Biology and pathology of turfgrass anthracnose

Anthracnose is a serious disease of cool-season turf on golf courses, but new genetic tools and cultivar development may limit the disease.

Editor's note: In the late 1990s and early 2000s, anthracnose disease and annual bluegrass weevils caused dramatic losses of annual bluegrass on putting greens in the northeastern United States. In response, in 2005, scientists from several universities formed the NE-1025 group to conduct research to solve problems related to these pests. As a result of the research, an initial set of best management practices was developed for anthracnose and annual bluegrass weevil control and published in GCM *in August 2008. The research project was completed in 2011, and the researchers are now publishing additional information on best management practices for anthracnose control in the May and June issues of* GCM. *The first two articles in the series make up this month's research section.*

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In the mid-1990s, anthracnose basal rot disease emerged as one of the key management issues facing superintendents who maintain annual bluegrass (*Poa annua*) putting greens. In this article, we provide an updated overview of the biology, host range, symptomology and epidemiological factors influencing the pathology of anthracnose basal rot.

Host susceptibility

Anthracnose is a common disease on grasses and cereal grain crops worldwide (3). Although numerous cool- and warm-season turfgrass hosts are susceptible to anthracnose, the disease is most damaging on annual bluegrass (*Poa annua*) and creeping bentgrass (*Agrostis stolonifera*) maintained at putting green height. For reasons not fully understood, annual bluegrass is particularly susceptible to anthracnose, with stands of the grass severely damaged when conditions are optimal for disease development. Because anthracnose attacks weakened or

Anthracnose on the annual bluegrass putting green at Ridgewood CC, Paramus, N.J. **Photo courtesy of P. Majumdar** senescent turf, annual bluegrass is especially vulnerable when maintained under conditions of low mowing, low fertility or drought stress. The risk of anthracnose infection to annual bluegrass turf is further intensified during hot, humid weather.

Anthracnose disease may also develop on other cool-season turfgrass species such as fine fescues (*Festuca* species), Kentucky bluegrass (*P. pratensis*), ryegrasses (*Lolium* species) and velvet bentgrass (*A. canina*), but is uncommon and rarely destructive on these grasses (7). Anthracnose also occurs on warm-season turfgrasses such as centipedegrass (*Eremochloa ophiuroides*) and bermudagrass (*Cynodon dactylon*) (6,15).

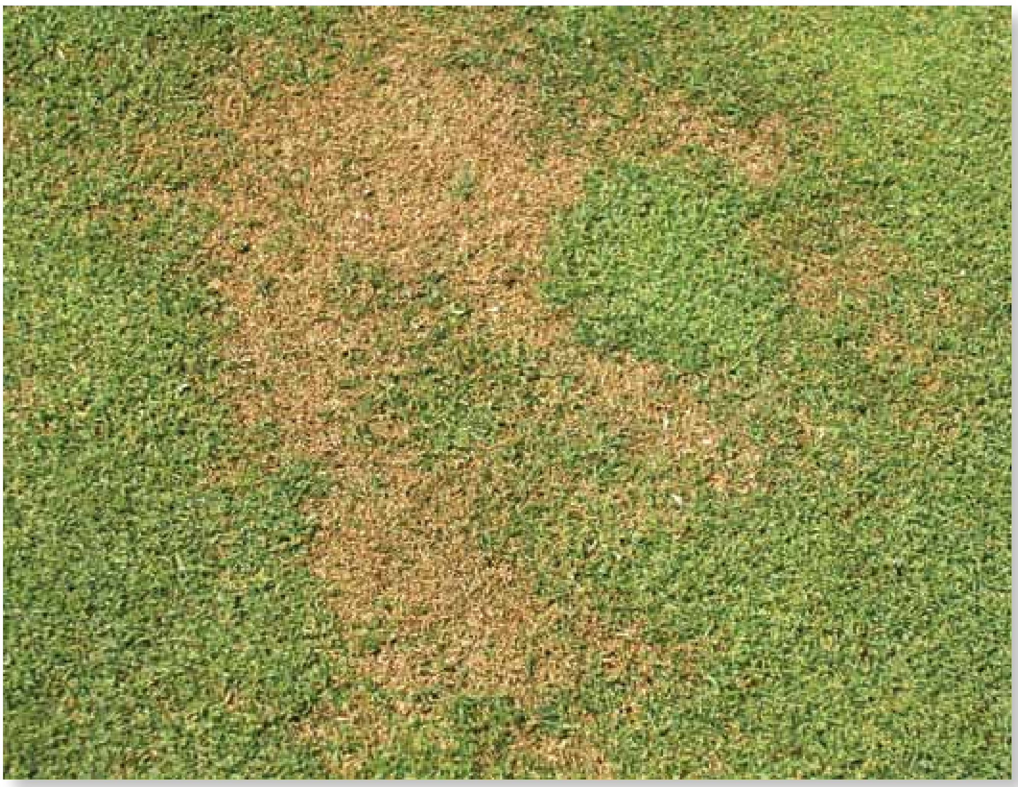
Anthracnose of cool-season turf

The pathogen causing anthracnose disease in cool-season grasses, the fungus *Colletotrichum cereale*, inhabits temperate climate zones across the United States, Canada, Western Europe, South America, Southeast Asia, New Zealand and Australia (3). *Colletotrichum cereale*, previously called *C. graminicola*, closely resembles other *Colletotrichum* fungi that cause anthracnose disease in corn, sorghum, switchgrass, sugarcane and other members of the grass family. However, while *C. cereale* and other grass anthracnose pathogens are related to each other, DNA fingerprint analysis shows they are unique organisms, each infecting entirely different hosts (4).

