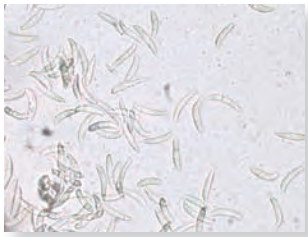
Managing anthracnose with fungicides

The future for anthracnose management looks brighter with new chemistries and an integrated management approach.



Editor's note: In the late 1990s and early 2000s, anthracnose disease and annual bluegrass weevil caused dramatic losses of annual bluegrass on putting greens in the northeastern United States. In response, scientists from several universities formed the NE-1025 group in 2005 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 published additional information on the biology of anthracnose disease and best management practices for cultural control of anthracnose in the May issue of* GCM. *The series concludes this month with the third and fourth articles, which discuss chemical control of anthracnose and the results of a survey concerning BMPs practiced by superintendents in their efforts to control the disease. To help communicate the results of this research, Bruce Clarke, Ph.D., and Jim Murphy, Ph.D., will present a 90-minute webcast about practical applications and BMPs for anthracnose control on Tues., Nov. 13, 12 p.m. CDT. For more details, see www.gcsaa.org/Education/Webcasts.aspx.*

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Golf course superintendents have struggled with anthracnose management since the 1970s, when this disease was first recognized as a problem on annual bluegrass (*Poa annua*) putting greens. Since then, the disease has become a major concern for both annual bluegrass and creeping bentgrass putting green management. Control of anthracnose has been complicated by many factors, principally that anthracnose is a stress-induced disease that attacks severely weakened turfgrass.

As detailed in the May issue of *GCM* (7), anthracnose development on greens is closely tied to cultural practices. Today's intensive putting green management regimes create turfgrass that is constantly stressed, so any lapse in fungicide protection can lead to rapid outbreaks of anthracnose. Indeed, curative approaches and applications of single fungicides often do not provide adequate control of the disease, so a preventive approach including tank-mixtures of multiple chemistries is commonly recommended for successful anthracnose control.

Anthracnose control with fungicides is further complicated by a lack of understanding of the disease biology. Scientists have not yet discovered where the pathogen overwinters in the turf canopy and what specific environmental conditions trigger pathogen activation and initial infection

This creeping bentgrass green is infected with anthracnose basal rot. The most severe damage appears in high-traffic or stress areas. **Photos by L. Tredway**

Fungicides for anthracnose control

Chemical class*	Fungicide	Systemicity	Utility†	FRAC class	Resistance risk	Examples
Benzimidazole[s]	thiophanate-methyl	acropetal penetrant	p/c	1	high	3336, Cleary Chemical
Dicarboximide[s]	iprodione	localized penetrant	p	2	moderate	Chipco 26GT, Bayer
DMI[s]	metconazole	acropetal penetrant	p/c	3	moderate	Tourney, Valent
	myclobutanil	acropetal penetrant	p/c		moderate	Eagle, Dow
	propiconazole	acropetal penetrant	p/c		moderate	Banner Maxx, Syngenta
	triadimefon	acropetal penetrant	p/c		moderate	Bayleton, Bayer
	tebuconazole	acropetal penetrant	p/c		moderate	Torque, Cleary Chemical
	triticonazole	acropetal penetrant	p/c		moderate	Trinity, BASF Triton FLO, Bayer
Mineral oil[m]	mineral oil	contact	p	NC	low	Civitas, PetroCanada
Nitrile[m]	chlorothalonil	contact	p	M	low	Daconil, Syngenta
Phenylpyrrole[s]	fludioxonil	local penetrant	p	12	moderate	Medallion, Syngenta
Phosphonate[s]	fosetyl-Al	true systemic	p	33	low	Chipco Signature, Bayer
	phosphite salt	true systemic	p	19	low	Alude, Cleary Chemical
Polyoxins[s]	polyoxin D	local penetrant	p		moderate	Endorse, Arysta
QoI[s]	azoxystrobin	acropetal penetrant	p/c	11	high	Heritage, Syngenta
	fluoxastrobin	acropetal penetrant	p/c		high	Disarm, Arysta
	pyraclostrobin	acropetal penetrant	p/c		high	Insignia, BASF
	trifloxystrobin	local penetrant	p/c		high	Compass, Bayer
SDHI[s]	penthiopyrad	acropetal penetrant	p	7	moderate	Velista, DuPont[§]

