should be allowing play during late autumn or winter thaws. Making the decision to allow or not allow play ultimately comes down to weighing the amount of income and goodwill generated against the impact it has on turf quality and repair costs. The situation provides an excellent opportunity for fostering communication between the superintendent and club management to determine what's best for the course, while enhancing mutual respect for each others' position, knowledge, and professionalism. Each situation is different, and a number of agronomic, economic, and social/political factors have to be assessed to arrive at the best decision.

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Fungicide Resistance in Turfgrass – Future Trends and Possible Problems

By Paul Koch, *Turfgrass Diagnostic Lab, University of Wisconsin - Madison*

Author's note: This is the third in a three-part series looking at fungicide resistance in turfgrass.

Organisms resistant to chemical control have become commonplace in national news stories. Antibiotic resistant tuberculosis has been around for years, and just a few months ago several outbreaks of drug-resistant staph infections in high school locker rooms caused widespread panic. While the nationwide panic over the development of fungicide resistance in turfgrass diseases promises to be comparatively subdued, the threat to our ability to control disease is just as real. In two previous issues of *The Grass Roots* I have written about the history of fungicide resistance as it pertains to turfgrass, as well as some recent resistance research done here at the University of Wisconsin (Koch, 2007a; Koch 2007b). While great strides have been made in deepening our knowledge of fungicide resistance, much is still unknown. More troubling is that reports of fungicide failure due to resistant isolates of *Sclerotinia homoeocarpa* (dollar spot), *Pyricularia grisea* (gray leaf spot), and *Colletotrichum cereale* (anthracnose) are on the rise.

There is no singular explanation for the increase in nationwide resistance reports. Rather a myriad of factors appear to be increasing the buildup of resistant organisms in fungal populations faster than ever before. More selective fungicides are continually being developed to minimize non-target effects in response to environmental concerns, but these newer fungicides often have single-site modes of action that can be overcome by a single fungal mutation (Eckert, 1988). Lower fungicide rates and extended spray intervals

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are touted as ways to reduce application costs and environmental contamination, but certain research has shown these strategies may allow resistant organisms to build up in a population (Koch 2007b). Repeated fungicide applications within a single class may be an obvious factor in resistance development to many superintendents, but there is still a remarkably large number who apply propiconazole four to five times in a season for their disease control program. With some of our fungicides, the DMIs in particular, time appears to be a large factor in the development of resistance. Unlike the benzimidazoles or strobilurins, resistance to the DMI fungicides takes years to develop even with repeated applications (Smith *et al.*, 1991). Since many golf courses have been applying DMI fungicides for 15 to 20 years, it is possible that resistant fungal isolates at these sites finally make up a significant enough percentage of the overall population to affect control.

A factor outside of the superintendent's control that is making resistance management more difficult is the lack of new fungicides from different chemistries being brought to the turfgrass market. While several new fungicides have been brought to market in recent years, most of them have either been combinations of older fungicides (Headway® is propiconazole and azoxystrobin, Tartan® is triadimefon and trifloxystrobin) or new active ingredients within an older class of fungicides (Trinity® in the DMIs, Disarm® in the strobilurins). While these new products often provide convenience or expanded disease control, they do not aide in preventing the buildup of resistant fungal isolates. Likely the major reason behind the lack of new products is the immense cost in terms of time and money to the chemical companies to discover and develop a molecule and bring it to market. Upwards of ten years and 100 million dollars is probably a conservative estimate for the time and money it takes to complete this process. The lack of new chemistries being developed for disease control in turfgrass, coupled with the increasing governmental regulation of some of our older and more effective chemistries (i.e. chlorothalonil), has made control of fungicide resistant organisms difficult for both superintendents and researchers alike.

With all the uncertainty surrounding fungicide resistance, what can you as a superintendent do to prevent resistance from becoming a serious problem at your course? Or if you believe resistance already is a serious problem on your course, what can you do to minimize or even reduce it? The answers to these questions are going to be specific to each individual golf course based on the fungicides in question, but

there are some overall strategies every superintendent can use to prevent or limit the development of fungicide resistance.

As with many things, preventing something from happening is oftentimes much easier to accomplish than reversing it once it has already occurred. The same concept applies to fungicide resistance, even though it is debatable how easy it is to prevent the development of resistance. The first thing to do when trying to combat resistance is to understand the basic chemical classes that house the major turfgrass fungicides (Table 1). Understanding the chemical classes is critical to developing a fungicide program that alternates properly amongst classes and is effective in preventing or delaying the onset of resistance. Once a basic understanding of the chemistry has been attained, a plan for effectively controlling all the major diseases seen in a typical growing season can be developed. Care should be taken to rotate amongst classes every second or third application to expose the fungal population to different modes of action. Not only are the fungicides themselves important in managing fungicide resistance, but the manner in which they are applied is important as well. Courses that strictly followed label recommendations for spray rate and interval had lower resistance levels to the DMI fungicide propiconazole in research done at the University of Wisconsin in the summer of 2006 (Koch 2007b). Following these basic recommendations (Table 2) will not guarantee the prevention of fungicide resistance at your course, but at the very least should significantly delay the onset years into the future.

