for improved grasses. To satisfy golfer demands, superintendents were pushing the envelope and mowing lower. In some environments, such as the rainy, cloudy coastal states along the Gulf of Mexico, a condition developed known as “bermudagrass decline.” The demethylation inhibitor (DMI) fungicides that are very useful for managing root-rot diseases of cool-season grasses were damaging bermudagrass, especially when applied at summertime temperatures of 90 degrees Fahrenheit or warmer. Therefore, the common refrain for controlling bermudagrass decline was to raise the height of cut and avoid DMI fungicides. Generally, more leaf area benefits root development and survival.

The other factor that fueled the need for ultradwarf bermudagrass greens — at least in hot, humid Transition Zone environments — was the expense and risk of managing high-quality bentgrass putting greens. One can debate whether climate change due to man-made causes is real or not, but record-breaking heat in many southern locations definitely increases the challenge of growing bentgrass. While there are many examples of excellent bentgrass greens in heat-challenged areas, there is no doubt that prolonged high temperatures weaken the plant and make it more susceptible to stresses of all types — including disease.

Of high significance to pest management is the fact that the sterile, interspecific hybrid bermudagrasses — i.e., crosses of *Cynodon dactylon* x *C. transvaalensis* — were, and are, vegetatively propagated in field soil or sand-based rootzones. Soil and plant material can harbor pathogens, including damaging plant-parasitic nematodes. However, fumigating field sites and planting fields with Foundation Certified plant material reduce the chance of high-level pathogen occurrences during early stages of establishment. As fields age, however, the chance of pathogens being introduced and proliferating is inevitable. Likewise, the chances of off-types occurring increase and, if off-types hide in grower fields, they can become abundantly clear when planted and cultured on highly maintained putting greens. The ultradwarf grasses now have been commercially cultured on greens for up to 18 years, explaining why the occurrence of off-types commonly is discussed. Sometimes, off-types react differently to both natural and man-made environmental changes, causing color and texture differences, tearing during verticutting, and potentially different responses to pathogenic fungi like leaf spot diseases.

Generally, the adoption of ultradwarf bermudagrasses has been very successful. In the hands of skilled superintendents, ultradwarf bermudagrasses make outstanding putting surfaces. Many conversions from older bermudagrass cultivars or bentgrasses to one of the ultradwarf cultivars have taken place in the southern U.S. and well into the cooler Transition Zone. Superintendents and others have had to adapt cultural and maintenance practices to accommodate the newer ultradwarf cultivars. For instance, when planted on sandy rootzones with relatively high water infiltration rates, turf will be more prone to drought. Because the ultradwarf bermudagrasses — including TifEagle, Champion, and MiniVerde — generally have a shallower root system than Tifdwarf, the risk of drought and localized dry spots is greater on ultradwarf greens (Figure 1). Furthermore, when root-active pathogens like *Gaeumannomyces graminis* var. *graminis* — a pathogenic component of bermudagrass decline — or plant-parasitic nematodes are present, the reduced root system of ultradwarf bermudagrasses becomes a liability that must be recognized. Even diseases that are active on leaves — like dollar spot and leaf spot (*Bipolaris cynodontis*) — can be more prevalent when rootzones are dry and nutrient uptake is reduced. To improve the performance of ultradwarf bermudagrass cultivars with shallow root systems, consider using rootzone mixes that hold moisture and nutrients a little more firmly. A rootzone mix containing 3-5 percent field soil by volume can be effective as long as soil tests show that drainage is not compromised. At Clemson, a research green was built in sections with sand and sphagnum peat combinations: 85 percent sand/15 percent peat with a 35-mesh sand; 85 percent sand/15 percent peat with a 65-mesh sand (i.e., much smaller particle size distribution), or 95 percent sand/5 percent peat with 35-mesh sand. The 95 percent sand/5 percent peat with 35-mesh sand mix had a hydraulic conductivity of greater than 18 inches per hour and, after establishment, showed a much higher incidence of dollar spot and leaf spot than the other mixes (Figure 2). The 65-mesh sand mix had an initial hydraulic conductivity of about 12 inches per hour and exhibited the least amount of disease. Similar results have been observed as the putting green matured.

What about the disease susceptibility of ultradwarf bermudagrasses? There are no studies comparing the occurrence and severity of diseases in ultradwarf bermudagrasses compared to the older cultivars. However, it would be like comparing apples to oranges, as the context of management is completely different. Some management practices routinely used on putting greens today increase the susceptibility of turf to various diseases — like mowing ultradwarf bermudagrasses at very low heights, e.g., 0.09 inch. Older bermudagrass cultivars were not as tolerant of extremely low mowing heights — 0.188 inch was low for Tifgreen, and 0.156 inch was considered too low for continuous mowing of Tifdwarf — and bermudagrass decline was promoted when bermudagrass greens were mowed at or below 0.156 inch. Aerating to remove thatch is still considered a necessary practice, but frequent topdressing to dilute thatch has increased. Generally, superintendents topdress ultradwarf bermudagrass putting greens more frequently — as often as weekly during the growing season — and with smaller sand particle sizes than with Tifdwarf greens. Frequent topdressing is considered necessary to maintain surface firmness and prevent scalping at low cutting heights because ultradwarf bermudagrasses are prolific producers of thatch. Finer topdressing materials also are utilized so the sand can be efficiently incorporated in the surface. However, more research is needed to understand the long-term consequences of routinely using fine topdressing sands. Fertilization levels have decreased in practice and likely are lower on average than most university agronomists recommend — i.e., generally about 0.25 pound of nitrogen per growing week. Growth regulators, like trinexapac-ethyl, help conserve nutrients, but remember that mobile nutrients like nitrogen and potassium still can be depleted in sandy rootzones that drain. When nutrients are limiting, turfgrass plants can become more susceptible to certain diseases. Furthermore, the ability for turfgrass to recuperate from disease outbreaks is reduced when essential plant nutrients are limiting. Remember, in sandy rootzone mixes, mobile nutrients are more mobile.

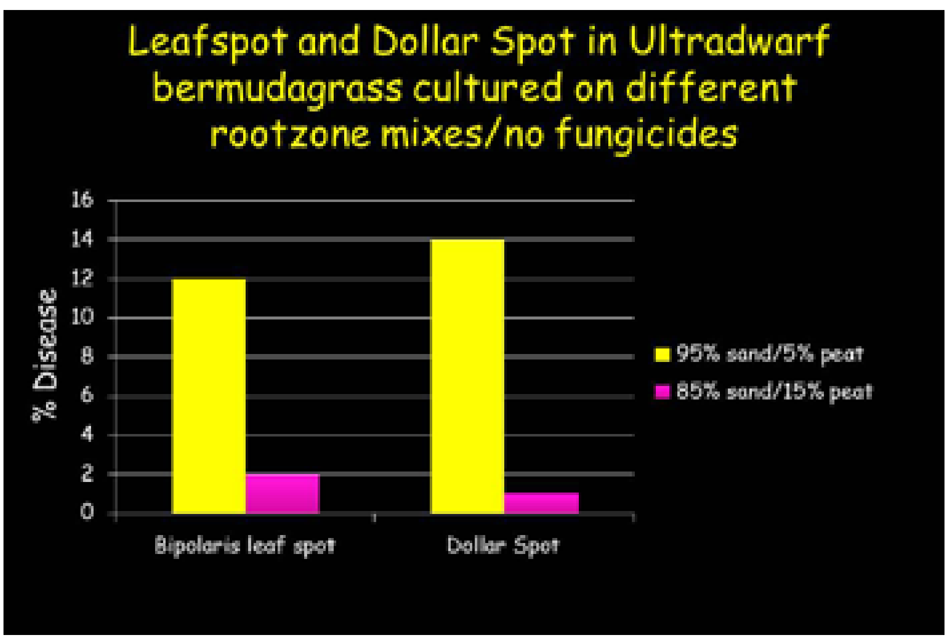

Figure 2. High leafspot and dollar spot disease in ultradwarf bermudagrass growth in drought-prone mix versus a typical USGA rootzone. Photo by S. B. Martin.