Colletotrichum cereale has been documented in the United States for more than a century (7). The fungus was first described in 1908 from Ohio, where *C. cereale* was observed infecting several cool-season grasses, including Kentucky bluegrass, redtop (*Agrostis gigantea*), orchardgrass (*Dactylis glomerata*), and grain crops such as wheat (*Triticum aestivum*) and rye (*Secale cereale*) (3). Anthracnose of annual bluegrass was first diagnosed in 1928 from New Jersey, where *C. cereale* was observed infecting roots and basal leaves (16).

Colletotrichum cereale inhabits many environments outside of golf courses, including ornamental grasses, residential lawns, meadows, forage grasses, prairies and natural grasslands (7). Sporadic anthracnose disease outbreaks caused by *C. cereale* occurred in wheat, cereal rye and oats (*Avena sativa*) during the first part of the 20th century, often in association with low fertility (3). Today, with the exception golf course turfgrass, *C. cereale* rarely triggers disease; however, the fungus is able to colonize other hosts without visibly affecting plant health (7).

Even though *C. cereale* infects a wide range of cool-season grasses, DNA fingerprint analysis of the fungus collected from cool-season grasses in the United States, Canada, Japan, Australia and Europe has shown that individuals from different host plants are members of 11 distinct population groups (7). These populations are predominantly



Anthracnose symptoms on annual bluegrass putting green turf. Photo courtesy of B. Clarke

divided according to host association. Only one of the 11 *C. cereale* populations includes individuals from both turfgrass and non-turfgrass hosts (for example, agronomic crop plants, native grasses, etc.). Most turfgrass strains of this pathogen possess unique DNA fingerprints that separate them from *C. cereale* collected from other host plants. Additionally, DNA fingerprints from individuals of *C. cereale* infecting annual bluegrass are dissimilar from fingerprints of the fungus infecting creeping bentgrass.

Anthracnose of warm-season turfgrasses

Anthracnose in warm-season turfgrass is less common and less destructive than the disease that affects annual bluegrass and creeping bentgrass. Consequently, anthracnose has been poorly studied in warm-season turfgrasses. Recent DNA research has shown that anthracnose of warm-season turfgrasses is not caused by the same species of *Colletotrichum* that is responsible for disease in cool-season

Top: Anthracnose on centipedegrass turfgrass. Photo courtesy of M. Tomaso-Peterson
Bottom: *Colletotrichum cereale* acervuli with setae on leaf sheath of annual bluegrass. Photo courtesy of L. Stowell

turfgrass (*C. cereale*), although these fungi do share similarities in their appearance (5). Given the many anatomical, structural, metabolic and biochemical differences between cool-season and warm-season grasses, this finding is not surprising. The dissimilarity between the different anthracnose pathogens may reflect adaptations to the unique hosts that they infect.

Anthracnose of centipedegrass is caused by *C. eremochloae*, a newly discovered fungus that is a closely related sibling of the fungus responsible for sorghum anthracnose, *C. sublineola* (6). Recent DNA fingerprinting of anthracnose fungi from preserved centipedegrass samples intercepted by United States port authorities in 1923 indicates that *C. eremochloae* was likely introduced along with the host when it was first imported from China during the early 20th century (6). Anthracnose on zoysiagrass (*Zoysia* species) and bahiagrass (*Paspalum notatum*) is associated with *C. caudatum* and *C. paspali* in Japan, but it is unknown whether these fungi are present on these turfgrass hosts in North America (3). The anthracnose pathogen of bermudagrass is a species of *Colletotrichum* that has not yet been identified.

Symptomology, diagnosis and the disease cycle

Host infection by the anthracnose fungus

Knowledge of anthracnose biology in turfgrass is still incomplete. Nonetheless, several stages of the life cycle of *Colletotrichum cereale* are known, and research from related *Colletotrichum* grass pathogens provides insight into how the infection process presumably works in annual bluegrass and bentgrass.

Although anthracnose outbreaks sometimes occur on infected turfgrass in winter, the fungus is believed to be largely inactive during cold weather. *Colletotrichum cereale* is thought to survive harsh winter conditions as fungal mycelium in decaying plant residues or living host tissues. On oats and barley (*Hordeum vulgare*) crops, *C. cereale* survives the winter months by forming dormant resting structures called *sclerotia* on roots close to the soil surface, but this aspect of the fungal lifecycle has not been studied in turf (3).

Colletotrichum cereale spreads from plant to plant through the movement of crescent-shaped, asexual reproductive spores called *conidia*. Warm weather, high humidity and high light intensity all serve to promote conidia formation. This is one of the reasons why anthracnose is so common in summer. Laboratory studies have shown that some isolates of *C. cereale* grow best between 70 F and 88 F (21.1 C and 31.1 C) and are able to cause foliar infection between 81 F and 91 F (27.2 C and 32.8 C) (8).

Colletotrichum cereale conidia are transported by wind and water, or mechanically through foot trafffic, mowers or other equipment. Upon contact with a susceptible turfgrass plant, the conidia germinate within approximately two to six hours, and a structure called a *germ tube* is produced. Formation of the germ tube leads to the development of a suction cup-like object called an *appressorium*, a dark-brown, dome-shaped structure measuring less than 0.01 inch (0.25 millimeter) in diameter. Appressoria (plural of appressorium) adhere firmly to the host, allowing the fungus to penetrate the outer plant cuticle into the underlying tissue via a penetration peg that forces its way into the plant using tremendous pressure.

