//BMPs AND RECENT RESEARCH

Lessen your anthracnose struggles

By Brian Aynardi, John Inguagiato, Ph.D., Steve McDonald, Bruce Clarke, Ph.D., and Wakar Uddin, Ph.D.

Anthracnose (*Colletotrichum cereale*) has been a persistent problem on putting greens, particularly in the northeastern United States, where many golf courses have *Poa annua* greens, some by choice, others to the superintendent's distain.

While anthracnose can also occur on creeping bentgrass, superintendents managing *Poa* greens know it to be nothing short of a nightmare. *Poa* greens, however, have some advantages. They produce less thatch than bentgrass, have high turf density and have the potential to provide fast green speeds.

Perhaps the biggest disadvantage: Unless superintendents follow Best Management Practices (proper nitrogen fertility, mowing, sand topdressing, irrigation, fungicides, etc.), *Poa* greens can sustain significant damage from anthracnose (Figure 1), be it basal rot or foliar blighting.

Effective anthracnose management first should include sound agronomic practices. Stress from improper management (or environmental stress) contributes to increased disease severity. Therefore, pay special attention to incorporating practices that optimize turf growth and minimize stress. Implement these practices long before weather conditions conducive for anthracnose develop and before you apply fungicides.

To combat this disease, researchers from Rutgers University, the University of Connecticut and other institutions in the NE-1046 Regional Turf Research Group have developed a set of Best Management Practices (BMPs). Research by this group has demonstrated that proper nitrogen fertility, mowing and rolling, topdressing, irrigation and the use of plant growth regulators (PGRs) are important agronomic components in managing this disease.

NITROGEN, MOWING AND PGRs

Nitrogen (N) fertility is one of the most important tools for reducing the severity of anthracnose. Research has demonstrated that the use of quick-release, water-soluble nitrogen greatly reduces severity of this disease. The timing and frequency of N applications also has implications for reduction of anthracnose severity. For example, an application of 0.1 lbs. N/1,000 sq. ft. every seven days, as opposed to an application every 28 days, provided a 24-percent reduction in disease. A good rule of thumb is to apply 0.1 to 0.2 lbs. of soluble-N/1,000 sq. ft. every seven days during summer months (i.e., May to August) to reduce anthracnose severity. N applications every other week on the higher end of that spectrum provide a noticeable effect on disease severity as well. Apply potassium to maintain greater than 50 ppm K in the mat layer, and soil pH should be between 5.8 and 6.0 to help keep this disease in check.

Mowing is a stressful practice that reduces the photosynthetic capacity of turf. At low heights of cut (less than

FIGURE 1

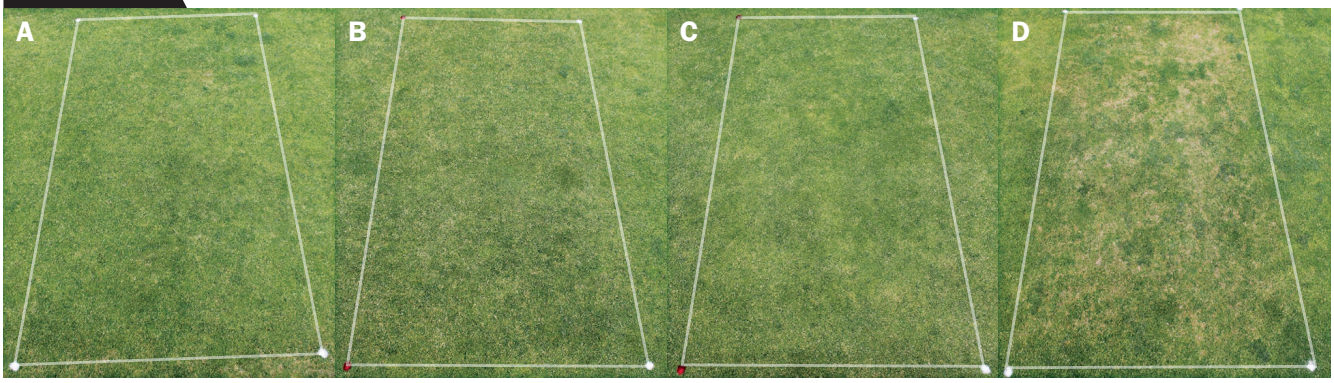
Destruction of *Poa annua* by anthracnose caused by the fungus *Colletotrichum cereale.* Untreated control plot in lower left with unaffected bentgrass filling in dead or thinned areas. Plots with treatments varying in efficacy are seen in the background.