ULTRADWARF BERMUDAGRASS PUTTING GREEN MANAGEMENT

Countless articles have highlighted the consequences of intensifying management practices to chase putting green speed expectations. Practices like ultralow mowing, reduced nitrogen fertility, frequent sand topdressing, and sand-based rootzone construction make disease management in creeping bentgrass, annual bluegrass, and ultradwarf bermudagrasses a fundamental consideration. Evolving management practices over the past 25 years have had a profound effect on turfgrass disease in cool- and warm-season turfgrass systems. The list of potentially damaging turfgrass diseases is long and beyond the scope of this article. The following sections will highlight the most prevalent diseases currently affecting cool- and warm-season putting greens, emphasize how changes in host and manage-

Figure 3. Dollar spot on a bentgrass putting green. Photo by J. C. Inguagiato.

ment have influenced disease incidence and discuss best management practices.

DISEASES OF CREEPING BENTGRASS AND ANNUAL BLUEGRASS PUTTING GREENS

DOLLAR SPOT

Arguably, every golf course in the northern U.S. experiences dollar spot outbreaks each year. Today, routine fungicide applications typically keep dollar spot outbreaks from becoming devastating. Thus, the threat of losing large areas of turf to dollar spot is low; however, the resources invested in the chemical and cultural control of this persistent disease make it a very important issue on cool-season turfgrasses.

Dollar spot has always been a problem on golf course playing surfaces (Figure 3). Monteith and Dahl described dollar spot and its management in 1932, their text serving as one of the earliest reviews of the biology and management of turfgrass diseases. Surprisingly, the causal agent of dollar spot — *Sclerotinia homoeocarpa* — would not be identified for another five years. Interestingly, the recommendations made by Monteith and Dahl for dollar spot control are much the same as those advocated today: “the judicious use of fertilizer and water and resistant strains of grasses.” Monteith and Dahl even suggested removing morning dew to manage dollar spot. In some respects, it would appear that the cultural management of dollar spot has not evolved much in the past 80 years. Fortunately, there have been many effective fungicides that have provided good control of dollar spot over the years. However, dollar spot continues to plague golf courses and, for some, the disease has become more difficult to control due to numerous factors. However, two factors are particularly relevant to recent trends in disease management — managing for green speed and the routine use of fungicides with single-site modes of action.

Reducing mowing height and minimizing nitrogen fertility are often-used strategies to meet golfer demands for fast green speeds. The trend of reducing annual nitrogen rates over the past 40 years from 6-7 pounds of nitrogen per 1,000 square feet to as low as 1.5 pounds of nitrogen per 1,000 square feet has impacted putting green performance in many ways. Low nitrogen fertility enhances turfgrass susceptibility to dollar spot. The impact of low nitrogen fertility may be particularly evident on sandy soils with low nutrient-holding capacity like sand-based rootzones or soil rootzones modified with a thick sand topdressing layer. Soil-based putting greens have greater nutrient-holding capacity and mineralization potential. Another consequence of reduced nitrogen fertility is reduced ability of turf to recover from dollar spot infections. Fortunately, over the past few years annual nitrogen fertilization has begun to rebound, and many turf managers are increasing nitrogen rates to more moderate levels to help turf cope with abiotic and biotic stresses.

Fungicides have always been an important component of dollar spot management on putting green turf. However, a serious concern about the efficacy of this approach arose in 1973 when the first case of fungicide resistance in *S. homoeocarpa* was documented — resistance to the benzimidazole fungicide class e.g., thiophanate-methyl (Warren, et. al., 1974). Since then, resistance of *S. homoeocarpa* to several fungicide classes has been reported, including resistance to the dicarboximides — e.g., iprodione, vinclozolin — and demethylation inhibitors — e.g., propiconazole, triadimefon, tebuconazole, etc. The development of fungicide resistance is a consequence of fungicide-use patterns and single-site mode of action technology. Repeated use of fungicides with the same mode of action can eventually select for pathogen strains that are resistant or less sensitive to all fungicide active ingredients within a particular chemical class. Fortunately, to date there have been no reports of cross-resistance between chemical classes. Thus, resistance-management strategies have focused on rotating active ingredients from different chemical classes and combining single-site mode of action fungicides with multi-site mode of action fungicides that have much less potential for resistance development.

Another approach to managing resistance has been to optimize efficacy of disease-control products. Innovation in spray nozzles has produced flat-fan nozzles and air-induction technology that help provide better fungicide coverage on leaf surfaces compared to raindrop and flood-jet nozzles (Kennelly and Wolf, 2009). Spray coverage is particularly important when using contact fungicides that require direct contact with the fungus for disease control. Better spray coverage ensures fewer sites on leaf surfaces are left unprotected, limiting potential infection sites. Using carrier volumes of 1 to 2 gallons per 1,000 square feet combined with air-induction, XR, Turbo TwinJet, or TurboDrop twin-fan nozzles has provided excellent dollar spot control on putting green turf (Kennelly and Wolf, 2009).

Many currently available fungicides provide good dollar spot control when applied properly at recommended rates. Despite the potential for fungicide resistance, DMIs and dicarboximides continue to provide effective dollar spot control on many golf courses. Where reduced sensitivity to DMI fungicides is a concern, higher rates and shorter application intervals generally still provide adequate control; however, rotation and tank mixing with multi-site mode of action materials should be routinely practiced. Recent innovations in fungicide chemistry have provided a few additional active ingredients that will be important for future dollar spot management. Fluazinam (Secure®) is a contact fungicide with multi-site activity released in 2012 that provides excellent control of dollar spot alone or in a tank mix. The multi-site activity of fluazinam will be valuable for managing fungicide resistance. Fluxapyroxad (Xzemplar®) and penthiopyrad (Velista®) are new single-site mode of action fungicides with good to excellent dollar spot control in the succinate dehydrogenase inhibitor (SDHI) chemical class that will provide new options for fungicide rotation programs.

New creeping bentgrass cultivars also provide an opportunity for managing dollar spot. As a result of dedicated breeding efforts, several creeping bentgrass cultivars have been released in the past 10 years that offer significant improvements in host tolerance to dollar spot. Creeping bentgrass cultivars like Declaration, Benchmark DSR, Barracuda, and 13M consistently experience less dollar spot outbreaks than earlier varieties. However, the new bentgrass cultivars are not immune to dollar spot, but establishing them may reduce the severity of dollar spot outbreaks. Combining host resistance with appropriate cultural management also should improve the efficacy of fungicides or reduce the number of applications required to control dollar spot.

PYTHIUM DISEASES

Pythium blight and *Pythium* root diseases are major concerns on cool-season putting greens. Like dollar spot, *Pythium* blight was described by Monteith and Dahl in 1932. *Pythium* diseases continue to threaten putting greens during hot, humid weather. The *Pythium* root diseases have become more problematic in recent years, likely due in part to lower mowing heights that reduce rooting potential and predispose turfgrasses to damage from root infections. Each of the pathogens, hosts, and conditions contributing to the *Pythium* diseases are unique, often leading to confusion regarding their identification and control.

Pythium blight is often the most recognizable *Pythium* disease because it directly affects the turf canopy, typically producing visible mycelium when active. *Pythium* root rot and *Pythium* root dysfunction are more challenging to diagnosis since signs of the pathogen are only visible on turf roots. All three *Pythium* diseases are capable of killing infected plants, especially during the summer when cool-season turfgrasses are stressed and recovery is difficult. Damage from *Pythium* diseases can persist until cooler conditions prevail in the fall.

PYTHIUM BLIGHT

Pythium blight is a devastating disease because it quickly develops and spreads. Several different *Pythium* species have been found to cause foliar blighting, but *P. aphanidermatum* is most common. All cool- and warm-season turfgrasses are susceptible to *Pythium* blight. During optimum conditions, *Pythium* blight may affect large portions of putting greens in as few as 1-3 days. Initially, 1- to 6-inch-diameter

Figure 4. Pythium *blight on creeping bentgrass tee. Photo by S. B. Martin.*

reddish-bronze spots develop that can quickly enlarge and coalesce (Figure 4). Streaks of blighted turf also may develop if the pathogen is carried by flowing water or equipment. Disease development is limited to periods of extended high temperatures (86-95 degrees Fahrenheit; 68 degrees Fahrenheit or warmer night temperatures) and humidity (90 percent or greater). Putting greens in enclosed environments with little air movement and light penetration and greens with poor drainage are most often affected.

