Above: Dollar spot trial on bentgrass turf at the University of Illinois. Photos courtesy: Randy Kane.
Below: Heavy dollar spot in bentgrass fairway.

Development Of Fungicide Resistance On Intensively Managed Turf

By R.T. Kane And H.T. Wilkinson,
Chicago District Golf Association And University Of Illinois

Golf course greens, tees, fairways are undoubtedly the most intensively managed turf areas in the U.S., although some sports fields are approaching this level of management. Disease control on these intensively managed turf areas is achieved primarily through application of fungicides. In fact, statistics show that golf greens receive the greatest fungicide input per surface area of any U.S. crop, and the dollar value of the turf fungicide market is greater than for any other U.S. crop. Because of this intensive use pattern, fungicide resistance problems often show up on golf turf prior to any other crop application.

Fungicide resistance on golf turf is a fairly hot topic right now, primarily because of recent reports of dollar spot control failures with the newer systemic fungicides. However, fungicide resistance is not a new problem. Benzimidazole fungicides were introduced in the late 1960s; these products were the first widely used systemic fungicides, which displayed excellent long term preventative activity on a number of diseases. Disease control was so good with this revolutionary new chemistry that widespread, repeated, and intensive use of benzimidazole derivatives insued.

continued on page20

Surface Aspirating Aerator

The ultimate water management for landscape lakes and ponds. The TORO Surface Aspirating Aerator provides chemical-free control of odor and algae. The aerator mixes and destratifies water to decompose waste products, leaves, and fertilizer, and reduce sediment build-up. Decorative rock covers available. Operates inconspicuously with no spraying or splashing. Available in 1, 2, and 3 hp. Stainless-steel construction for maintenance-free operation.

AquaScape Technologies,
2611 North Second Street, Minneapolis, MN
55411 (612) 521-3321, Fax (612) 521-1455

Circle **110** on Postage Free Card

Permanent Landscape Boarders

Creative Curb machines produce continuous concrete curbs and landscape edging without the use of forms or precasting. The average cost is approximately one-fourth that of other conventional methods.Root systems are controlled, lawns and flower beds are separated, and edging is simplified, which reduces future maintenance costs. Creative Curb machines are easy to use, and can be a profitable addition to your business.

Creative Curb Marketing
26041 Pala, Mission Viejo, CA 92691
(800) 292-3488, Fax (714) 951-2656

Circle **111** on Postage Free Card

Fungicide Resistance

continued from page 19

Subsequent reports of dollar spot ("Sclerotinia") control failures with benomyl surfaced by 1973-74, about four years after registration.

The purpose of this article is to bring everyone up to date on current systematic fungicide use patterns and modes of action, fungicide resistance problems we have observed in Illinois and around the Midwest, and current thinking regarding ways to best avoid development of a fungicide resistance problem on your intensively managed turf.

Benzimidazoles

This class of systematic fungicides includes benomyl (e.g. Tersan 1991) and the thiophanates (Cleary 3336, Fungo 50). When first introduced, benzimidazoles were widely used to control dollar spot and brown patch. The mode of action of these products is at a specific biochemical site ("single-site inhibitor"), which means that only a single gene alteration or mutation by a fungal pathogen could produce reduced sensitivity, or in some cases, near immunity to the fungicide. Dollar spot control failures are the most common resistance problem with benzimidazoles, but we also have observed loss of control of anthracnose (*Colletotrichum graminicola*) on *Poa annua* and creeping bentgrass. Lab tests show that the sensitivity to benzimidazoles of the resistant *C. graminicola* isolates is 100-fold less than "wild-type" isolates obtained from golf courses where no control problems have occurred.

Reduced sensitivity to benzimidazoles also has been reported by other turf scientists for *Microdochium nivale* (pink snow mold) and *Laetisaria fusiformis* (red thread). Also, in 1991 we identified a benzimidazole-resistant type of dollar spot on a Chicago area golf course where use of these products was suspended in the late 1970s because of disease control failures. Even after more than 10 years without exposure, the fungi still maintained their benzimidazole-resistant traits—i.e. this type of resistance is very stable. It is also interesting to note that there (apparently) have been no reports of *Rhizoctonia* brown patch resistance to benzimidazoles. Perhaps the benzimidazole fungicides have multiple sites of action against *Rhizoctonia* fungi, thus making genetic changes toward fungicide resistance more difficult.

Phenylamides

This special class of fungicides is targeted at Phycomycote fungi including *Pythium* and *Phytophthera* species, and includes metalaxyl (Subdue, Apron). Metalaxyl was introduced to the turf market in the late 1970s as the first systemic fungicide to control Pythium blight, and has been widely used since. The first report of disease control failure due to fungicide resistance was in 1984. We have documented one case of metalaxyl resistance in Illinois, in 1988. Laboratory tests again showed a near 100-fold decrease in sensitivity of *Pythium aphanidormatum* taken from the failure site as compared to wild-type isolates.