Those superintendents who believe they already have a significant degree of fungicide resistance at their golf course may be contemplating a major shift in management strategy. Before changes are made, though, confirmation of resistance should be done through *in vitro* laboratory testing to confirm resistance is a problem. Labs such as the University of Wisconsin's Turfgrass Diagnostic Lab can complete a resistance test for *S. homoeocarpa* with regards to benzimidazole and DMI fungicides in approximately two weeks, giving the superintendent a much clearer picture of the role resistance is playing in the failure of disease control. If indeed a significant amount of resistance is observed from laboratory testing, changes should be made immediately to the fungicide program. Most scientific research indicates that resistance to thiophanate-methyl is non-reversible, meaning a high proportion of thiophanate-methyl resistant isolates could result in the permanent loss of that fungicide for the control of that particular disease (Koenraadt *et al.*, 1992). Research is more variable on the persistence of DMI resistant isolates in the environment, but there is

Table 1. Common fungicide classes, active ingredients, and their risk of developing resistance as measure by the Fungicide Resistance Action Committee (FRAC).

Fungicide Class	Active Ingredients	Resistance Risk
Benzimidazoles	Thiophanate-methyl, Propamocarb	High: Resistance Common
Strobilurins (QoI)	Azoxystrobin, Pyraclostrobin, Trifloxystrobin, Fluoxastrobin	High: Widespread resistance documented
Phenylamides	Mefenoxam, Metalaxyl	High: Resistance documented in Pythium
Demethylation Inhibitor (DMI)	Propiconazole, Myclobutanil, Triadimefon, Fenarimol	Medium: Resistance documented in turf
Dicarboximide	Iprodione, Vinclozolin	Medium: Resistance documented in turf
Carboximides	Boscalid, Flutoloanil	Medium: No resistance documented in turf
Phosphonates	Fosetyl-Al, phosphonates	Low: No resistance documented in turf
Nitrile	Chlorothalonil	Low: No known cases of resistance

Source: PACE Turfgrass Research Institute

evidence that over time in the absence of DMI fungicides the level of resistance drops (Sisler, 1988). The length of time it takes to regain a DMI sensitive population is unclear, but trying to develop a spray program in Wisconsin without the use of DMI fungicides for any length of time is very difficult. Instead of a program that eliminates DMI fungicides for a period of time I would recommend a program that instead rotates heavily amongst different fungicide classes, strictly follows label rates and spray intervals, limits the bulk of the DMI fungicide applications to times of the season when disease pressure is not as severe, and includes a low resistance risk fungicide such as chlorothalonil in the tank with every DMI application (Table 3). This program will not be an instant cure to your resistance ailments, but it should prevent or greatly slow the continued buildup of resistant isolates in the fungal population and may lower the overall resistance to the fungicide in question over time.

Much has been learned in over 40 years of research on fungicide resistance. But for all that research, relatively little is known about the genetic basis for resistance and the methods for managing fungicide resistance. More research needs to be conducted to determine the most effective methods for both preventing fungicide resistance as well as reducing the resistance already present at some golf courses. In the meantime, while we wait for those research results, format your plan for managing resistance at your golf course now...before it's too late.

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Table 2. Recommendations for preventing or delaying the onset of fungicide resistance.

1)	Learn or own reference on common turfgrass fungicide classes.
2)	Include fungicides from two to three different classes in your spray program every season.
3)	Follow label recommendations for fungicide rate and spray interval.
4)	Include chlorothalonil, a low resistance risk fungicide, in a tank-mix with other penetrant fungicides during times of severe disease pressure.

Table 3. Recommendations for halting or decreasing fungicide resistance.

1)	Have isolates tested for degree of fungicide resistance.
2)	Follow strict chemical class rotations every application.
3)	During times of heavy disease pressure, apply fungicide closer to the higher labeled rate or closer to the lower recommended spray interval, or both.
4)	If DMI or dicarboximide resistance is documented, limit DMI/dicarboximide fungicide applications during times of severe disease pressure.

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Green is the Color

By Tom Schwab, *O.J. Noer Turfgrass Research and Education Facility, University of Wisconsin-Madison*

The theme of this year's Turfgrass and Greenscape EXPO, "Going Green", was just what the industry wanted to hear. Going green is a very popular catch phrase these days, but it's a philosophy that the green industry has always believed in. Attendance increased by nearly 70 people this year, reflecting how much interest there is in the philosophy. There were 271 attendees that walked through the doors as compared to only 202 last year, and that doesn't include the 91 commercial members representing 34 companies in the trade show. They all came to hear the wonderful roster of speakers booked for this year's show.