FIGURE 2

Optimal control of anthracnose may be achieved through the use of tank-mixing and rotating fungicides with varying modes of action and through the implementation of Best Management Practices.

PHOTOS BY: BRIAN AYNARDI

FIGURE 3



Efficacy of Autilus 4SC (4 fl. oz./1,000 sq. ft.) + Harrell's Par (0.37 fl. oz./1,000 sq. ft.) **A**; Torque 3.6EC (0.6 fl. oz./1,000 sq. ft.) **B**; Velista 50WDG (0.50 oz./1000 sq. ft.) **C**; an untreated control (**D**) in research plots at the University of Connecticut, Storrs, Conn, in 2014 fungicide research trials.

0.125-inch), mowing has been shown to increase anthracnose severity. We recommend maintaining putting greens at or above 0.125-inch to avoid predisposing turf to this disease. Moreover, data show that double-cutting and rolling greens do not intensify anthracnose and can be tools to maintain acceptable ball roll distance (green speed) when raising cutting heights.

Verticutting and topdressing were once believed to enhance anthracnose severity, however, research has demonstrated that these practices can have important agronomic value without increasing disease severity. Superintendents can use shallow verticutting to improve plant vigor, and topdressing throughout the growing season (particularly in the spring) provides a layer that protects turfgrass crowns from environmental stress, effectively raising the height of cut by firming the surface and reduces disease. However, topdressing infrequently with ultra-low rates of sand may slightly increase anthracnose if the rates used fail to build a protective layer of sand around the crowns. With this in mind, consider using a heavier topdressing program in the spring when coring and a moderate, every-other-week topdressing program in the summer to match the growth of the grass. In addition, use irrigation to replace 60 percent to 80 percent of potential evapotranspiration, along with hand watering, to avoid drought stress.

PGRs are valuable tools for reducing *Poa annua* seedheads and vertical growth. Several research studies have concluded that PGRs like Primo MAXX (trinexapac-ethyl), Embark (mefluidide) and Proxy (ethephon) do not intensify anthracnose and sometimes can reduce disease severity when applied properly to suppress seedheads in the spring and vertical growth during the summer. The beneficial effects of PGRs should be a further consideration as part of your BMPs.

USING FUNGICIDES

BMPs for anthracnose control are not limited to cultural methods, but also include proper fungicide use. Despite your best efforts to incorporate recommended cultural practices, fungicides often are necessary to control anthracnose and maintain acceptable playing conditions.

Understanding which fungicides are most effective and when to use them has a great impact on the success of your anthracnose control program. Fungicide resistance is a real concern with anthracnose, and resistance has been demonstrated to the benzimidazole and QoI fungicides, as well as reduced sensitivity to the DMIs. Do not repeatedly apply fungicides within the same chemical class. In many cases, tank-mixing and alternating fungicides not only reduces the potential for developing resistance, but also improves disease control (Figure 2).