Although this pressure has never been calculated for *C. cereale*, optical wave measurements have shown that a single appressorium from the related corn pathogen *C. graminicola* is able to exert forces up to 25 µN on host tissue (1). To put this in perspective, if a force of 17 µN were exerted across the palm of a human hand, that individual would be able to lift a school bus weighing almost 17,000 pounds (7.7 metric tons). The formation of appressoria has been observed within six hours after conidia make contact with leaves or stems, and penetration of host tissue may occur within 24 hours (12). High humidity and/or extended periods of leaf wetness are critical during this time, since desiccation of germinating condia will greatly reduce the potential for infection.

Symptoms and signs of anthracnose basal rot on annual bluegrass. Photo courtesy of P. Landschoot

Symptoms/diagnosis of anthracnose on cool-season turf

It is unknown how long it takes for symptoms to develop once *Colletotrichum cereale* conidia first adhere to the surface of a susceptible host, and symptom expression may vary depending on environmental conditions. For example, in field studies performed over consecutive years in New Jersey, annual bluegrass turf exhibited symptoms of basal rot anthracnose between five or 18 days after inoculation with *C. cereale* conidia (10).

Infection of leaf or stem tissue with *C. cereale* results in the development of *acervuli* (reproductive bodies containing conidia) on the surface of the host tissue; these structures may become abundant as the disease progresses. Acervuli are cushion-like fruiting bodies composed of a mat of fungal *hyphae*. Hyphae within acervuli give rise to two important structures: *setae* and conidia. Setae are thin, tapering, black hair-like structures that project from the acervuli; these structures are a key diagnostic feature of the anthracnose fungus and can be easily detected using a hand lens. The acervuli are also the primary site of conidia production, and as such provide a source of future infections.

Conidia within the acervuli are suspended in a sticky liquid that serves to protect the conidia from drying, prevents the conidia from premature germination, and may aid the fungus in initiating infection (3). When acervuli are splashed with water, this liquid is diluted, germination inhibitors are broken down, conidia are moved to fresh new host tissue, and the disease cyle begins anew.

Anthracnose is most severe during warm, humid weather. Nonetheless, outbreaks may occur throughout the year, causing either a foliar blight or a basal rot of leaf sheaths, crowns and stolons (15). Both basal rot and foliar blight symptoms are favored by high temperatures (85 F-95 F; 29.4 C-35 C) and may be present simultaneously on annual bluegrass, especially when turf is under heat stress.

Anthracnose symptoms on cool-season turfgrasses vary based on the host plant. Symptoms on annual bluegrass initially emerge as yellow- to orange-colored spots between 0.25 and 0.5 inch (0.64-1.27 centimeters) in diameter (15). On creeping bentgrass, infected foliage becomes orange or red to reddish brown. If left uncontrolled, spots coalesce, forming large, irregular areas of blighted turf. Older or senescent leaves may be among the first colonized by the fungus. Infection of leaves close to the soil surface in close-cut turf often results in a characteristic "basal rot" symptom, where water-soaked, blackened tissue is easily pulled away from the crown.

Factors affecting disease severity

Scientists have observed that anthracnose is generally most destructive on weakened or senescent turf (15). During the past 10 years, research performed on annual bluegrass greens has provided data in support of this conclusion. Anthracnose may cause extensive injury when turf is maintained at a low height of cut, when fertility is low, or when the turfgrass is stressed by abiotic factors such as drought or excessive heat (10,11,13-15). However, contrary to earlier theories, data from recent field studies show that activities causing wounded tissue (for example, foot traffic, rolling, double-cutting and verticutting) do not appear to enhance the severity of anthracnose on turfgrass (10,11,13,14).

Consequently, although plant health and vigor have been demonstrated as major factors influencing disease severity, additional factors such as cultivar susceptibility, environment and variation in pathogen populations may also play a role in disease development. In particular, variable response to anthracnose has recently been documented on cultivars and experimental selections of creeping and velvet bentgrass (2). Anthracnose response from commercial cultivars of creeping bentgrass evaluated at Rutgers University ranged from very good disease tolerance (Shark, Penneagle II, Runner, Penn A-1, Tyee and Authority) to highly susceptible (Viper, Providence, Penncross, Brighton, Seaside II and Pennlinks II) (2). Similar research is ongoing with annual bluegrass, with certain clones and selections being developed at Penn State University that show improved tolerance to anthracnose disease (9).

Future research

Much remains to be learned about the anthracnose infection process and how differences across diverse populations of *Colletotrichum cereale* may affect disease severity and control on golf course putting greens. Progress in this area has been hindered by the lack of a reliable greenhouse inoculation procedure. Field inoculations have been sucessfully employed to evaluate the impact of management factors on anthracnose severity, resulting in the development of an evolving set of best management practices that have benefited superintendents throughout the world (see the companion articles in this issue and in the June 2012 *GCM*).

Development of a reliable greenhouse inoculation protocol will facilitate valuable investigations of turfgrass anthracnose disease under controlled environments, including dissections of the infection cycle, pathogenicity testing, screening of turfgrass cultivars for anthracnose resistance and experimental studies of the factors influencing host-pathogen interactions. Moreover, the use of an increasingly powerful and rapidly expanding set of DNA and genetic tools, including DNA sequencing of several anthracnose pathogen genomes, is continuing to enhance our ability to study and identify the mechanisms involved in the infection process and the suppression of anthracnose through improved management practices. This should also speed up new cultivar development by allowing breeders to identify and screen all of their turfgrass selections for anthracnose-resistance genes before even stepping foot into the field. The knowledge gained from this type of research will greatly enhance our understanding of anthracnose and the ability of superintendents to control this devastating disease in the future.