To date, no *Pythium* blight-resistant varieties of creeping bentgrass are available. Management of *Pythium* blight should focus on improving growing environments to facilitate rapid drying of the turf canopy. Tree removal can be a controversial topic on some golf courses but can often be the most effective way to increase air movement and light penetration on putting surfaces. Fans provide an effective alternative for improving air movement when tree removal is not an option.

Given the potential damage *Pythium* blight can cause to putting green surfaces, fungicides often are applied when conditions favor disease development. Several fungicides have been specifically developed to control *Pythium* diseases — e.g., mefenoxam, propamocarb, ethazole, cyazofamid, and the strobilurin class of fungicides. Recently, phosphonates and fosetyl-Al have been increasingly used to control *Pythium* blight and provide good control under low to moderate disease pressure (Cook, et. al., 2009). However, under high disease pressure, phosphonates may not provide reliable control, and applying dedicated *Pythium* fungicides may be a safer choice.

PYTHIUM ROOT ROT

Pythium root rot affects both annual bluegrass and creeping bentgrass putting greens. Foliar symptoms appear as chlorotic, thinning areas of turf in undefined patterns; however, patches of symptomatic turf may occasionally occur in creeping bentgrass. Most important, the roots and crowns of affected plants are water-soaked and root mass is reduced (Figure 5). *Pythium* root rot may occur any time of year but is dependent on temporarily saturated soils that occur as a result of poor drainage and/or frequent rain events. Older, soil-based greens with compacted rootzones may be particularly susceptible to *Pythium* root rot. Initial symptoms may develop as slow-growing, chlorotic turf in the spring that progressively worsen during hot temperatures and high humidity.

Figure 5. Dark, water-soaked appearing roots typical of Pythium *root rot. Photo by S. B. Martin.*

Several *Pythium* species are capable of causing root-rot symptoms on creeping bentgrass. To date, two surveys of *Pythium* root rot pathogens in turfgrass have been conducted. Studies performed in New York and North Carolina identified multiple *Pythium* species that were pathogenic to creeping bentgrass roots (Nelson and Craft, 1991; Abad, et.al., 1994).

Figure 6. Severe Pythium *root dysfunction in July. Photo by S. B. Martin.*

Many of the same *Pythium* species were identified in both studies, including *P. gramincola*, *P. aphanidermatum*, and *P. aristosporum*. Pathogenicity of certain *Pythium* species was dependent on temperature. In New York, all species were pathogenic at 55 degrees Fahrenheit, whereas only three species maintained their pathogenicity at 82 degrees Fahrenheit. The variability of pathogens capable of causing *Pythium* root rot makes its management challenging. Furthermore, depending on the pathogen species, *Pythium* root rot could occur during most times of the year, and fungicide efficacy could be variable. Future research is needed to further characterize prevalent *Pythium* root rot pathogens in various regions and determine critical temperatures at which different species may incite disease.

Management of *Pythium* root rot should focus on improving subsurface and surface drainage. In older soil-based greens, installation of sand-channel drains can improve rootzone drainage and has helped some courses with chronic *Pythium* root rot. Reduce irrigation on low, poorly draining areas of putting greens. Similar to *Pythium* blight, increasing air movement and light penetration will facilitate more rapid drying of turf surfaces. Increasing the height of cut also is important to encourage deeper, denser root systems. Increased rooting should help increase the ability of turf to tolerate minor root infection. Fungicidal control of *Pythium* root rot is difficult since it is not always known when infection will occur. In general, preventive applications of a true *Pythium*-control material should be applied to the upper two inches of the rootzone before sustained saturated soil conditions.

PYTHIUM ROOT DYSFUNCTION

Pythium root dysfunction has received considerable attention in recent years due to extensive research performed on putting green turf in the Southeastern U.S. *Pythium* root dysfunction is often confused with *Pythium* root rot, but the symptoms and conditions for *Pythium* root dysfunction are very different. *Pythium* root dysfunction initially develops in late spring as patches of wilted turf that later turn chlorotic, then orange during summer heat and drought stress (Kerns and Tredway, 2008). The foliar symptoms of *Pythium* root dysfunction are similar in appearance and timing to take-all patch. However, roots affected by *Pythium* root dysfunction appear tan, with bulbous root tips and a lack of root hairs. Root length may be reduced during summer months. *Pythium* root dysfunction occurs exclusively on creeping bentgrass grown on newly established sand-based rootzones.

Pythium root dysfunction can be caused by *P. volutum*, *P. aristosporum*, or *P. arrhenomanes*. Most recently, *Pythium volutum* has been characterized as causing disease in the Southeastern U.S. (Kerns and Tredway, 2008), whereas *P. aristosporum* and *P. arrhenomanes* are causing disease in the Mid-Atlantic (Feng and Dernoden, 1999) and Iowa (Hodges, 1985). Reports of *Pythium* root dysfunction occurring in other regions are not uncommon; however, the causal agent involved is rarely identified to the species level. Root infection typically begins during spring and continues through early summer. Diagnosis is typically made based on observation of oospores in infected roots during spring and fall, which presents a challenge in diagnosing *Pythium* root dysfunction since symptoms are most prominent during the summer and characteristic signs of the pathogen may not be present by the time samples are submitted for diagnosis.

Recent studies of root dysfunction caused by *P. volutum* have generated new approaches to managing this disease. Interestingly, many traditional *Pythium* fungicides are ineffective at controlling *P. volutum*. Best control and resistance management can be achieved with a rotation of cyazofamid, pyraclostrobin, propamocarb, and fosetyl-Al (Kerns et. al., 2009). Fungicide applications are recommended in fall and spring when soil temperatures are between 55 and 75 degrees Fahrenheit (Figure 6). Excessive irrigation should be avoided during spring and fall when the pathogen is active. Stress intensifies the severity of summer root dysfunction symptoms, so practices to minimize plant stress should be implemented. Light, frequent nitrogen fertility and slight increases in mowing height should help minimize disease severity. Some variation in creeping bentgrass tolerance to root dysfunction has been observed (Kerns et. al., 2009). Interestingly, some bentgrass cultivars developed for improved heat tolerance were more tolerant of *P. volutum*. Heat-tolerant varieties likely maintain roots better during summer and are therefore more tolerant of *Pythium* root dysfunction.

ANTHRACNOSE

Perhaps no better example of how evolving management practices on turfgrass have impacted disease exists than the story of anthracnose. Prior to the 1990s, anthracnose was a relatively minor turfgrass pathogen. Gradual reductions in mowing height and nitrogen fertility beginning in the 1980s eventually reached a point where annual bluegrass had become predisposed to anthracnose. Further contributing to the anthracnose epidemic was pathogen resistance to fungicides. A survey of nearly 1,000 superintendents throughout the U.S. and Canada conducted in 2011 reported 66 percent of all respondents had experienced anthracnose on their greens (Inguagiato, 2012). In regions where annual bluegrass was more prevalent, anthracnose incidence was approximately 80 percent.

Anthracnose affects both crown and leaf tissue and is sometimes referred to as basal rot or foliar blight anthracnose to indicate where infection is occurring. Basal rot anthracnose is typically the only form of the disease observed in the spring between March and June (Figure 7). However, both forms of anthracnose routinely are observed together on putting greens when temperature and humidity are high during summer months. Anthracnose epidemics typically begin in June and intensify, causing severe turf loss, in July and August (Figure 8). Annual bluegrass is the most common host, particularly in the northern U.S., but anthracnose also affects creeping bentgrass in the transition zone. The pathogen *Colletotrichum cereale* causes anthracnose in turfgrasses and was recently designated after it was determined the pathogen affecting turfgrass was different than the pathogen causing anthracnose of corn (Crouch and Clarke, 2012).

The effect of common putting green management practices on anthracnose has been extensively researched over the past decade, and a comprehensive set of best management practices has been developed that can greatly reduce the severity of anthracnose on

Figure 7. Typical anthracnose basal rot symptoms showing dark, water-soaked stem bases with black acervuli. Photo by J. C. Inguagiato.