When resistance isn't an issue, fungicides within the following chemical classes typically provide good control of anthracnose: DMIs (FRAC Code 3, Figure 3), QoI's (FRAC Code 11), Phenylpyrroles (FRAC Code 12), Phosphonates (FRAC Code 33), Polyoxins (FRAC Code 19), and Nitriles (FRAC Code M5). Fortunately, in light of the observed cases of resistance among some existing fungicide classes, (Table 1) several new products for anthracnose management recently have come on the market. These include the succinate dehydrogenase inhibitor (SDHI) penthiopyrad (Velista; Syngenta), fluazinam (Secure; Syngenta) and the aromatic hydrocarbon PCNB (Autilus; AMVAC). These fungicides also control a wide range of other diseases.

The active ingredient penthiopyrad (FRAC Code 7) was introduced as Velista in the spring of 2015. Researchers have evaluated Velista for turfgrass disease control over the past decade. Most recently, Velista was evaluated for anthracnose control by four university and independent researchers during

Continued on page 32

PHOTOS BY: JOHN INGUAGIATO

TABLE 1

Fungicides Labeled for Anthracnose Control

Class	Active Ingredients	FRAC Code	Risk for Resistance[b]
Anilines	fluazinam	29	Low-Medium
Aromatic Hydrocarbons	pentachlorobitrobenzene (PCNB)	14	Low
Benzimidazole	thiophanate-methyl	1	High
Demethylation inhibitor (DMI)	difenoconazole, metconazole, myclobutanil, propiconazole, tebuconazole, triticonazole, triadimefon	3	Medium
Dicarboximide	iprodione	2	Medium-High
Nitrile	chlorothalonil	M5	None reported
Not classified	mineral oil (isoparrafin)	NC	Unknown
Phenylpyrrole	fludioxonil	12	Low-Medium
Phosphonate	aluminum-tris (fosetyl-al), salts of phosphorus acid	33	Low
Polyoxins	polyoxin-D	19	Medium
Succinate dehydrogenase inhibitor (SDHI)	penthiopyrad	7	Medium-High
Stobilurin (QoI)	azoxystrobin, fluoxastrobin, pyraclostrobin, trifloxystrobin	11	High

[a] Selected examples of active ingredients used for the control of anthracnose. *Any mention of trade names associated with active ingredients from this list does not constitute an endorsement, nor does it imply approval to the exclusion of other suitable products.*

[b] Risk for resistance as designated by Fungicide Resistance Action Committee; FRAC Code List©2015 (http://www.frac.info/publications/downloads).

Continued from page 31

2014 and 2015. At each location, Velista was applied at 0.3 oz./1000 and 0.5 oz./1,000 sq. ft. every 14 days. In 2014 and 2015, the average percent control of anthracnose among the four locations was 88 percent (Table 2, Figure 3) and 85 percent (Table 2), respectively. Generally, Velista alone has provided good-to-excellent anthracnose control at the 0.5 oz./1,000 sq. ft. (Figure 3), or when applied at 0.3 oz./1000 sq. ft. as a tank-mixture with a reduced rate of another effective anthracnose fungicide.

REEVALUATING AN OLDER COMPOUND

Fluxapyroxad and isofetamid, recently released and marketed as Xzemplar (BASF) and Kabuto (PBI-Gordon), are also SDHI fungicides, however, they are not labeled for anthracnose control and have not been efficacious against this disease in field research trials. At the same time university researchers were evaluating the effect of these SDHI fungicides for the control of anthracnose, they re-evaluated an older compound, PCNB (FRAC Code 14), to see if it could suppress this disease without causing chlorosis or necrosis during hot weather.

Researchers at Penn State University first evaluated the active ingredient PCNB for the control of anthracnose in the summer of 2013. In 2014 and 2015, PCNB was evaluated in field trials in multiple locations to test its efficacy against anthracnose and its potential for causing phytotoxicity.

Researchers at four locations in the Northeast (Rutgers University, the University of Connecticut and the independent contracting company, Turfgrass Disease Solutions [Pennsylvania]) applied PCNB as a stand-alone fungicide, as well as in rotation programs. On average, it provided greater than 95 percent control of anthracnose across all of the trials when applied at 8.0 fl. oz./1000 sq. ft. in 2014 (Table 2), and 90 percent control at 6.0 fl. oz./1000 sq. ft. in 2015 (Table 3).