The research says

➔ Anthracnose is a serious disease of annual bluegrass and creeping bentgrass, but knowledge of anthracnose biology in turf is still incomplete.

➔ Anthracnose is most severe during warm, humid weather, but outbreaks may occur throughout the year.

➔ Anthracnose is most destructive on weakened or senescent turf; low fertility, low mowing heights, drought and excessive heat enhance the disease.

➔ Activities causing wounded tissue do not appear to enhance the severity of anthracnose on annual bluegrass putting greens.

➔ Cultivar susceptibility, environment and variation in pathogen populations may play a role in disease development.

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Best management practices for anthracnose on annual bluegrass

Using the correct cultural practices can lessen the severity of anthracnose disease on annual bluegrass.

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Anthracnose (caused by *Colletotrichum cereale*) is a destructive fungal disease that can destroy weakened turf and is particularly severe on annual bluegrass (*Poa annua*). It occurs throughout the United States, Canada and Western Europe (19) as well as Australia and Japan (2). Outbreaks of anthracnose on golf course putting greens started to increase in frequency and intensity during the mid-1990s (4,5,10,11). Since then researchers have determined that the severity of anthracnose is influenced by many of the management practices used by superintendents.

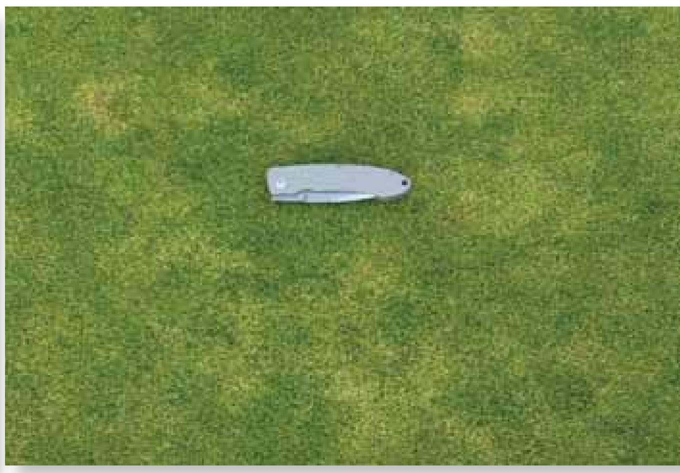
Scientists within the NE-1025 multi-state turf research project have reported their initial findings of how annual bluegrass management practices affect anthracnose disease (16). That report addressed the effects of nitrogen fertility, chemical growth regulation, mowing, rolling, topdressing, verticutting and irrigation on anthracnose of annual bluegrass putting green turf. This report updates our conclusions on these practices since 2008. These results are being used to revise a comprehensive set of best management practices for the control of anthracnose disease on golf courses.

Nitrogen fertility

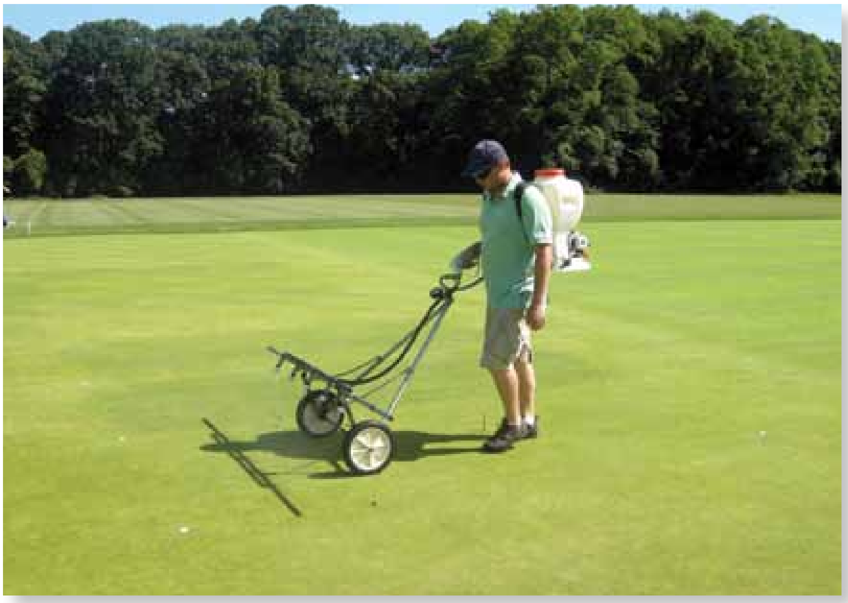
Soluble nitrogen

Management of nitrogen fertility is crucial to maintaining the health and vigor of the turf, which, in turn, affects playability ("speed" and smoothness of ball roll) on putting greens. Initial research clearly indicated that applying soluble nitrogen (0.1 pound/1,000 square feet [4.9 kilograms/hectare]) on a seven-day schedule from late spring through summer reduces anthracnose severity up to 24% compared to applying the same nitrogen rate every 28 days (5).