Figure 8. Severe anthracnose infestation on an annual bluegrass putting green. Photo by J. C. Inguagiato.

putting green turf. Of the management factors studied, maintaining moderate nitrogen fertility, reasonable mowing heights, and routine sand topdressing appear to be the most important to reducing anthracnose. Nitrogen should be applied at 1-2 pounds per 1,000 square feet in the spring, and a total of 1.5-3.0 pounds per 1,000 square feet should be applied in routine, low-rate applications throughout the summer. Also, recent research has found that high levels of soil potassium — i.e., approximately 100 pounds per acre — should be maintained to reduce anthracnose (Schmid et. al., 2013). Mowing below 0.125 inch should be avoided to increase photosynthesis and minimize plant stress. Ball roll distances of 10 feet can be maintained at mowing heights of 0.125-0.141 inch without enhancing anthracnose if greens are double cut daily or rolled every other day.

One surprise is that sand topdressing reduces anthracnose. It was long believed that abrasion associated with sand topdressing caused wounds that would enable anthracnose infection and cause greater disease. While sand topdressing may increase the potential for anthracnose when first initiated, multiple studies have found that routine topdressing and the accumulation of sand topdressing around crowns and tiller bases reduces anthracnose severity. It has been hypothesized that a layer of topdressing sand protects crowns and stem bases, firms the surface, and increases the effective height of cut by better supporting the weight of mowers. A summary of research on cultural management and BMPs for anthracnose is available in the May 2012 edition of *Golf Course Management* (Murphy et al., 2012).

Several fungicide chemistries have been identified as effective anthracnose-control products. However, chemical control of anthracnose is challenging because applications of single fungicides rarely provide consistent control. Rather, tank mixes of fungicides from two or more chemical classes are generally necessary to achieve adequate disease control. The anthracnose pathogen can quickly develop resistance to single-site mode of action fungicides. Anthracnose resistance to benzimidazole, strobilurin, and DMI chemical classes has been reported (Tredway and Wong, 2012).

Given the high risk of fungicide resistance and poor efficacy of fungicides when applied alone, the most effective anthracnose-control programs utilize tank mixes and rotations of several chemical classes throughout the season. Where susceptible populations of anthracnose exist, benzimidazoles and strobilurins are very effective. However, in many regions fungicide resistance to benzimidazoles and strobilurins is common, making these materials ineffective. Demethylation inhibitors are widely used for anthracnose control. Comparison of select DMIs in lab and field trials has shown that tebuconazole followed by triticonazole and propiconazole are very effective. Fungicide resistance to DMIs is typically expressed as a reduction in sensitivity rather than a complete loss of efficacy. Demethylation inhibitors may still be used at increased rates where resistance has occurred, but preferably they should be used in a tank mix with another effective fungicide chemical class. Tank mixes of fosetyl-Al with chlorothalonil — or either fungicide combined with polyoxin-D, fludioxonil or penthiopyrad — all provide very good anthracnose control with low risk of turf injury. Tank mixes are a good option during July and August in lieu of DMIs, which can cause a reduction in putting green quality during hot weather.

DISEASES OF BERMUDAGRASS PUTTING GREENS

SPRING DEAD SPOT (SDS)

The Compendium of Turfgrass Diseases, Third Edition, states, “Spring dead spot is the most important disease of *Cynodon dactylon* and *Cynodon* hybrids in North America and Australia.” Certainly that statement is true in Transition Zone environments, as SDS disease symptoms appear during spring green-up after winter dormancy (Figure 9). Usually, spring dead spot only sporadically develops in cooler regions and does not occur on bermudagrass greens in semi-tropical or tropical environments. The fungi that cause SDS infect bermudagrass roots and colonize cortical and stele tissues, weakening susceptible grasses and causing poor survival after cold winters. Bermudagrasses that have been specifically developed for better low-temperature tolerance — e.g., Patriot, Latitude 36, and others — also have better tolerance of SDS. None of the currently cultured ultradwarf bermudagrasses were developed for low-temperature tolerance; therefore, all are quite susceptible to SDS when cultured in environments where they go dormant or semi-dormant during winter.

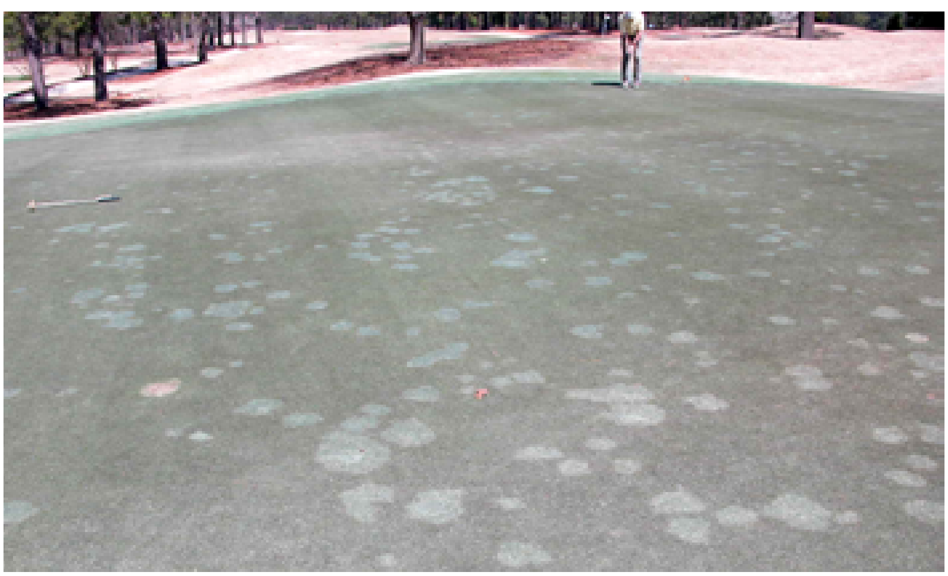

Figure 9. Spring dead spot in ultradwarf bermudagrass green at spring greenup. Photo by S. B. Martin.

Major progress identifying and understanding SDS causal agents and their occurrence has been made over the past two-and-a-half decades. It is currently accepted that SDS can be caused by any of three species of *Ophiosphaerella*: *O. korrae*, *O. herpotricha*, and *O. narmari*. Research has confirmed that *O. herpotricha* is rare in the Southeastern U.S. but occurs with higher frequency in the Midwestern states of Oklahoma, Kansas, and Missouri. *O. korrae* is the primary pathogen in the southeastern U.S. *O. narmari* is rare in the U.S. but does occur in California. Recently, *O. herpotricha* was identified as the only pathogen causing SDS in Argentina and Uruguay (Canegallo and Martin, unpublished).

Research conducted at North Carolina State University suggests that knowledge of the specific causal agent at a site may be important. In a three-year study, plots inoculated with *O. herpotricha* had less disease when fertilized with ammonium sulfate, an acidifying fertilizer, while disease in plots inoculated with *O. korrae* was not suppressed with ammonium sulfate but was suppressed with calcium nitrate. Additional research is needed on this topic, which opens the potential for SDS suppression without the use of fungicides.

Spring dead spot was not unknown in older cultivars of hybrid bermudagrasses like Tifgreen and Tifdwarf. However, the use of fenarimol (Rubigan®) for *Poa annua* control in overseeded bermudagrass putting greens also controlled SDS. When applied in multiple applications before *Poa annua* germination, Rubigan® was the best material for *Poa annua* control (Bert McCarty, personal communication). Rubigan® also was identified as the most efficacious of the labeled fungicides for SDS control. Furthermore, application timing to control both SDS and *Poa* coincided in late summer and fall. However, a couple of factors led to dramatic outbreaks of SDS in ultradwarf bermudagrass putting greens. One factor was that superintendents began using alternative methods to control *Poa annua*, such as sulfonylurea herbicides that allowed the use of single applications in early postemergence programs rather than up to 12 ounces of Rubigan® in two or three applications. The other factor was that some single-component fungicides labeled for SDS control — e.g., azoxystrobin, fluoxastrobin and thiophanate-methyl — have limited efficacy controlling SDS, causing many superintendents to question whether SDS was actually a disease. Concerns about SDS control led to research that demonstrated the relative efficacy of labeled fungicides for SDS on putting green turf, reconfirming the efficacy of Rubigan®.