This product recently has been launched under the trade name Autilus, with a recommended application rate of 6.0 fl. oz./1000 sq. ft. (Figure 3). During hot weather, PCNB can cause chlorosis or necrosis of creeping bentgrass, and therefore, the label indicates that superintendents should apply Autilus only in the spring and fall months during cool weather (when air temperatures are not predicted to be above 85°F), and that it be mixed with a pigmented product (e.g., Par, Foursome, GreenPig, etc.) to avoid any potential discoloration of the turf. Tank-mixing with pigmented fungicides such as Appear or any of the StressGard formulations (Bayer) (e.g., Mirage, Signature Xtra or Fiata) can enhance disease control and prevent discoloration. A pre-mix product of PCNB and tebuconazole

TABLE 2

Data from four trials conducted in 2014 showing efficacy of active ingredients penthiopyrad and PCNB in controlling anthracnose

Active Ingredient	FRAC Group	fl. oz. product/ 1,000 sq. ft.	Pennsylvania[z]				New Jersey[y]				Pennsylvania[x]				Connecticut[w]				Average Percent Control
			28-Jul-14		11-Aug-14		16-Aug-14		26-Aug-14		03-Sep-14		10-Sep-14		01-Aug-14		15-Aug-14		
			%Disease	% Control	%Disease	% Control	%Disease	% Control	%Disease	% Control	%Disease	% Control	%Disease	% Control	%Disease	% Control	%Disease	% Control	
PCNB[vu]	14	4.0 fl. oz.	0.5 c	97.8	0.5 b	98.0	15.3 d	78.1	10.3 c	84.6	0.0 c	100.0	0.8 de	81.4	0.1 ef	99.9	5.5 cde	91.2	91.4
PCNB[vu]	14	8.0 fl. oz.	0.0 c	100.0	0.0 b	100.0	4.5 fg	93.6	3.3 ed	95.1	0.3 bc	90.9	0.5 de	88.4	0.3 c-f	99.6	1.2 c-g	98.1	95.7
tebuconazole[t]	3	0.6 fl. oz.	0.0 c	100.0	0.0 b	100.0	5.3 e-g	92.4	5.5 c-e	91.8	3.5 ab	0.0	3.8 a-d	11.6	0.1 ef	99.9	0.1 fg	99.8	74.4
penthiopyrad[s]	7	0.3 oz.	0.0 c	100.0	0.0 b	100.0	10.3 de	85.2	9.3 cd	86.1	0.5 abc	84.8	0.3 e	93.0	10.7 b	86.0	18.6 b	70.1	88.2
azoxystrobin[r]	11	1.0 oz.	6.0 b	73.1	3.5 b	85.7	53.3 b	23.6	67.3 a	0.0	3.8 a	0.0	2.8 a-e	34.9	76.5 a	0.0	55.1 a	11.4	28.6
UTC		–	22.3 a	–	24.5 a	–	69.8 a	–	67.0 a	–	3.3 abc	–	4.3 abc	–	76.2 a	–	62.2 a	–	–

[z] Trial conducted in Pottstown, Pa., by Steve McDonald, Turfgrass Disease Solutions. Percent anthracnose means followed by the same letter are not significantly different (p=0.05; Tukey's HSD).

[y] Trial conducted in New Brunswick, N.J., by Bruce Clarke, Ph.D., Rutgers University. Percent anthracnose means followed by the same letter are not significantly different (p=0.05; Waller-Duncan k-ratio t-test (k=100)).

[x] Trial conducted in University Park, Pa., by Brian Aynardi and Wakar Uddin, Ph.D., Penn State University. Percent anthracnose means followed by the same letter are not significantly different (p=0.05; Tukey's HSD).