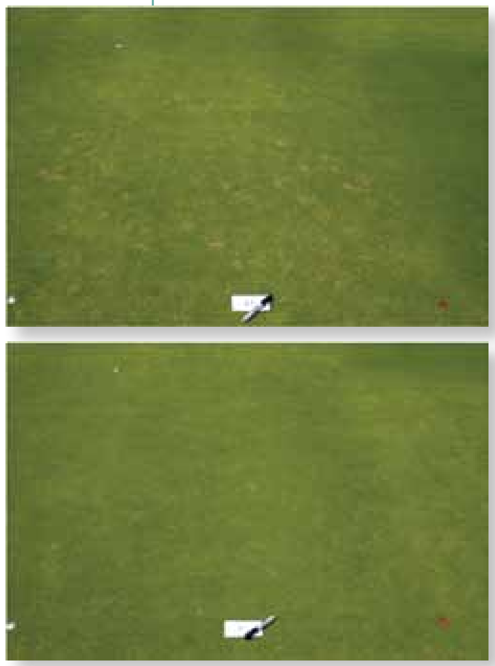
The exact reason(s) for reduced anthracnose severity in plants receiving greater nitrogen nutrition are not known, but improved plant vigor has been proposed (23). More recently, researchers have discovered that frequent soluble nitrogen fertilization reduces anthracnose severity as the nitrogen rate increases up to the equivalent



Anthracnose on annual bluegrass (basal rot and black acervuli on lower stem, left, and severe thinning associated with the disease on a golf course putting green, right). Photos by J. Roberts



Nitrogen is applied with a spray hawk to evaluate the impact of different nitrogen sources and rates on anthracnose. **Photo by J. Murphy**



Fall applications of granular nitrogen fertilizer (**top**) are not as effective as spring applications (**bottom**) in reducing anthracnose severity of annual bluegrass turf. **Photos by C. Schmid**

of 0.2 pound/1,000 square feet/week (9.8 kilograms/hectare/week) (15). In fact, short-term use of nitrogen at rates of 0.4-0.5 pound/1,000 square feet/week (19.5-24.4 kilograms/hectare/week) applied before disease symptoms become severe are very effective at reducing anthracnose severity. However, if these high rates are continued into the summer, disease severity increases dramatically (14,15).

A recent trial conducted to assess the effect of soluble nitrogen source on anthracnose severity of annual bluegrass putting green turf showed that potassium nitrate reduced disease severity, whereas weekly applications of ammonium sulfate increased anthracnose compared to urea, ammonium nitrate and calcium nitrate (15). Follow-up trials were initiated in 2011 to specifically assess the effect of potassium fertilization and soil pH on anthracnose. Further research is needed to confirm and clarify the first-year observations in these trials, but it appears that potassium deficiency may increase the severity of this disease. Greater soil acidity reduced the vigor of annual bluegrass, but it was not clear how much impact it had on anthracnose severity.

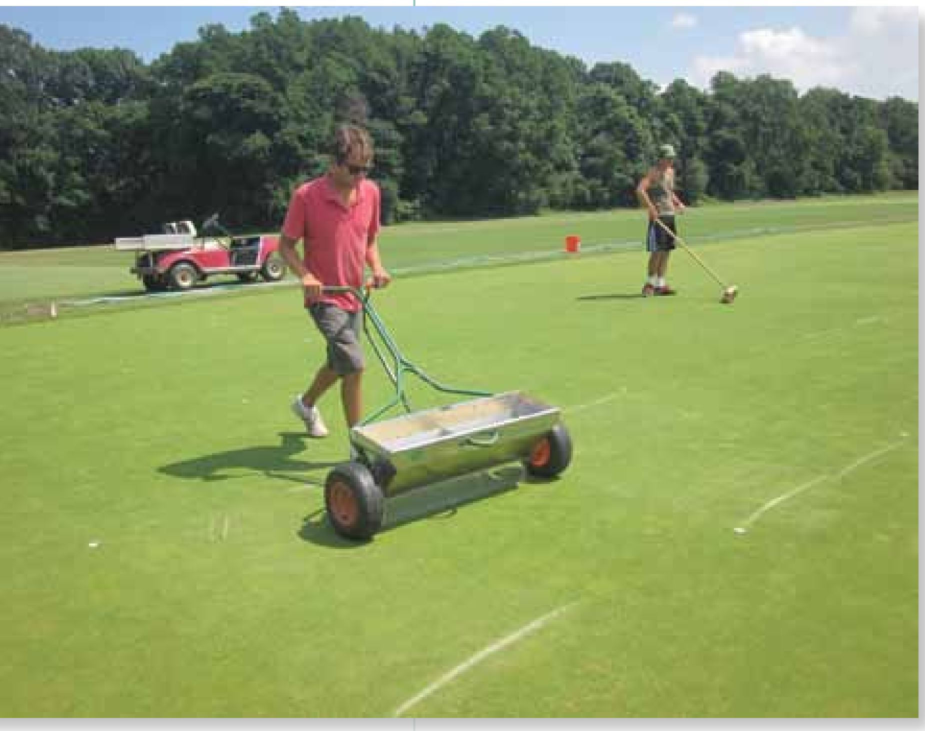
Granular nitrogen

Similar to previous results with soluble nitrogen, research on granular nitrogen (slow-release) has shown that applying higher rates of nitrogen in spring before anthracnose becomes severe reduces anthracnose severity. Interestingly, while slow-release granular nitrogen applied in the fall can reduce disease severity the next growing season, this tactic requires considerably more nitrogen (1.5 pounds or more per 1,000 square feet [≥73.2 kilograms/hectare]) than spring applications (13,14). Thus, superintendents with a history of anthracnose on their putting greens need to re-evaluate the common practice of late-season nitrogen fertilization because it is not an efficient or cost-effective tactic for managing anthracnose disease on annual bluegrass turf. Superintendents should strongly consider shifting more of their granular nitrogen from the fall to the spring if their program is currently weighted toward the fall.

Scientists have further observed that, despite the positive effects of spring fertilization with granular nitrogen, frequent soluble nitrogen applications are also needed through the summer to adequately suppress late-summer symptoms of anthracnose. Thus, best management practices for nitrogen fertilization include an emphasis on granular nitrogen fertilization from early to mid-spring (1-2 pounds/1,000 square feet [48.8-97.6 kilograms/hectare], possibly more under severe disease pressure), and frequent low-rate soluble nitrogen from late spring through summer (up to 0.2 pound/1,000 square feet every seven days).