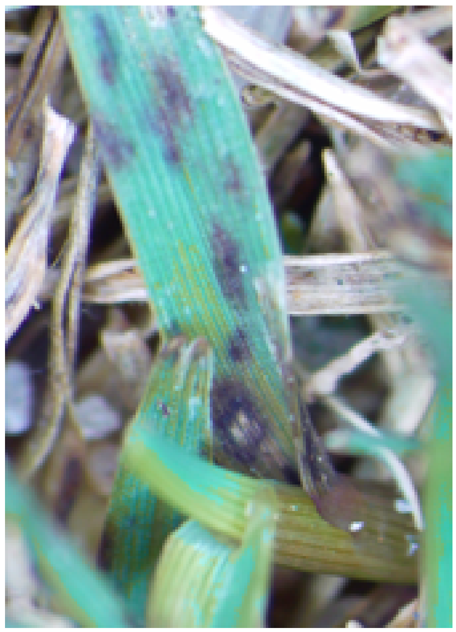

Figure 10. Leafspot on ultradwarf bermudagrass. Photo by S. B. Martin.

However, Rubigan® has been discontinued for sale and only existing stocks can be used until depleted. The discontinuation of Rubigan® increased the reliance on other fungicide chemistries — like formulations of tebuconazole — which, compared to Rubigan®, moderately control SDS but can achieve better efficacy when used in tank mixes with thiophanate-methyl. For instance, applications of 0.6 fluid ounce of Torque™ per 1,000 square feet followed by an application of 0.6 fluid ounce of Torque™ and 5 fluid ounces of Cleary's 3336®F per 1,000 square feet generally provide moderate to good control of SDS in TifEagle or MiniVerde. Although tebuconazole is a potent growth regulator of bermudagrass, it becomes somewhat safer when mixed with thiophanate-methyl. Some new fungicide mixtures — like Briskway™ (a combination of azoxystrobin and difenoconazole) applied at 0.725 fluid ounce per 1,000 square feet and alternated with Headway® (azoxystrobin plus propiconazole) at 3 fluid ounces per 1,000 square feet — also provide very good control of SDS. In trials on ultradwarf bermudagrass greens, Briskway™ did not result in any noticeable growth regulation; however, multiple low-rate applications or a single application of 3 fluid ounces per 1,000 square feet of Headway® produced a growth-regulating effect. Furthermore, two new SDHI fungicide products — Velista™ (penthiopyrad) and Lexicon™ (a combination of pyraclostrobin and fluxapyroxad) — have provided excellent SDS control in recent trials without regulating growth. Also, both SDHI products provide control of additional diseases such as dollar spot, leaf spot, and *Rhizoctonia* leaf and sheath spot, among others. Modern fungicides also can be used at much lower rates than older materials. For instance, complete control of SDS has been achieved with two applications of 0.7 ounce per 1,000 square feet fall of Velista or with two applications of 0.47 fluid ounce per 1,000 square feet fall of Lexicon. Comparable control with Rubigan® generally utilized two applications of at least 4 fluid ounces per 1,000 square feet.

Superintendents managing bermudagrass greens in environments where SDS can occur now have very good disease-management tools, even for newly established greens where turf is not completely mature and where DMI-fungicide options are less desirable.

LEAF SPOT DISEASES

Leaf spot diseases on ultradwarf bermudagrasses can be caused by three or more species of *Bipolaris*: *B. cynodontis*, *B. spicifera*, or *B. sorokiniana*. In recent work, *B. cynodontis* appears to be the most commonly encountered pathogen in the southern U.S. (Figure 10). Leaf spot occurs most often during cooler seasons when bermudagrass growth slows — e.g., fall in the Transition Zone or fall, winter, and spring in states like Florida. Leaf spot is a chronic disease promoted by low fertility levels, increased thatch, dry rootzones, and humid turf canopies. In other words, conditions that closely mimic those that promote dollar spot. It is not uncommon to find both active dollar spot and leaf spot on bermudagrass during fall months.

more visible when not concealed by overseeded grasses. If symptoms of any disease occur on turf that is dormant or semi-dormant, they can persist, cause damage, or be very unsightly. Disease symptoms are visible even through paints or pigments.

With increased disease concerns, should overseeding greens be resumed? Not unless it is acceptable to return to the days of difficult spring transitions. Rather, fungicide programs similar to those used on bentgrass or *Poa* greens during summer are being studied and used to control diseases on non-overseeded ultradwarf bermudagrass greens. As with bentgrass in heat-stress environments in the South, be careful with most of the DMI fungicides due to their growth-regulating properties. In fact, DMI fungicide use largely will be relegated for fairy ring control in early spring applications. Applying fungicides should be based on knowledge of disease infection periods, damage potential, and the likelihood of specific disease outbreaks or problems as well as fungicide strengths, weaknesses, label restrictions, resistance issues, and price.

Figure 11. Leafspot and algae on a bermudagrass green. Photo by S. B. Martin.

Leaf spot and other cool-weather diseases have become more important in recent years, possibly due to weather conditions that favor disease development. Also, many courses have eliminated overseeding dormant bermudagrass with cool-season grasses. Rather than overseeding, superintendents are skillfully painting or treating greens with pigments to provide color for aesthetic reasons. Eliminating overseeding has been very successful, and it is obvious that the health of bermudagrass has definitely improved. When overseeding is eliminated, winter weed control is much simpler and more successful, and spring transition is more successful. However, leaf spot, winter *Pythium*, pink patch, and *Microdochium* patch are more apparent without overseeding, likely because disease symptoms are

Cultural practices such as increasing fertility levels, managing thatch, limiting periods of leaf wetness, and being careful with growth regulators when turf is slowly growing may discourage leaf spot. Relying on fungicides as the primary method to control leaf spot may lead to the development of fungicide-resistant populations of leaf spot pathogens. Multi-site mode of action contact fungicides — e.g., chlorothalonil and mancozeb — should be included in leaf spot control programs for good control and managing disease resistance. Fungicides like chlorothalonil and mancozeb also are excellent materials for combating algae infestations that often follow leaf spot epidemics (Figure 11). Additionally, new fungicide active ingredients, such as the multi-site contact fungicide fluazinam (Secure™) and some of the new SDHI fungicides, are effective management tools for winter diseases of bermudagrass. Avoid the overuse of QoI (strobilurin) fungicides, which have a high potential for developing disease resistance.

RHIZOCTONIA LEAF AND SHEATH SPOT (ALSO KNOWN AS ´MINI-RING´)

There is no group of fungi more diverse than those in the genus *Rhizoctonia*. In fact, fungal taxonomists have proposed splitting the *Rhizoctonia* genus into at least three taxa: *Moniliopsis*, *Chrysorhyza*, and *Ceratorhyza*. The group of pathogens known as *Rhizoctonia solani* are the best-known members of the *Rhizoctonia* genus. In order to understand modern terminology and the context of turf diseases caused by different *Rhizoctonia* pathogens, we need to review some history.

Rhizoctonia solani was first described in 1858 as a pathogen of potatoes and since then has continued to be the most studied species group within the *Rhizoctonia* genus. *Rhizoctonia solani* is actually a group of separate and distinct biological species that we identify as subspecific groups. In turfgrass, the disease “large brown patch” first was observed on a bentgrass putting green at a golf course near Philadelphia in 1913. It was not until 1917 that C. V. Piper and H. S. Coe identified *R. solani* as the suspected causal agent of “large brown patch” in a red fescue turf garden in Philadelphia. Members of the species group *R. solani* affect all of the major warm- and cool-season turf species. But what are the characteristics of the genus *Rhizoctonia*? Most fungi produce spores as a result of sexual or asexual reproduction, but members of *Rhizoctonia* do not produce asexual spores. Members of the *Rhizoctonia* genus only are composed of mycelia and sclerotia in the asexual state, limiting the characteristics that can be used taxonomically.