Table 1. Updated list of fungicides for anthracnose control.
* s, single-site inhibitor fungicide; m, multi-site inhibitor fungicide.
†p, preventive; c, curative.
§Not labeled for use at this time, but in late stages of commercial development.

of the turf in the spring. In anthracnose diseases in other crops, such as strawberry, the pathogen commonly infects the plant long before symptoms of the disease are expressed. These "latent" infections often turn pathogenic in the presence of certain environmental conditions such as high air temperatures or plant stress.

Because they do not know when the initial infections occur, superintendents often end up controlling anthracnose on a curative basis, after the fungus has already infected the turf plant. This limits the number of control options at the superintendent's disposal, as very few anthracnose fungicides have curative activity. The anthracnose pathogen is also more likely to become resistant to the chemistries with curative activity, such as the benzimidazoles, DMIs and QoIs. Resistance to the benzimidazoles and QoIs is now widespread in populations of the anthracnose pathogen, *Colletotrichum cereale*, and these products are no longer an effective option in many areas.

Fungicides for anthracnose control

Fungicides belonging to nine chemical classes are currently labeled for anthracnose control in turfgrasses. Since the 2008 publication of best management practices for anthracnose (6), several new products have been labeled for anthracnose in the United States, including several combination products (Tables 1, 2). These vary widely in their effectiveness against anthracnose and also in their ability to control the disease curatively (Table 3). As mentioned above, only the benzimidazole,

This creeping bentgrass shows characteristic symptoms of anthracnose basal rot.

Some combination products for anthracnose control

Chemical classes	Active ingredients	Product
Nitrile + DMI	chlorothalonil + propiconazole	Concert, Syngenta
Nitrile + DMI	chlorothalonil + triticonazole	Reserve, Bayer
Nitrile + QoI	chlorothalonil + fluoxastrobin	Disarm C, Arysta
Nitrile + QoI	chlorothalonil + azoxystrobin	Renown, Syngenta
Nitrile + SAR inducer	chlorothalonil + acibenzolar-S-methyl	Daconil Action, Syngenta
QoI + dicarboximide	trifloxystrobin + iprodione	Interface, Bayer
QoI + DMI	fluoxastrobin + myclobutanil	Disarm M, Arysta
QoI + DMI	azoxystrobin + propiconazole	Headway, Syngenta
QoI + DMI	trifloxystrobin + triadimefon	Tartan, Bayer
QoI + SDHI	pyraclostrobin + boscalid	Honor, BASF

Table 2. Examples of combination products available for anthracnose control.

Efficacy rankings

Active ingredient	Chemical class	Product name(s)*	Tredway ranking	Vincelli ranking
Azoxystrobin	QoI	Heritage	++++	3
Fluoxastrobin	QoI	Disarm	++++	3
Pyraclostrobin	QoI	Insignia	++++	3
Tebuconazole	DMI	Torque	++++	3
Chlorothalonil	nitrile	Daconil, Chlorostar (Regal), Echo (Sipcam), Legend (Cleary)	+++	3
Metconazole	DMI	Tourney	+++	3
Triticonazole	DMI	Trinity, Triton	+++	3
Polyoxin D	polyoxins	Endorse, Affirm	+++	3
Fludioxonil	phenylpyrolle	Medallion	+++	2+
Myclobutanil	DMI	Eagle	+++	2
Propiconazole	DMI	Banner Maxx, Kestrel (Phoenix), Savvi (Regal), Spectator (Lesco)	+++	2
Thiophante-methyl	benzimidazole	Cleary's 3336, Systec (Regal), T-Bird (Phoenix), T-Storm (Lesco)	+++	2
Triadimefon	DMI	Bayleton	++	1+
Trifloxystrobin	QoI	Compass	++	3+
Mineral oil	hydrocarbon	Civitas	+	2+