Topdressing practices

Initial speculation frequently suggested that sand topdressing would contribute to anthracnose epidemics on putting greens. Although researchers have observed that sand topdressing may slightly increase disease when applications



Routine applications of sand topdressing at appropriate rates can significantly reduce anthracnose severity. Photo by R. Wang

are made at insufficient rates and/or intervals, this effect contrasts with the significant reduction in disease severity that occurs with routine applications of sand at appropriate rates. Research has consistently confirmed that aggressive programs involving frequent, moderate-rate topdressing (100 or 200 pounds/1,000 square feet [4.9-9.8 metric tons/hectare] every seven or 14 days) substantially reduce anthracnose during the growing season (9,12). Moreover, the beneficial effect of sand topdressing has been proved to hold true under conditions of intense foot traffic (that is, the equivalent of 200 rounds per day) with golf shoes fitted with soft spikes (12).

A study examining the method of sand incorporation (stiff- vs. soft-bristled brush, vibratory rolling or none) showed no effect on anthracnose. Moreover, sand particle shape (round vs. sub-angular) had little effect on disease severity, but, when a difference was observed, disease severity was lower in plots topdressed with sub-angular sand (unpublished data).

Summer sand topdressing has proved to be very successful at reducing anthracnose severity, yet superintendents have substantial challenges that limit the implementation of an aggressive topdressing program during mid-season. As a result, researchers have more recently examined the impact of spring and fall topdressing programs on anthracnose (15). Findings from this research indicate that fall and spring applications are also effective at reducing anthracnose severity, with spring being the most beneficial time of application. Therefore, it would be best for superintendents to implement an aggressive topdressing program (for example, 400-800 pounds/1,000 square feet [19.5-39 metric tons/hectare]) in spring, especially if it is not feasible to make frequent, moderate-rate topdressing applications during the summer. This research also indicates that superintendents should not forgo spring topdressing even if they implement an aggressive fall topdressing program. Although fall topdressing is beneficial, its positive effects on anthracnose do not last as long into the summer as those of spring topdressing, especially when summer topdressing is limited.

Irrigation management

Turf growing in saturated soil caused by poor surface drainage and slow internal drainage is more susceptible to anthracnose than turf that is not overwatered (20,22). In addition, research conducted in a growth chamber indicates that annual bluegrass plants subjected to drought stress before inoculation exhibit greater anthracnose disease (3). Field research has now confirmed that drought stress increases anthracnose severity on annual bluegrass (18). Specifically, irrigation regimes that subject turf to frequent wilt stress during warm, dry weather (that is, less than 60% ETo) will increase anthracnose disease. Moreover, overwatering turf (100% ETo) often results in increased anthracnose severity by the end of the summer. Superintendents should manage irrigation to minimize drought stress (that is, irrigating at 60%-80% ETo) while implementing practices that prevent saturated soil conditions to reduce anthracnose on putting greens.

Verticutting

Verticutting is used on putting greens to minimize puffiness (improve surface playability) and other problems associated with thatch accumulation. Although verticutting has been reputed to enhance anthracnose by wounding host plant tissue (4,10,19), research has not confirmed such speculation (5). Recent detailed studies examining the potential impact of mechanical injury (verticutting, coring and solid tining) on anthracnose while the disease was active indicate that wounding of leaves, crowns or stolons does not increase anthracnose severity on annual bluegrass putting greens (15). Thus, superintendents should not be overly concerned about cultivation (verticutting, coring and solid tining) programs contributing to anthracnose disease problems. In fact, a well-designed and properly implemented cultivation program should benefit an anthracnose management plan by creating an environment that supports healthy turf growth.

Mowing and rolling

Research has shown that low cutting height has a greater effect on anthracnose severity on putting greens than any other part of a mowing and rolling program. Low cutting heights will increase anthracnose severity (1,19), whereas more frequent mowing (double cutting) has no effect on this disease (6). It was formerly speculated that double cutting would intensify anthracnose by wounding leaf tissue but, as discussed above, recent mechanical injury studies have not supported this theory. Similarly, lightweight rolling, used to smooth the turf canopy and improve ball roll, was thought to increase stress and susceptibility to anthracnose on putting greens, but research (either with a vibratory or sidewinder unit performed every other day) indicates this practice either has no effect or slightly reduces the severity of this disease (6,13,14,17).

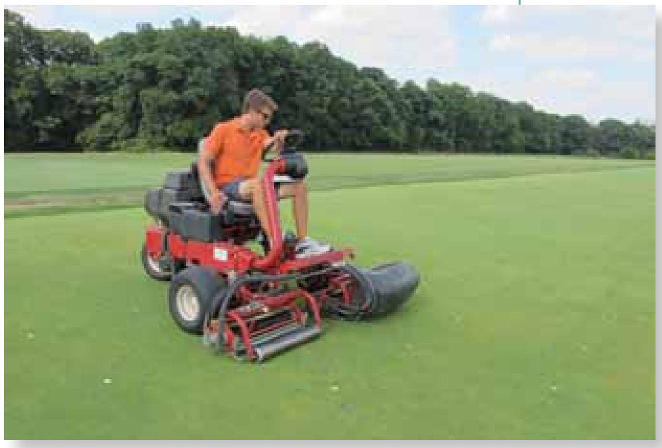
A study assessing the impact of additional traffic caused by the change of direction from rolling equipment and clean-up mowing along the perimeter of putting greens showed no intensification of anthracnose (12,17). Thus, any incidence of greater anthracnose severity at the perimeter of putting green is likely due to other factors.