Rhizoctonia solani fungi have a rapid growth rate and may or may not be pathogenic. Over many years, different forms of *R. solani* have been identified based on physiological and genetic differences that determine host range, pathogenicity, ecological niche, etc. We refer to "AG," which stands for "anastomosis group," followed by numbers and letters to identify specific forms. In turf, at least 4 AGs have been identified, with specific subgroups beyond AG. These are: AG 1, AG 2, AG 4, and AG 5. For example, AG 2-2IIIB is a cause of brown patch of tall fescue, ryegrass, and creeping bentgrass. Another subgroup of AG 2 is *R. solani* AG 2-2 LP, which causes large patch disease on warm-season grasses. We now generally distinguish the diseases and pathogen associations as "brown patch" on cool-season turf and "large patch" on warm-season turf.

OTHER RHIZOCTONIA

From the original identification of *R. solani* on red fescue until the mid-1970s, *R. solani* was the only fungus associated with turf diseases. However, in the mid-70s several researchers began to pay attention to "cool-season brown patch" that was being caused by a binucleate species of *Rhizoctonia* that obviously was not *R. solani*. Originally, cool-season brown patch was observed on bentgrass, *Poa*, and zoysiagrass. Eventually, Lee Burpee, now at the University of Georgia, identified the cool-season brown patch fungus as *R. cerealis* and named the disease it causes "yellow patch."

In the late 1970s and early 1980s, Martin and Lucas were the first to associate *Rhizoctonia zeae* with turfgrass diseases in the United States, although the fungus had been associated with Gramineae since its original description as a corn pathogen in 1932. Also, *R. oryzae* — originally identified in 1938 as a pathogen of rice causing "leaf and sheath spot" — was identified on turfgrass. *Rhizoctonia zeae* and *Rhizoctonia oryzae* are the names given to the asexual state of the pathogens that do not produce spores. However, both *R. zeae* and *R. oryzae* sometimes produce sexual states classified as *Waitea circinata* — a disease becoming common in *Poa* and *Poa*/bentgrass greens better known as "Waitea patch" or "brown ring patch."

In 1979, Christensen identified *Waitea circinata* as a *Rhizoctonia* disease on turfgrasses in New Zealand, but noted that the sexual state was not formed with his isolates. Interestingly, Christensen also reported *Waitea circinata* isolates in his trials were immune to benomyl. A couple of years later, isolates of *R. zeae* from the United States were also shown to be immune to benomyl. It is now accepted that *R. zeae*, *R. oryzae*, and *R. circinata* var. *circinata* are intolerant of benzimidazole fungicides — including benomyl and thiophanate-methyl — complicating the management of *Rhizoctonia* leaf and sheath spot in bermudagrass.

LEAF AND SHEATH SPOT ON BERMUDAGRASS

Outbreaks of a different disease on bermudagrass putting greens began to be more frequent after the introduction and use of ultradwarf bermudagrasses. Symptoms of the new disease included distinct rings from a few inches to greater than a foot in diameter occurring in spring and fall on non-overseeded putting greens (Figure 12). Disease symptoms initially were prominent in the southeastern U.S. and Gulf coastal regions, but they also have been observed across the world on bermudagrass putting greens. The disease became known as "mini ring," and initially the causal agent was unknown. However, symptoms of the disease corresponded exactly with symptoms of leaf and sheath spot caused by *R. zeae*.

In states like South Carolina, North Carolina, Georgia, Mississippi, Alabama, Louisiana, and Texas, similar symptoms have been observed on ultradwarf bermudagrass putting greens. In South Carolina, *R. zeae* is a well-documented pathogen of creeping bentgrass putting greens, causing brown patch-like symptoms in the heat of summer. *R. zeae* also has been frequently observed causing similar

Figure 12. Severe Rhizoctonia leaf and sheath spot. Photo by S. B. Martin.

Figure 13. Rhizoc leaf and sheath from aggressive verticutting. Photo by S. B. Martin.

symptoms on overseeded turfgrasses, primarily *Poa trivialis*, during fall and spring when temperatures are warm and humidity is high. Additionally, *R. zeae* has been identified and pathogenicity documented on St. Augustinegrass, centipedegrass, and seashore paspalum. In all cases, the disease has not been controlled with benzimidazole fungicides.

Recent outbreaks of *Rhizoctonia* have occurred in the southeastern U.S. on both of the common ultradwarf bermudagrass cultivars on putting greens, Tifdwarf and Tifgreen. Although timing varies, disease generally is first noticed in mid-August to early fall in the northern hemisphere. Sometimes infections may persist throughout winter and into spring, leaving necrotic rings similar to spring dead spot. However, overwintering rings caused by *Rhizoctonia* generally heal rapidly as temperatures warm and promote good bermudagrass growth.

Initial symptoms of *Rhizoctonia* are bronze patches from a few inches to a foot or more in diameter. If not controlled quickly with fungicides, the pathogen blights and bleaches the lower leaves of turfgrasses, resulting in a persistent distinct patch symptom that is very slow to heal when days are shorter and night temperatures cooler. Difficulty healing from the disease likely is more problematic in Transition Zone climates than in more tropical or subtropical environments where turf recuperative potential is prolonged. However, persistent symptoms have been noted in other locations, including more tropical climates.

Why are *Rhizoctonia* outbreaks increasing in frequency? Possible reasons include a now familiar refrain: reduced fertility, adoption of shallow-rooted ultradwarf bermudagrass cultivars, nutrient deficiency due to culture in sand-based greens, increased use of thiophanate-methyl in summer for bermudagrass decline or nematode suppression, increased emphasis on low cutting heights to provide fast putting green speeds. In several instances, stress induced by aggressive verticutting has preceded severe outbreaks of *Rhizoctonia* leaf and sheath spot (RLSS) (Figure 13). Low nutrition or reduced recuperative potential caused by any of the reasons outlined would be expected to increase disease severity and prolong symptom expression.

Where are we now with the management of RLSS? Much better off for several reasons: Generally, superintendents are increasing height of cut and incorporating more topdressing and rolling, a lesson learned from previous research outlined in this article on cool-season greens. Also, superintendents have learned that ultradwarf bermudagrasses do not heal quickly when aggressively verticut and have adopted strategies to groom and verticut less aggressively while incorporating more fine-sand topdressing to manage grain and thatch and improve putting surfaces. As other options to manage nematodes have been adopted — e.g., the use of Avid® 0.15EC — while paying heed to potential flare-ups of RLSS with thiophanate-methyl, incidents of RLSS have decreased. Another possibility is that we have better, although not complete, information regarding timing of preventive fungicides. As a

Table 1
Currently available SDHI fungicides and their relative efficacy for controlling major diseases of cool- and warm-season turfgrasses

Trade Name	Velista™	Xzemplar®	Lexicon™	Emerald®	ProStar®
Common Name	penthiopyrad	fluxapyroxad	fluxapyroxad pyraclostrobin	boscalid	flutolanil
Formulation	50WG	2.47SC	4.17SC	70WG	70WG
Phytomobility	acropetal	acropetal	acropetal	acropetal	acropetal
FRAC Code	7	7	7 + 11	7	7
Year of Release	2015	2014	2014	2003	early 1990s
	------ **Efficacy Rating** ------				
Cool-Season Turf					
Anthracnose	+++[z,y]	N	++++[x]	N	N
Brown Patch	++++	++++	++++	N	++++
Brown Ring Patch	++	L	L	N	++++
Dollar Spot	+++	++++	++++	++++	N
Fairy Ring	L	L	L	L	++
Summer Patch	L	L	+++	N	N
Warm-Season Turf					
Large Patch	++++	+++	++++	L	++++
Spring Dead Spot	++++	++	++++	N	N
Leaf Spot (*Bipolaris* spp.)	++	++++	++++	N	N
Leaf and Sheath Spot	L	L	L	N	+++

[z] Rating system for fungicide efficacy is as follows: 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness.

[y] Efficacy ratings based on Vincelli and Munshaw 2015. Chemical control of turfgrass diseases 2015, and performance of fungicides in various disease control trials.

[x] Rating based on assumption that *C. cereale* population is susceptible to strobilurin fungicides.

pathogen that grows best around 90 degrees Fahrenheit, initial infections typically begin in May to June but can persist throughout summer. Because bermudagrass grows vigorously in summer heat, symptoms may not occur until late summer and fall. Spring and summer fungicides aimed at suppressing fairy rings in greens also may provide some preventive control of RLSS. Still, symptoms of RLSS can appear quickly and are seen every year. More research is needed to investigate whether specific nutrients affect the development of RLSS. Other stress conditions, such as aggressive verticutting, drought stress, and the presence of nematodes may influence RLSS. Alleviating stresses may provide management solutions. Fungicides and fungicide programs clearly also help, but it has become clear that curative fungicide applications are likely to fail unless coupled with increased fertilization.