Table 3. Relative effectiveness of anthracnose fungicides based on multi-year performance, comparing observations from Tredway (http://turfdiseasemanagement.ncsu.edu/nc) and Vincelli and Williams 2012 (12). Rankings are from highest to lowest: ++++ to + (Tredway) and 3+ to 1 (Vincelli).

*Company names are in parentheses for products that are not mentioned elsewhere in the article.

DMI and QoI fungicides have significant curative activity against anthracnose. Because of these limited options and the high risk for resistance, it is imperative that anthracnose be managed on a preventive basis.

The recent trend toward the use of combination products offers some benefits in the sense that these often can control additional diseases such as dollar spot and brown patch, offer some control when fungicide resistance is present (for example, using a DMI and QoI if QoI resistance was present) or provide other plant quality or health effects. However, it should be noted that resistance to multiple fungicides still may develop, even in combination products, when both partners are single-site mode of action and if the combination products are overused.

Fungicide resistance: a widespread problem

Certain turfgrass pathogens, including *Colletotrichum cereale*, can develop resistance to single-site inhibitor fungicides. Widespread resistance to the QoI and benzimidazole fungicides, and to a lesser degree the DMIs, presents another major challenge in anthracnose management today. When treating any pathogen that is prone to develop resistance, single-site inhibitor fungicides must be used judiciously and in conjunction with multi-site inhibitor fungicides and appropriate cultural practices to slow or prevent resistance development.

The benzimidazole fungicides were first applied to turf in the 1960s, and the first cases of benzimidazole resistance in anthracnose populations were documented in the 1980s. The QoI fungicides were released into the turf market in 1997, and cases of QoI-resistant *C. cereale* were reported as early as 2000 (1). Several members of the NE-1025 project worked to document the distribution of fungicide resistance in U.S. populations of *C. cereale* and characterize the mechanisms responsible for resistance. The results of these surveys have been quite alarming and highlight the importance of judicious use of fungicides that are at risk for resistance development.

A survey of QoI sensitivity in California anthracnose populations was conducted after several control failures were observed in 1999 and 2000 (15). Isolates of *C. cereale* were collected from eight golf courses that had treated their greens with QoIs three or more times per year from 1997 to 2002. All of the isolates were classified as resistant to azoxystrobin, pyraclostrobin and trifloxystrobin in petri dish assays, and these fungicides also failed to control these isolates in growth chamber studies. Similar results

were reported in the southeastern U.S. (18). Of 19 *C. cereale* populations from creeping bentgrass and annual bluegrass, 18 were dominated by QoI-resistant isolates. Although the distribution of QoI resistance has not been formally surveyed in other parts of the country, lack of anthracnose control from QoIs has been observed in trials in Pennsylvania (10,11) and New Jersey (9).

Surveys of benzimidazole resistance in anthracnose populations have yielded similar results. In California, seven of 10 *C. cereale* populations were dominated by benzimidazole-resistant isolates (13). In the southeastern U.S., all the populations that were QoI-resistant were also benzimidazole-resistant (17).

Because of the widespread nature of QoI and benzimidazole resistance in anthracnose populations, these fungicides are no longer considered an effective control option in most locations. New facilities or those that have not previously used benzimidazoles or QoIs may be able to obtain anthracnose control from these products but should proceed with extreme caution, avoid sequential applications, and tank-mix them with a fungicide that has a low risk of resistance (for example, chlorothalonil) in an effort to slow the buildup of resistant strains.