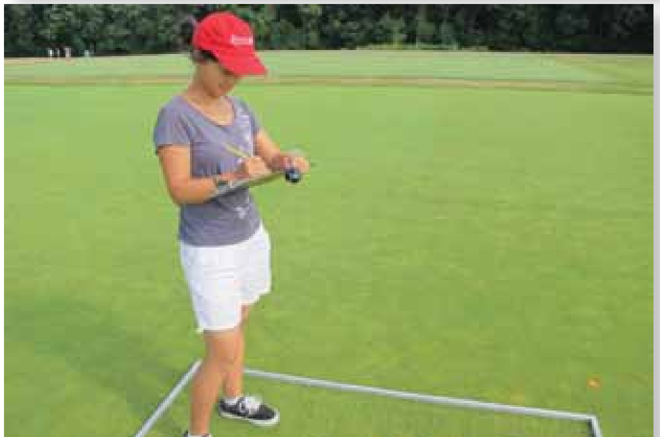
To improve anthracnose management, superintendents should favor a mowing and rolling program that avoids reducing the mowing height (for example, not less than 0.125 inch [3.2 millimeters]) and adopts the practices of either double cutting and/or rolling to improve playability (ball roll).

Plant growth regulators

Many superintendents use plant growth regulators (PGRs) to manage golf course turfgrass. Growth regulators commonly used to enhance annual bluegrass turf include Embark (mefluidide, PBI/Gordon) and Proxy (ethephon, Bayer), to regulate seedhead development, and Primo Maxx (trinexapac-ethyl, Syngenta) to improve shoot density and reduce shoot elongation. As stated in our previous *GCM* article, studies have not demonstrated any consistent effects of these PGRs on anthracnose disease (16).

Two recent studies examining the use of these PGRs alone or in combination indicate that, although they do not intensify anthracnose as was previously speculated, they can reduce disease severity in some cases (7,8). In fact, research suggests that PGR use may contribute to anthracnose suppression by enhancing nitrogen nutrition (8). However, more research on the interaction of PGRs and nitrogen nutrition is needed to gain better insight into this matter. Superintendents should continue to use PGRs to enhance turf quality and playability of annual bluegrass turf without concern that they might enhance anthracnose severity.





Top: Verticutting was not found to increase anthracnose severity on annual bluegrass putting greens. **Photo by R. Miller**

Bottom: Anthracnose disease severity was rated on test plots as part of the research carried out at Rutgers University. **Photo by J. Hempfling**

Summary

Best management practices for the control of anthracnose disease on annual bluegrass turf include adequate nitrogen fertilization in early spring followed by a frequent low-rate nitrogen fertility program initiated in late spring and continued through summer. Granular nitrogen rates of 1 to 2 pounds/1,000 square feet in early to mid-spring combined with frequent, soluble nitrogen applied at 0.1 to 0.2 pound/1,000 square feet/week in late spring and summer will be helpful in reducing anthracnose severity.

An aggressive topdressing program during the spring is particularly important if it is not feasible to implement a frequent program of moderate topdressing during the summer. Although fall topdressing can be important for other reasons, superintendents need to realize that its positive effects on anthracnose will not last as long into

BMPs for anthracnose on annual bluegrass greens

Nitrogen

- Apply nitrogen to maintain vigor of the putting green turf without overfertilizing.
- Apply granular nitrogen fertilization at rates of 1-2 pounds/1,000 square feet (48.8-97.6 kilograms/hectare) in spring (rather than fall) to reduce disease severity. Nitrogen rates up to 3.0 pounds/1,000 square feet (146.5 kilograms/hectare) in spring effectively suppress anthracnose but are recommended only if the historical disease pressure has been severe. At higher rates, include slow-release nitrogen as part of the fertilizer to extend the response and avoid a surge in growth.
- Begin summer nitrogen programs earlier in the year to allow nitrogen buildup in the turf, which will decrease anthracnose severity. In summer, apply a cumulative soluble nitrogen rate of 1.5-3.0 pounds nitrogen/1,000 square feet (73.2-146.5 kilograms/hectare) to reduce anthracnose severity. A program using a higher rate over summer will likely need less nitrogen in the spring; a higher spring rate is recommended if anthracnose is historically a problem in mid- to late spring.

Topdressing

- Sand topdressing applied every 7 days at 100 pounds/1,000 square feet or every 14 days at 200 pounds/1,000 square feet (4.9 or 9.8 metric tons/hectare) provides a protective layer of sand around the crown, slightly raising the effective height of cut and thus reducing anthracnose.
- Anthracnose is not affected by sand incorporation techniques; select methods that best incorporate sand yet minimize turf injury and wear on mowing equipment.
- Foot traffic on turf topdressed with sand reduces disease severity. Areas that receive daily foot traffic and sand topdressing will have better wear tolerance and decreased disease.
- Implement an aggressive topdressing program (for example, 400-800 pounds/1,000 square feet [19.5-39 metric tons/hectare]) in spring; apply rates at the higher end of this range if summer topdressing is not feasible. Spring topdressing is more effective at reducing anthracnose severity than fall topdressing.

Irrigation

- Increased anthracnose can result when annual bluegrass is consistently subjected to wilt stress or excessively wet conditions.
- Irrigating to replace 60%-80% of reference evapotranspiration and hand watering as needed to avoid wilt stress will provide high-quality playing conditions and reduce conditions favorable for anthracnose.