It does appear that RLSS is another disease that has become more common due to combinations of factors associated with modern putting green management.

INNOVATION IN SUCCINATE DEHYDROGENASE INHIBITOR (SDHI) CHEMISTRY

Development of fungicide active ingredients within the SDHI chemical class has produced new options for disease control. Recently, two new SDHI fungicides have been released: Xzemplar® (fluxapyroxad) in 2014 and Velista™ (penthiopyrad) in 2015. However, SDHI fungicides are not a new chemical class. Existing SDHI fungicides include Emerald® (boscalid) and ProStar® (flutolanil), both of which are effective materials but have limited spectrums of activity. Emerald® is almost exclusively used for dollar spot control, and ProStar® is primarily used to control *Rhizoctonia* diseases and fairy ring. What makes the new SDHI fungicides unique is that they have a broader spectrum of activity against several important diseases of cool- and warm-season grasses (Table 1). Xzemplar® and Velista™ are both single-site mode of action fungicides and work by inhibiting fungal respiration in complex II of the mitochondrial electron transport chain. Both

Table 2
Dollar spot incidence and brown patch severity affected by SDHI fungicides applied preventively to SR 7150 colonial bentgrass fairway turf at the Plant Science Research and Education Facility in Storrs, Conn., during 2013

Treatment	Rate per 1,000 ft^2	Int[z]	Dollar Spot Incidence		Brown Patch Severity		
			4 July	19 July	4 July	11 July	19 July
			---- # of spots $18ft^{-2}$ ----		--------- % plot area blighted ---------		
Emerald	0.13 oz	21-d	0.6 b	0.6 b	18.5 b	54.1 b	67.0 b
Emerald	0.18 oz	21-d	0.0 b	0.4 b	0.4 c	5.2 c	22.3 c
ProStar	1.5 oz	21-d	21.6 a	19.4 a	0.0 c	0.0 d	1.3 d
ProStar	3.0 oz	21-d	20.5 a	17.2 a	0.0 c	0.0 d	0.0 e
Velista	0.3 oz	21-d	1.5 b	2.9 b	0.0 c	0.0 d	0.0 e
Velista	0.5 oz	21-d	0.6 b	1.7 b	0.0 c	0.0 d	0.0 e
Xzemplar	0.16 fl oz	21-d	0.2 b	0.9 b	0.0 c	0.0 d	0.4 d
Xzemplar	0.26 fl oz	21-d	0.0 b	0.5 b	0.0 c	0.0 d	0.0 e
Untreated			13.2 a	11.6 a	40.1 a	75.0 a	87.1 a
Days after treatment		21-d	7	1	7	14	1

[z] All treatments were applied on 27 June and 18 July.

[y] Treatment means followed by the same letter, within each column, are not significantly different based on Fisher's protected least significant difference test ($\alpha = 0.05$).

Xzemplar® and Velista™ are acropetal penetrants, moving upward in the xylem.

In field trials conducted in Connecticut, Xzemplar® and Velista™ have provided good to excellent control of dollar spot and brown patch (Table 2). Xzemplar® has provided better dollar spot control than Velista™ at extended application intervals; however, both provide excellent control when applied on a 14-day interval (Figure 14). Based on a few reports, both fungicides provide suppression of summer patch and may be useful where disease pressure is low. Xzemplar® and Velista™ differ in the ability to control anthracnose. Velista™ applied at 0.5 ounce per 1,000 square feet, or tank mixed at a lower rate with another effective fungicide, has provided good anthracnose control on annual bluegrass putting greens (Figure 15). Lexicon™ Intrinsic™ — a premix

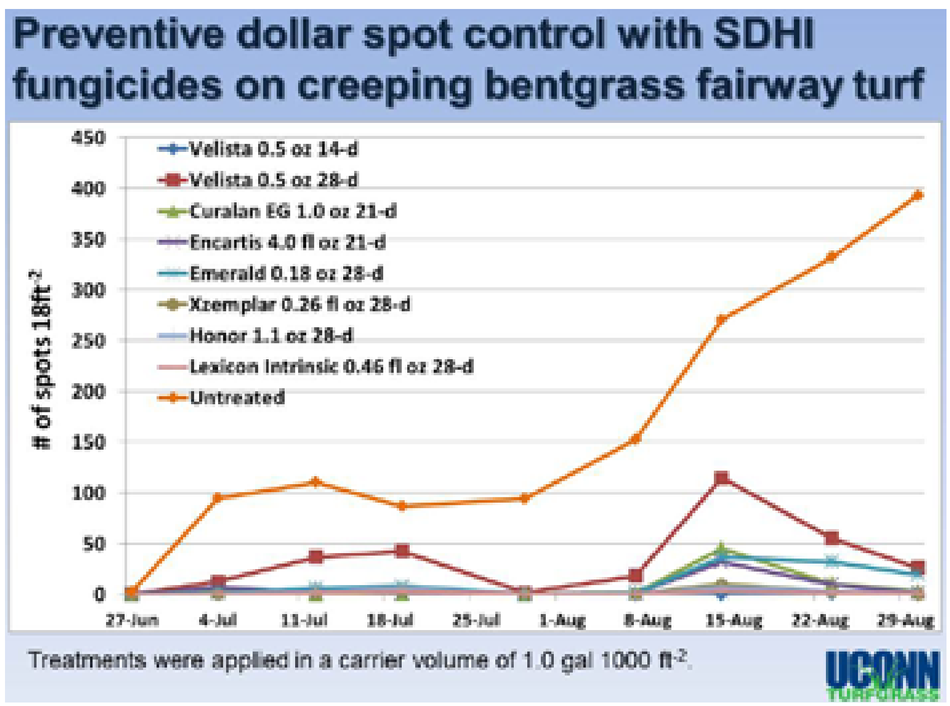

Figure 14. A difference among SDHI fungicides is the duration of effective dollar spot control that is possible.

of fluxapyroxad (Xzemplar®) and pyraclostrobin (Insignia®), was released at the same time as Xzemplar®. The addition of pyraclostrobin to fluxapyroxad will improve control, compared to Xzemplar alone, of diseases like summer patch and anthracnose where strobilurin-resistant *C. cereale* populations do not exist.

Limited testing of new SDHI fungicides has been conducted on warm-season turfgrass diseases, but some data are being generated that show very good results on bermudagrass diseases. One of the most significant results is that both Xzemplar® and Velista™, as stand-alone active ingredients, provide moderate to excellent control of spring dead spot. Although results are preliminary, it looks as though Velista™ is providing near-perfect control of SDS on ultradwarf greens at the high rate of 0.7 ounce per 1,000 square feet. Velista™ is labeled for SDS with a 2ee label — label expansions typically are added as data show consistent efficacy for new diseases not on the original label. Based on trials in South Carolina, Xzemplar® may provide less SDS control as a stand-alone product, but Lexicon™ Intrinsic™ is providing outstanding control of SDS with two fall applications at 0.47 ounce per 1,000 square feet (Figure 16). Interestingly, the outstanding results from Lexicon™ appear to be a case of true synergism, as SDS is poorly controlled by QoI fungicides, including pyraclostrobin. It should be noted that Insignia® Intrinsic™ was never labeled for SDS due to this poor efficacy.

Dollar spot is less of a problem on bermudagrass than creeping bentgrass or annual bluegrass greens, but both Xzemplar® and Velista™ provide excellent dollar spot control on bermudagrass and cool-season species.

Also, Xzemplar® and Velista™ both control bipolaris leaf spot. Data from South Carolina show somewhat better bipolaris leaf spot activity from Xzemplar® than Velista™. Both fungicides also appear to have very good activity as components of managing fairy ring caused by *Lycoperdon pyriforme* on bermudagrass.