Because DMI fungicides also carry a moderate risk for fungicide resistance, California populations of *C. cereale* were surveyed for sensitivity to DMIs (14). Isolates from locations that were routinely treated with DMI fungicides for at least 10 years showed some reduced sensitivity to the DMIs. However, after researchers demonstrated that DMIs effectively controlled these isolates in growth chamber experiments, they concluded that the observed reductions in sensitivity were not sufficient to significantly affect the efficacy of DMIs in the field.

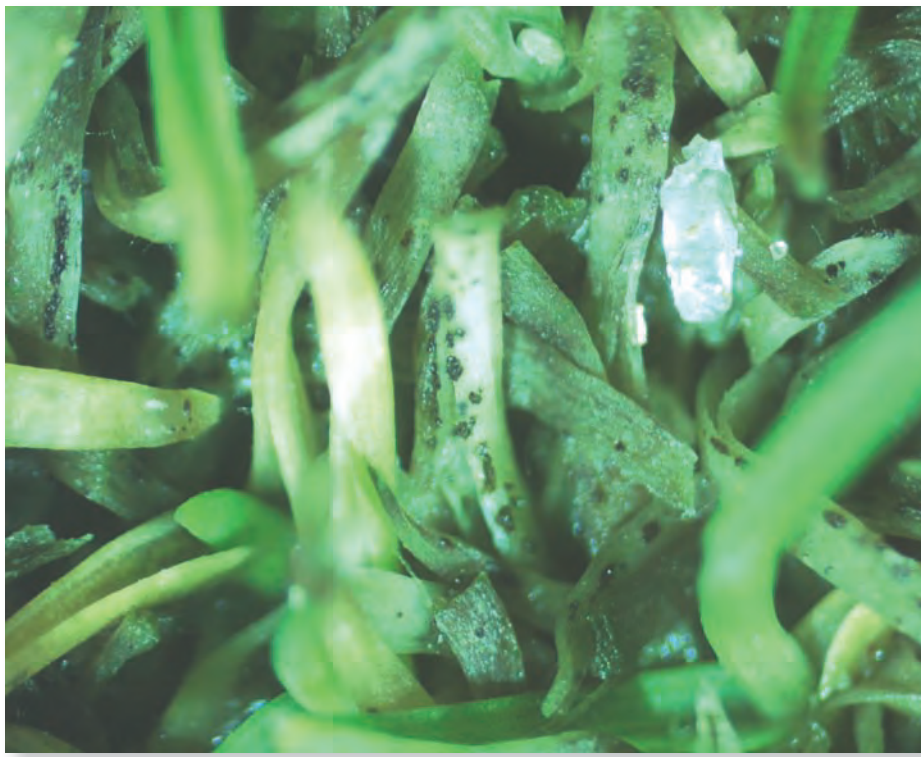
Anthracnose control timing

Although the precise timing of disease initiation is unknown, it is generally recommended that superintendents initiate a preventive program at least one month before the normal onset of anthracnose in their area. Since anthracnose and summer patch often occur together on annual bluegrass, anthracnose fungicide applications can be timed to coincide with preventive applications made when average soil temperatures exceed 65 F to 68 F (18.3 C-20 C). For example, in one study, timing anthracnose control with a fungicide program was most effective when preventive applications were made when soil temperatures were between 64 F and 71 F (17.7 C-21.6 C) (13).

Acceptable control

Active ingredients	Field trial date/state
Chlorothalonil	2006, 2007, 2008 NJ; 2007 CT
Fludioxonil	2006 NJ, 2006 CA
Fludioxonil + fosetyl-Al	2007 CT
Fosetyl-Al	2006 NJ
Fosetyl-Al + chlorothalonil	2006 CA
Fosetyl-Al + iprodione	2006 CA
Metconazole	2008 NJ, 2009 CA
Polyoxin D	2006 NJ, 2006 CA
Propiconazole	2006 NJ, 2009 CA
Tebuconazole	2006, 2007, 2008 NJ; 2007 CT; 2009 CA
Tebuconazole + fosetyl-Al	2008 NJ
Triticonazole	2008 NJ, 2009 CA

Table 4. Active ingredients showing acceptable control in various field trials conducted by NE-1025 researchers.