Mowing and rolling

- Mowing below 0.125 inch (3.2 millimeters) should be avoided whenever possible. If feasible, raise the cutting height as high as 0.141 inch (3.6 millimeters) for greater suppression of anthracnose. Slight increases in mowing height can significantly reduce disease severity.
- To maintain acceptable ball roll distances (~10 feet [3 meters]) at higher mowing heights, roll and/or increase mowing frequency. Rolling, regardless of roller type, and double cutting increase ball roll but will not enhance the disease.
- Rolling every other day may slightly reduce anthracnose severity.

Plant growth regulators

- Routine Primo Maxx (trinexapac-ethyl) use even at high rates and short intervals does not increase anthracnose severity. Benefits of improved turf tolerance to low mowing and enhanced plant health may help reduce disease in some cases.
- Embark (mefluidide) and Proxy (ethephon) can be used to suppress seedhead formation in annual bluegrass without increasing anthracnose.
- Embark or Proxy applied in March or April at label rates with subsequent applications of Primo Maxx at 0.125 fluid ounce/1,000 square feet (0.40 liter/hectare) every seven to 14 days, or 0.1 fluid ounce/1,000 square feet (0.32 liter/hectare) every seven days will provide the best turf quality and may reduce anthracnose.

Table 1. Best management practices for anthracnose disease on annual bluegrass putting green turf.

the summer as spring topdressing, so thorough spring topdressing is essential.

Deficit irrigation is important to maintain playability and conserve water, but it must be managed to avoid subjecting the turf to frequent episodes of wilt stress. In a successful deficit irrigation program, routine monitoring of turf and soil water content are essential to ensure the accurate detection of threshold conditions that precede wilt stress and trigger the decision to apply water.

Mowing and rolling programs should include either double cutting and/or rolling to improve playability (ball roll). Superintendents should also avoid reducing the mowing height to improve anthracnose management.

Chemical growth regulation with Embark, Proxy and Primo Maxx should not intensify and, in some cases, may reduce disease severity.

Funding

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The research says

- ➔ Provide adequate nitrogen fertilization in early spring, initiate frequent low-rate nitrogen fertility in mid- to late spring and continue through summer.
- ➔ If frequent moderate topdressing is not feasible in summer, aggressive topdressing in spring is essential.
- ➔ Fall topdressing will not replace spring topdressing for anthracnose control.
- ➔ Deficit irrigation must avoid subjecting the turf to frequent episodes of wilt stress.
- ➔ Use double cutting and/or rolling to improve playability, avoid reducing the mowing height to improve anthracnose management.
- ➔ Chemical growth regulation with Embark, Proxy and Primo Maxx should not intensify disease severity and may reduce it.

Teresa Carson

Photo by A. Chaves

Bacterial wilt of creeping bentgrass

Bacterial wilt of bentgrass, caused by *Acidovorax avenae* (presumably variety *avenae*), is widely distributed throughout the United States, where it causes a wilt and decline of creeping bentgrass. In the growth chamber, *A. avenae* isolates were fully pathogenic on several creeping bentgrass cultivars and colonial and velvet bentgrass, moderately affected annual ryegrass, and did not attack annual bluegrass or other turf-type grasses. Disease depends on weather conditions and health of the turf. Highly stressed turf (e.g, golf course turf) under high temperatures is most likely to be damaged. No chemical pesticides are currently labeled for control of the disease. Growth chamber studies showed that Daconil Action (acibenzolar-S-methyl + chlorotalonil, Syngenta) is effective at limiting disease symptoms when applied preventively, and Primo Maxx (trinexapac-ethyl, Syngenta) does not appear to increase disease symptoms. This work is funded by the USGA. **— Nathaniel Mitkowski, Ph.D. (mitkowski@uri.edu), University of Rhode Island**

Photo by A.D. Genovesi

Seeded zoysiagrass

This research focuses on the development of seeded zoysiagrass cultivars that are genetically stable with improved turf quality, high seed yields, persistence and competitive ability. In 2000, interspecific hybrids of *Zoysia japonica* and *Z. matrella* were made, yielding 1,600 progeny. After a two-year grow-in period, 53 lines were selected, 19 of which were fine-textured. The focus is on fine texture, seedhead production (density and height), turf quality and flowering time. Progeny derived from the fine-texture class seed parents have been advanced to a spaced plant nursery in 2011 for another cycle of a recurrent selection. Simultaneously, a replicated field trial was planted in 2011 for 15 of the fine-textured seeded families to evaluate their turf quality in 2012. This work is funded by the USGA. **— A. Dennis Genovesi, Ph.D. (d-genovesi@tamu.edu), and Ambika Chandra, Ph.D., Texas AgriLife Research Center-Dallas, Texas A&M University**

Photo courtesy of M. Fidanza

Fairy ring management

The causal organism for fairy ring may vary because multiple fungi cause the disorder. In 2011, the first year of a three-year study, 17 chemical and cultural treatments, including untreated healthy turf and untreated turf with fairy ring, were evaluated for suppression of active fairy ring on a golf course in Barrington, Ill. On July 18, treatments were applied and watered-in. Treatments were rated for visual quality (1-9) and color intensity (0-4), and Normalized Difference Vegetation Index was taken. There were no significant differences in visual quality or NDVI on any date, and no phytotoxicity occurred. On July 23, fairway flooding ended the aggressive outbreak of fairy ring, which did not return. This work is funded by the USGA. **— Michael Fidanza, Ph.D. (maf100@psu.edu), Pennsylvania State University; Derek Settle, Ph.D., Chicago District Golf Association; Henry Wetzel, Ph.D., Sustainable Pest Management**

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