Finally, outbreaks of *Microdochium* patch (*Microdochium nivale*) are occurring on non-overseeded bermudagrass greens during winter and spring. *Microdochium* patch may be a significant pathogen complicating spring transition. Less *Microdochium* patch has been observed in winter trials with Xzemplar®, Lexicon™ Intrinsic™, and Velista™ —

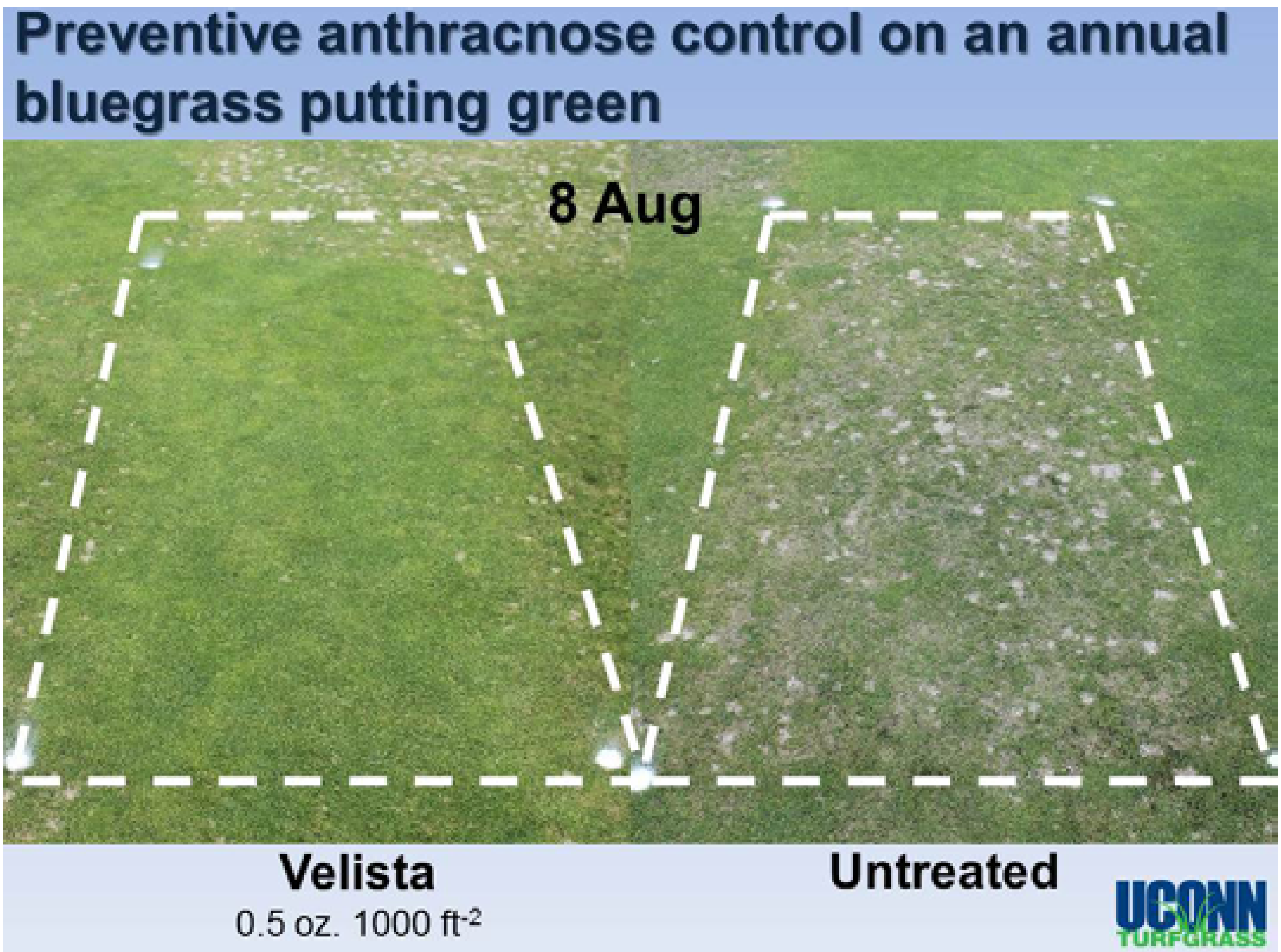

Figure 15. Good anthracnose control has been achieved with Velista as a low rate tank mix or alone at increased rates.

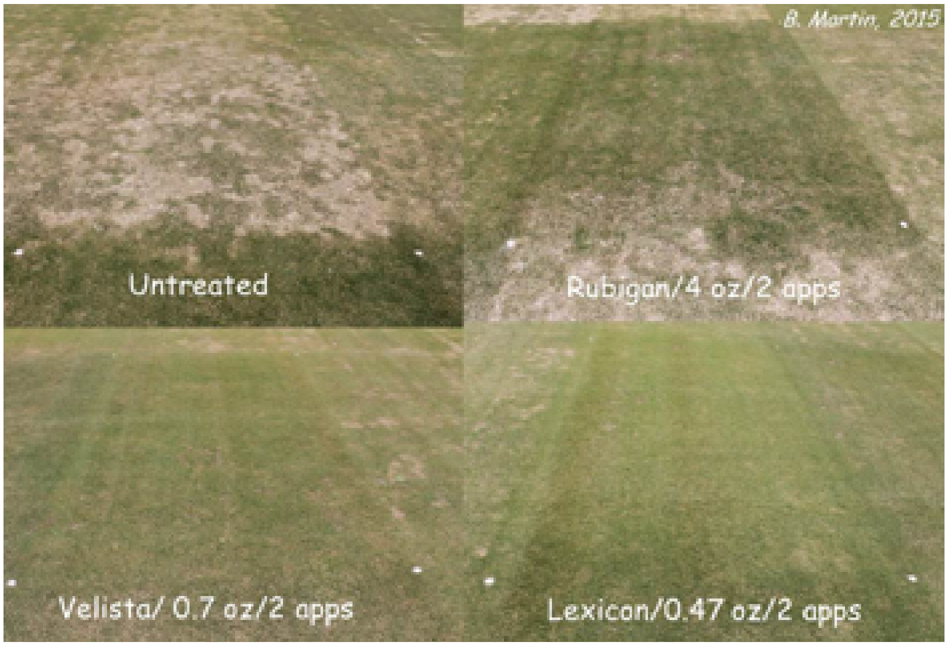

Figure 16. Disease severity of spring dead spot in ultradwarf bermudagrass on April 6, 2015. Each application noted was made in mid-September (first application) followed by a second application 28 days later (mid-October).

corresponding to better spring turf quality as a consequence.

The increase in SDHI fungicides with an expanded spectrum of activity will provide excellent opportunities for disease control and give more options for fungicide rotation programs and resistance management. However, recognize that resistance to SDHI fungicides also is very likely to develop over time. More SDHI fungicides are expected to come to market in the near future. With a broader spectrum of disease control being demonstrated by current-generation SDHIs and the increasing number of available SDHI products, there is no question that SDHI fungicides will be applied more often than before. For pathogens with a high potential to develop resistance — e.g., dollar spot, anthracnose, *Bipolaris* leaf spot, and possibly *Microdochium* patch — it will be very important to manage resistance to maintain the efficacy of SDHI fungicides for as long as possible.

SUMMARY

Controlling diseases of cool- and warm-season putting greens is particularly challenging due to the intensive level of management expected by golfers. As has been discussed, this is often due to several interacting factors; some we can control and some we can't. The good news is that lessons on the consequences of "ultra-putting green management" have been learned from outbreaks of diseases like anthracnose. Recently, putting green nitrogen fertility rates, and to some extent mowing heights, have started to increase. It seems golfer demands still influence many of our management decisions (Inguagiato, 2012).

Our knowledge of turfgrass diseases and the pathogens that cause them has come a long way since Monteith and Dahl wrote their manuscript in 1932. However, there still is much to learn. New opportunities for disease control using improved, disease-resistant cultivars, real-time environmental-monitoring devices, and plant activators are just a few emerging technologies that likely will play a more important role in disease management in the future. While there is much promise for the future, it is clear that there are many unanswered questions regarding the identification and biology of current and emerging turfgrass pathogens. A better understanding of turfgrass pathogens will continue to enhance our ability to develop sustainable, targeted, disease-management strategies.

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