Anthracnose foliar blight of annual bluegrass, with diagnostic acervuli and setae embedded in the diseased leaf tissue.

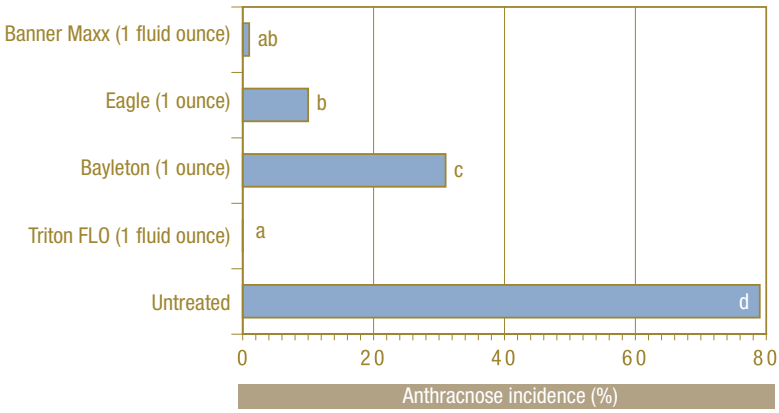
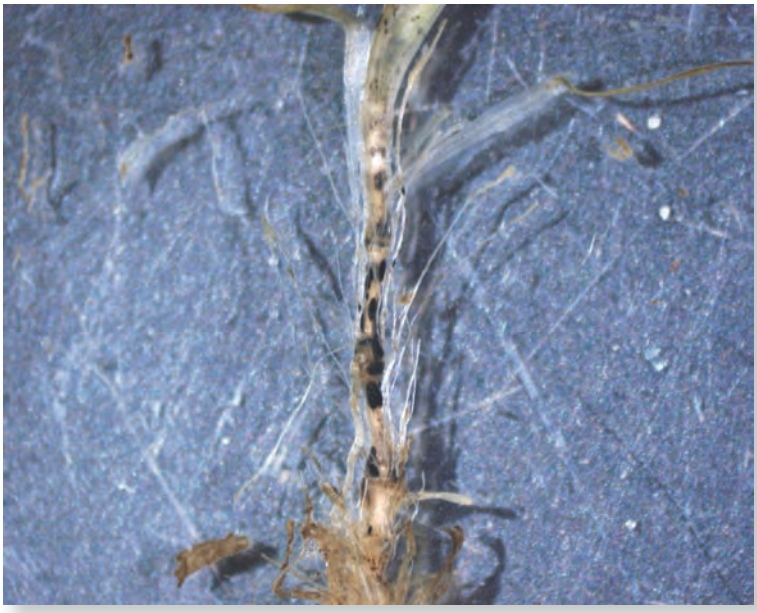


Figure 1. Control of anthracnose with different DMI fungicides. Active ingredients for the products tested are: propiconazole (Banner Maxx), myclobutanil (Eagle), triadimefon (Bayleton) and triticonazole (Triton FLO). Redrawn from Towers et al. 2003 (9).



Colletotrichum cereale has infected this creeping bentgrass stolon with anthracnose basal rot. The dark spots are acervuli.

Field trial results

As part of the NE-1025 Project, field trials were conducted in California, Connecticut, New Jersey and Pennsylvania from 2006 to 2009 to evaluate fungicide treatments for anthracnose control. Results were highly variable across years and locations, and very few consistencies can be extracted from the results. In fact, no single fungicide or tank-mixture provided excellent anthracnose control across all trials. Products containing chlorothalonil, fludioxonil and the DMI fungicides metconazole, propiconazole, tebuconazole and triticonazole provided the best overall control across these studies. Fosetyl-Al, polyoxin D and tank-mixtures of fosetyl-Al with either chlorothalonil, iprodione, fludioxonil or tebuconazole also provided good control in at least one location (Table 4).