[w] Trial conducted in Storrs, Conn., by John Inguagiato, Ph.D., University of Connecticut. Percent anthracnose means followed by the same letter are not significantly different (p=0.05; LSD).

[v] Treatments that included PCNB were tank-mixed with the pigment product Par at 0.37 fl. oz./1,000 sq. ft.

[u] Applied as Autilus 4SC

[t] Applied as Torque 3.6F

[s] Applied as Velista 50WDG

[r] Applied as Heritage 50WDG

(Oreon, AMVAC), which was due to be released in February, also was evaluated for anthracnose control at the four locations. The addition of tebuconazole with PCNB in the pre-mix improved anthracnose control (to greater than 98 percent) compared to PCNB alone at all pre-mix application rates (4.0, 6.0, and 8.0 fl. oz./1,000 sq. ft.) tested (Table 3). This improved efficacy with the pre-mix is supported by other studies that have found in general that tank mixes or pre-mixtures of formulated fungicides tend to provide improved anthracnose control compared to active ingredients applied alone.

Tank-mixing fungicides with different modes of action is an important management practice, particularly when controlling pathogens such as *Colletotrichum cereale* that have demonstrated resistance to fungicides. There currently are a number of pre-mixed products in addition to the previously mentioned materials labeled for the control of anthracnose (e.g., Briskway [Syngenta], Fame C [FMC], Fame T [FMC], Enclave [Quali-PRO], Headway [Syngenta], Interface Stressgard [Bayer] and Tartan Stressgard [Bayer]). All of these products control anthracnose, though efficacy may vary depending on differences in environmental conditions, management practices and the potential for fungicide-resistant strains of the pathogen present in certain sites.

Although penthiopyrad and PCNB have been shown to work well when tested as stand-alone products for the control of anthracnose, these products, like all fungicides, *should never be applied repeatedly for the control of any disease.* A proper rotation or tank-mixing program with fungicides of different modes of action (see Table 1) always is the best option to enhance disease control while reducing the potential for fungicide resistance. An attribute of PCNB as part of an anthracnose program is its low risk for fungicide resistance. Incorporation of active ingredients with a low potential for resistance into a spray program may benefit superintendents who have struggled with a loss in efficacy due to fungicide resistance.

Regardless of the fungicide choice, always make sure you're using solid agronomic practices from the start. The BMP cultural practices described in this article have been shown to reduce the number of fungicide applications required to control anthracnose and provide acceptable turf quality.

Also, don't be afraid to add a small amount of nitrogen to your spray tank (0.1 to 0.2 lbs. N/1,000 sq. ft.) when anthracnose is present, as well as raise the height of cut and double cut and/or roll to maintain ball-roll distance, irrigate and syringe to avoid drought stress, topdress to maintain a canopy full of sand to match the growth of the grass and use PGRs to suppress seedheads and vegetative growth on putting greens. It's your job as a superintendent to explain why the incorporation of BMPs are vital to providing the best putting surface possible.

Continued on page 34

TABLE 3

Data from four trials conducted in 2015 showing efficacy of active ingredients penthiopyrad and PCNB in controlling anthracnose