There were three tracks of education provided which offered education for everyone in the turfgrass management profession. The three tracks were golf turf, sports and grounds turf, and landscape turf. Many attendees roamed between the different tracks to hear talks that most interested them. For instance, there were many golf turf managers in the landscape section when Dr. Fred Whitford from the University of Illinois gave his presentation "The Five Minute Drill to Handling a Pesticide Spill", and several lawn care providers were in the sports turf section when Dr. Chris Williamson gave his talk on strategies for white grub control.

The general session was likewise very interesting when Rick Fletcher from Cleary Chemical and Dr. Jennifer Grant from Cornell University presented. Rick shed vast insight into the efforts and costs it takes to develop new pesticides in today's regulatory environment. Jennifer presented her research from the Bethpage Experiment of reducing pesticides for putting green management. Bethpage is a golf course in the New York State Parks System that investigated going pesticide free as one of the variables. Her data has helped the state parks reduce pesticide use while still maintaining acceptable quality. One especially interesting note from Dr. Grant's presentation came from a survey of golf course user's attitudes towards pesticide use: 35% wanted the best quality turf no

Rick Fletcher from Cleary Chemical addressing the crowded general session.

Superintendents Jerry Kershasky and Brian Ferrie, with golf course architects Bob Lohmann and Dr. Mike Hurdzan discuss modern environmental golf course design.

Dr. Fred Whitford from the University of Illinois gave a very lively, hands-on, and informative presentation about handling a pesticide spill.

2008 Wisconsin Turfgrass and Greenscape EXPO Research and Scholarship Recipients

Scholarship Donor	Recipient	Amount
David Mergatroyd Memorial Scholarship	Bill Kreuser	$500
WTA Scholarship	Brendan Dolan	$600
WTA Scholarship	Brad Williams	$600
WTA Scholarship	Brad DeBels	$600
WTA Scholarship	Patrick Bastron	$600
WGCSA/ James R. Love Scholarship	Shane Griffith	$1,500
Spring Valley Turf Products Scholarship	Kevin Schneider	$600
Bayer Environmental Turf Scholarship	Bill Kreuser	$1,000
National Seed/ Egon Herrmann Turf Scholarship	Brad DeBels	$1,000

Research Donors	Recipient	Amount
Stevens Point CC	WTA	$600
Bull's Eye CC	WTA	$435
Westmoor CC	Distinguished Graduate Fellowship	$2,400

matter what, 54% wanted reasonable quality with judicious use of pesticides, 4% wanted minimum pesticide use regardless of what happens to the turf, and 2% said no pesticides should be used. The majority in the survey said reasonable quality and pesticide use is best, which indicates most citizens are reasonable about pesticide use.

Dr. Bruce Branham from the University of Illinois gave a thought provoking presentation on environmentally sound nitrogen fertilization. His research showed when a lawn matures it doesn't need as much fertility, as long as clippings are being returned. He also presented a case for natural organic fertilizer being more sustainable than synthetic fertilizers because it takes less carbon to produce and usually doesn't have to be transported as far which additionally reduces carbon use.

Several roundtable discussions grabbed the interest of attendees. The sports turf section had three different turf specialists from school districts and universities discuss managing people. The golf turf section had two world renowned golf course architects, Mike Hurdzan and Bob Lohmann, and two golf course superintendents, Jerry Kershasky and Brian Ferrie, discuss complementing the environment in new construction and renovations of golf courses. A lawn care roundtable provided different perspectives of what a healthy lawn means from the view of a traditional lawn care provider and two organic service providers.

Other interesting talks were given by Deb Hauser from the Wisconsin Interscholastic Athletic Association, Raechal Volkening of the Milwaukee Brewers and Volkening Consulting, Karol Huenerberg from Mercy Health Systems, Dr. John Clark from the University of Massachusetts and so many more including the turf team from the UW-Madison of Drs. Stier, Williamson, Soldat, and Koch.

Complementing the interesting educational presentations was the informative table-top trade show. Thirty four companies filled the hall and were ready to inform attendees about every machine, service, or supply that could be used to manage turf in a green friendly way. The list of all the exhibitors and contact information is listed on page 44. Mentioned above are the names of the scholarship recipients that were given out during the general session. We hope all these students continue to find new and better ways to continue making environmental stewardship a priority for the green industry and turf management.

This year's EXPO presented so many ideas for attendees to enhance their environmental stewardship. The industry is very good with environmental action now, but the future looks even 'Greener'.