Researchers compared several DMI fungicides for their activity against *Colletotrichum cereale* isolates in vitro (14). They found that, regardless of previous exposure to DMI fungicides, isolates were most sensitive to tebuconazole and propiconazole, less sensitive to myclobutanil, and least sensitive to triadimefon. These differences are well correlated to the performance of these fungicides for anthracnose control in the field. For example, in an earlier study, another group of researchers observed excellent anthracnose control from Triton FLO (triticonazole) and Banner Maxx (propiconazole), moderate control from Eagle (myclobutanil) and poor control from Bayleton (triadimefon) (9) (Figure 1).

In addition to excellent anthracnose activity, newer DMI fungicides such as Tourney (metconazole), Torque (tebuconazole) and Trinity and Triton FLO (triticonazole) also offer reduced growth regulation and phytotoxicity on cool-season grasses compared to older DMIs. However, these should still be used cautiously when turfgrass is under periods of high environmental stress or being treated with high rates of other plant growth regulators.

Comparison of phosphonate fungicides

The phosphonate fungicides contain various forms of the phosphite ion (PO_3^-), which has direct fungicidal properties against certain fungi and may also stimulate natural defense responses in the plant. The first phosphonate fungicide, fosetyl-Al, became available to turf managers in the early 1980s but was not recognized as an effective anthracnose fungicide until the early 2000s (4).

Since 2000, a new generation of phosphonate fungicides has been developed, the phosphite salts, which contain potassium and/or ammo-

nium salts of PO_3^-. There are two important differences between fosetyl-Al and the phosphite salts. First, the phosphite salts contain the active ingredient in its most basic form, while fosetyl-Al has to be broken down inside of the plant to release the phosphite ion. Second, certain fosetyl-Al formulations, such as Chipco Signature, contain a proprietary pigment that is known to increase the overall quality and stress tolerance of putting green turf, and thus may further help to reduce anthracnose development.

As part of the NE-1025 Regional Project, independent research projects at Penn State University and North Carolina State University sought to compare the efficacy of fosetyl-Al and phosphite salts for anthracnose control. On a creeping bentgrass/annual bluegrass putting green in Pennsylvania, fosetyl-Al + pigment (Chipco Signature) provided significant anthracnose suppression in 2004 and 2005, but fosetyl-Al alone (Aliette, Bayer) or potassium phosphite (Alude) did not (5) (Figure 2). The authors concluded that the pigmented StressGard formulation or other characteristics of the Signature product were primarily responsible for anthracnose suppression in their studies.

A similar comparison of phosphonate fungicides was made on annual bluegrass and creeping bentgrass putting greens in North Carolina in 2005 and 2006. Fosetyl-Al + pigment (Chipco Signature) and potassium phosphite (Alude) provided excellent anthracnose control on an annual bluegrass putting green. In contrast, on a creeping bentgrass green, fosetyl-Al + pigment (Chipco Signature) was only moderately effective and potassium phosphite (Alude) provided no significant suppression of the disease. (6)

A review of the literature (4) noted inconsistencies in the efficacy of phosphonate fungicides across years and locations and proposed that this was due to differences in phosphite sensitivity of *Colletotrichum cereale* isolates. Others (5) further observed that disease severity, environmental conditions, presence of disease at the time of application and number of applications before disease development were related to anthracnose control in published reports. The phosphonates tended to provide significant anthracnose suppression in the absence of weather extremes and when at least two applications were made before the onset of disease development. This further highlights the importance of early preventive applications for anthracnose management.