Active Ingredient	FRAC Group	fl. oz. product/ 1,000 sq. ft.	Pennsylvania[z]				New Jersey[y]				Pennsylvania[x]				Connecticut[w]				Average Percent Control
			13-Jul-15		22-Jul-15		08-Aug-15		18-Aug-15		31-Jul-15		11-Aug-15		30-Jul-15		07-Aug-15		
			%Disease	% Control	%Disease	% Control	%Disease	% Control	%Disease	% Control	%Disease	% Control	%Disease	% Control	%Disease	% Control	%Disease	% Control	
PCNB[vu]	14	6 fl. oz.	0.0 b	100.0	0.0 b	100.0	29.0 b	68.3	24.3 b	74.1	7.5 efg	90.8	11.3 h-k	85.4	0.0 f	100.0	0.5 e	99.2	90.0
PCNB[vt] tebuconazole	14 3	4.0 fl. oz.	0.0 b	100.0	0.0 b	100.0	5.0 cd	94.5	2.5 c	97.3	2.5 g	96.9	2.5 jk	96.8	0.0 f	100.0	0.3 e	99.6	98.1
PCNB[vt] tebuconazole	14 3	6 fl. oz.	0.0 b	100.0	0.0 b	100.0	2.8 cd	96.9	2.8 c	97.0	0.0 g	100.0	0.0 k	100.0	0.8 ef	98.4	0.5 e	99.2	98.9
PCNB[vt] tebuconazole	14 3	8 fl. oz.	0.0 b	100.0	0.0 b	100.0	0.3 d	99.7	1.3 c	98.6	2.5 g	96.9	7.5 ijk	90.3	0.2 f	99.6	0.3 e	99.6	98.1
tebuconazole[s]	3	0.6 fl. oz.	0.0 b	100.0	0.0 b	100.0	8.5 c	90.7	6.0 c	93.6	25.0 c-g	69.2	25.0 e-j	67.7	7.9 d	85.1	18.5 d	72.1	84.8
penthiopyrad[r]	7	0.5 oz.	0.0 b	100.0	0.0 b	100.0	9.5 c	89.6	3.8 c	95.9	25.0 c-g	69.2	22.5 f-k	71.0	7.5 d	85.9	18.8 d	71.7	85.4
UTC		–	17.5 a	–	19.3 a	–	91.5 a	–	93.8 a	–	81.3 a	–	77.5 a	–	53.3 f	–	66.3 b	–	–

[z] Trial conducted in Pottstown, Pa., by Steve McDonald, Turfgrass Disease Solutions. Percent turf symptomatic with anthracnose means followed by the same letter are not significantly different (p=0.05; Tukey's HSD).

[y] Trial conducted in New Brunswick, N.J., by Bruce Clarke, Ph.D., Rutgers University. Percent turf symptomatic with anthracnose followed by the same letter are not significantly different [p=0.05; Waller-Duncan k-ratio t-test (k=100)].

[x] Trial conducted in University Park, Pa., by Brian Aynardi and Wakar Uddin, Ph.D., Penn State University. Percent turf symptomatic with anthracnose means followed by the same letter are not significantly different (p=0.05; Tukey's HSD).

[w] Trial conducted in Storrs, Conn., by John Inguagiato, Ph.D., University, Connecticut. Percent turf symptomatic with anthracnose means followed by the same letter are not significantly different (p=0.05; LSD).

[v] Treatments that included PCNB were tank-mixed with the pigment product Par at 0.37 fl. oz./1,000 sq. ft.

[u] Applied as Autilus 4SC

[t] Applied as Oreon 4SC (4.0 lb. a.i./gal of PCNB and 0.2 lb. a.i./A tebuconazole)

[s] Trade formulation applied as Torque 3.6F

[r] Trade formulation applied as Velista 50WDG

Continued from page 33

Fungicides should be part of the answer, but they are not the sole answer to effectively combating anthracnose.

When planning your anthracnose spray program for the upcoming season, make sure you're rotating modes of action as well as combining products into a single spray. It's also suggested that you become a researcher on your own. Try evaluating different fungicide rotations and incorporate the new modes of action into your program. You won't only be reducing the likelihood of developing resistance; You may enhance disease control and like what you see.

Any mention of trade names associated with active ingredients in this article does not constitute an endorsement, nor does it imply approval to the exclusion of other suitable products by the authors.

Brian Aynardi is a Ph.D. candidate at Penn State University, John Inguagiato, Ph.D., is at the University of Connecticut, Steve McDonald is with Turfgrass Disease Solutions, Bruce Clarke, Ph.D., is at Rutgers University, and Wakar Uddin, PhD., is at Penn State University. Brian Aynardi can be reached at baa5001@psu.edu for more information.