The future of anthracnose control

Based on the results reviewed thus far, the

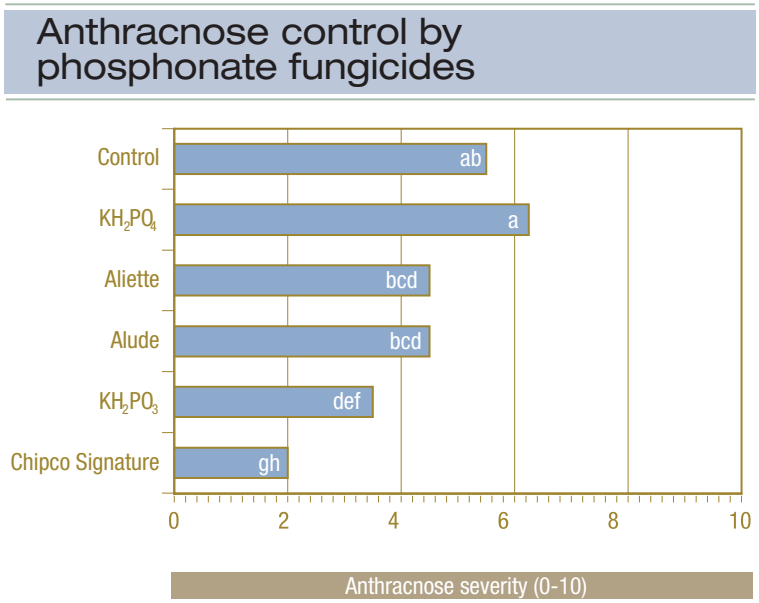
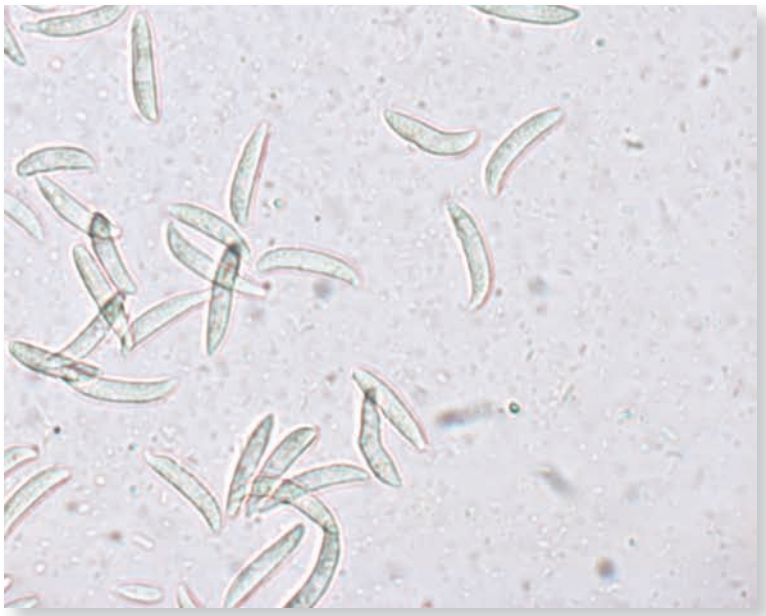


Figure 2. Comparison of phosphonate fungicides for anthracnose control on annual bluegrass. Data were collected July 5, 2005, following five applications on 14-day intervals. The active ingredients for the products listed are: fosetyl-Al (Aliette, Chipco Signature) and potassium phosphite (Alude). Redrawn from Cook et al. (5).



Conidia (spores) of *Colletotrichum cereale* are released from an acervulus.

future of anthracnose management using fungicides may appear grim. However, new chemistries either recently or soon to be released into the turfgrass market may offer some relief.

Plant health promotion

Several manufacturers are using plant health promotion from fungicides as a strategy for managing anthracnose. This, in combination with direct control of plant pathogens by the fungicides, is being pursued by a few companies as a strategy to improve fungicide performance.

For example, BASF's Intrinsic brands of fungicides use the up-regulation of oxidative stress mechanisms by pyraclostrobin to help increase plant stress tolerance. Daconil Action from Syngenta uses acibenzolar-S-methyl to induce systemic acquired resistance to plant pathogens, and Bayer's StressGard Formulation Technology line of fungicides uses trifloxystrobin and/or pigment-based technologies to improve plant health under stress conditions. The impact of these plant health promotion strategies can be significant, but active ingredients in these products still must provide direct control of the disease for this strategy to be most effective.

New fungicides

Velista (penthiopyrad). Velista is a succinate dehydrogenase inhibitor (SDHI) fungicide that is in late-stage development by DuPont. Some trials have shown good activity in controlling anthracnose when applied on a 14-day schedule at higher rates or tank-mixed with other fungicides. (3,16). This material would be especially useful as a rotation partner in summer programs to reduce the reliance on QoI, DMI and other site-specific fungicides.

Civitas (mineral oil). Civitas is a refined mineral oil that is to be applied with Harmonizer, a pigment-based product. It has shown good effectiveness against anthracnose in Massachusetts (8) and Pennsylvania (2,3), but other published studies are limited at this time. Research at universities is helping to determine how best to use this product in anthracnose control programs.

Daconil Action (chlorothalonil + acibenzolar-S-methyl). As mentioned above, Daconil Action combines a contact fungicide, chlorothalonil, with an inducer of systemic acquired resistance. Published research on the effectiveness of the product on anthracnose is limited at this time.

Developing fungicide programs for anthracnose

Developing a preventive program for anthracnose control can be challenging, but there are a significant number of products available as detailed by this review. The following guidelines can help in setting up an effective preventive program.

- Start applications early when average soil temperatures exceed the 65 F-68 F (18.3 C-20 C) range. DMI fungicides are especially useful at this time. Application of fungicides during low disease pressure at 14- to 28-day intervals is acceptable, but applications at seven- to 14-day intervals are recommended when there is significant summer stress and high disease pressure.
- Since anthracnose is prone to developing fungicide resistance, rotate applications between chemical classes to minimize the risk of resistance to site-specific fungicides. Application of multi-site fungicides that carry no resistance risk (for example, chlorothalonil) is especially helpful.
- Combination products that have two or more active ingredients will help control other diseases and minimize the chances of disease breakthrough. However, overuse of combination products may still result in significant pressure toward resistance development to the individual components of the mixture.
- Phosphonate applications alone may provide some anthracnose suppression, but should be mixed with other anthracnose-active fungicides for best effects. Fosetyl-Al and phosphite-based products can perform differently based on formulation, timing and the sensitivity of *Colletotrichum cereale* to the products.
- Be aware of the development of QoI and benzimidazole resistance; if resistance is present for these chemical classes, do not rely on them for anthracnose control although they can be used for the control of other diseases such as brown patch or summer patch. If the classes are still effective, use them judiciously for anthracnose control and rotate with other fungicides from other classes.

The need for IPM in fungicide programs for anthracnose

Recent research outlined in the May issue of *GCM* (7) has identified key cultural practices, such as increased mowing heights, moderate fertilization, frequent topdressing and lightweight rolling, that can reduce anthracnose development by creating a healthier, more disease-resistant turf. The reduced disease pressure that results from implementing these agronomic practices is almost certain to improve fungicide performance and perhaps reduce the number of applications required to obtain acceptable control.

The research says

- Anthracnose control is difficult because the timing of initial infection is unknown, which means curative applications are often necessary. However, only the benzimidazole, DMI and QoI fungicides have significant curative activity.
- Resistance to the benzimidazole and QoI fungicides is widespread in areas that were surveyed as part of this project. Reduced sensitivity to the DMI fungicides was also detected, but not to levels expected to affect control performance.
- To prevent resistance, single-site inhibitor fungicides must be used judiciously as part of a program and in conjunction with multi-site inhibitor fungicides and appropriate cultural practices.
- Phosphonate fungicide performance can vary significantly depending on the active ingredient, formulation, weather conditions and application timing.
- Appropriate cultural practices and an effective fungicide program can improve anthracnose control.

Future research should evaluate how cultural practices influence fungicide performance and the necessary inputs. Researchers also need to work on identifying when and where the pathogen survives and causes initial infections so that preventive fungicide applications can be targeted toward these key steps in the disease cycle.

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