References

1. Fungicide Resistance Action Committee. 2015. FRAC Code List© 2015: Fungicides sorted by mode of action (including FRAC Code numbering). Revised February 2015. (http://www.frac.info/publications/downloads)
2. Hempfling, J.W., B. B. Clarke, and J. A. Murphy. 2015. Anthracnose disease on annual bluegrass as influenced by spring and summer topdressing. *Crop Sci.* 55: 437-443.
3. Inguagiato, J.C., J.A. Murphy, and B.B. Clarke. 2008. Anthracnose severity on annual bluegrass influenced by nitrogen, fertilization, growth regulators, and verticutting. *Crop Sci.* 48:1595-1607.
4. Inguagiato, J.C., J.A. Murphy, and B.B. Clarke. 2009. Anthracnose disease and annual bluegrass putting green performance affected by mowing practices and lightweight rolling. *Crop Sci.* 49:1454-1462.
5. Inguagiato, J.C., J.A. Murphy, and B.B. Clarke. 2009. Anthracnose of annual bluegrass putting green turf influenced by trinexapac-ethyl application interval and rate. *J. Int.Turf Soc.* 11: 207-218
6. Inguagiato, J.C., J.A. Murphy, and B.B. Clarke. 2010. Anthracnose development on annual bluegrass affected by seedhead and vegetative growth regulators. *Applied Turf Sci.* DOI:10.1094/ATS-2010-0923-01-RS.
7. Inguagiato, J.C., J.A. Murphy, and B.B. Clarke. 2012. Sand topdressing rate and interval effects on anthracnose disease severity of an annual bluegrass putting green. *Crop Sci.* 52:1406-1415
8. Inguagiato, J.C., J.A. Murphy, and B.B. Clarke. 2013. Topdressing sand particle shape and incorporation effects on anthracnose severity of an annual bluegrass putting green. *J. Int.Turf Soc.* 12: 127-134
9. Murphy, J. A., B.B. Clarke, and J.A Roberts. 2008. Development of best management practices for anthracnose disease on annual bluegrass putting green turf. In: 2008 USGA Turfgrass and Environmental Research Summary. USGA Turfgrass and Environmental Research Online 7(23):5.
10. Murphy, J.A., J.C. Inguagiato, and B.B. Clarke. 2012. Best management practices for anthracnose on annual bluegrass. *Golf Course Management* 80(5): 104-110.
11. Murphy, J.A., B.B. Clarke, C.J. Schmid, et al. 2011. Development of best management practices for anthracnose disease on annual bluegrass putting green turf. In: 2011 USGA Turfgrass and Environmental Research Summary. USGA Turfgrass and Environmental Research Online 10(23):2
12. Murphy, J., F. Wong, L. Tredway, J.A. Crouch, J. Inguagiato, B.B. Clarke, T. Hsiang, and F. Rossi. 2008. Best management practices for anthracnose on annual bluegrass turf. *Golf Course Management* 24: 93-104.
13. Roberts, J. A., J. C. Inguagiato, B. B. Clarke, and J. A. Murphy. 2011. Irrigation Quantity Effects on Anthracnose Disease of Annual Bluegrass. *Crop Sci.* 51: 1244-1252.
14. Roberts, J.A., B.B. Clarke, and J.A. Murphy. 2012. Lightweight rolling effects on anthracnose of annual bluegrass putting greens. *Agron. J.* 104(4):1176-1181.
15. Smiley, R.W., P.H. Dernoeden, and B.B. Clarke. 2005. Compendium of turfgrass diseases. 3rd ed. APS Press, St. Paul, Minn.
16. Tredway, L., and F. Wong. 2012 Managing anthracnose with fungicides: The future for anthracnose management looks brighter with new chemistries and an integrated management approach. *Golf Course Management* 80(6): 90-96.