In the last two years, we have had our first reports of control failures with DMI on turf in the U.S.

Like benomyl, metalaxyl is a single-site inhibitor that can be overcome by a single gene change in a developing *Pythium* population. In some cases, it is believed that the population shift toward insensitivity is not due to a newly occurring mutation, but to selection over time of an already existing resistant genotype that was present in a very low percentage of the population.

Keep in mind that we have seen only one true case of metalaxyl resistance in Illinois over the 10 or so years of the product's use. Most disease control "failures" with this product can be attributed to one of the following: application rates are too low for a certain disease pressure; application is made too late (metalaxyl works best on a preventative basis with a 48-hour lead time); or, interval time between applications is too long.

On a related note, there are two fairly new systemic fungicides for control of Pythium blight—propamocarb hydrochloride (Banol) and fosetyl-aluminum (Aliette). So far, we have seen no reports of fungicide resistance or loss of field control with these products, although Sanders and coworkers at Penn State have induced resistance to fosetyl-Al in the laboratory. The models of action of both may be such that field resistance is unlikely.

Demethylation Inhibitors (DMIs)

This broad class of fungicides include the triazole derivative systemic fungicides, such as triadimefon (Bayleton), propiconazole (Banner), and myclobutanil (Systhane or Eagle). Also included are pyrimidine-methanol derivatives such as fenarimol (Rubigan). The site of action in sensitive fungi is the biochemical pathway for synthesis of a fungal sterol called ergosterol, so you may see this class of fungicides referred to as sterol biosynthesis inhibitors (SBIs) or ergosterol biosynthesis inhibitors (EBIs). It is now known that toxicity to fungi stems from inhibiting demethylation of ergosterol precursors, thus the name "demethylation inhibitors."

DMI fungicides are considered to have a single-site (or perhaps two-site) mode of action. This would seem to put these products at the same risk level for resistance development as benzimidazoles or phenylamides. However, until recently there were very few reports of field resistance to DMIs. Reports of reduced effectiveness of DMIs have appeared on a number of agricultural and fruit crops—primarily from Europe where DMI use is more intensive.

In the last two years, we have had our first reports of control failures with DMI on turf in the U.S. The culprit again is dollar spot. In the Chicago area, we have documented one golf course site where DMI products have gradually lost there effectiveness in controlling dollar spot. The level of control on affected fairways is now totally unacceptable. Laboratory tests of dollar spot isolates from this site indicate that the decrease in fungicide sensitivity is fairly low (10-fold), i.e. the fungi have become "tolerant" of the fungicide, not totally resistant as with benzimidazoles. We may see development of more of a problem with DMIs over the next few years, if use patterns don't change (more about this later).

Another important aspect of DMI use on golf courses is application of growth retardants such as paclobutrazol (TGR) and flurprimidol (Cutless). Paclobutrazol is a triazole compound similar to the triazole fungicides, and flurprimidol is a pyrimidine-methanol derivative similar to fenarimol. The mode of action of these growth retardants is also very similar to the fungicides; they are sterol biosynthesis inhibitors. Plant growth rates are reduced by inhibiting syntheses of the hormone gibberellin, a type of sterol molecule found in plants. Repeated use of DMI fungicides and growth retardants on fine turf can have several consequences. One is possible adverse effects on health of desirable grass species from an overdose of DMIs. Phytotoxicity, increased or prolonged growth suppression, increased coarseness or steminess, and increased susceptibility to certain diseases have all been observed.

Dicarboximides

This class of fungicides includes the turf fungicide iprodione (Chipco 26019)

and vinclozolin (Vorlan, Curalan). These products are broad spectrum and generally regarded as contact fungicides, although they have been shown to have some systemic activity. The mode of action of these products is not well known, but they are usually considered along with single-site inhibitors. Field resistance to these fungicides has been observed for a number of years on fruit and vegetable crops, and a few reports of dollar spot and pink snow mold resistance have appeared in the turfgrass literature. We have not observed any resistance problems with these fungicides in Illinois.

Avoiding Resistance Problems

Fungicide resistance usually results from repeated long-term use of a systemic fungicide to control a particular target disease. For benzimidazoles and phenylamides, resistance may develop in as little as two to three years of repeated use. We have seen resistance develop in Illinois in as little as three years with metalaxyl, while development of DMI resistance dollar spot was observed after eight years of frequent (though not exclusive) use.

The current thinking is that to avoid resistance, single-site inhibitor systemic fungicides should be tank-mixed or alternated with multi-site inhibitor contact fungicides such as chlorothalonil (Daconil 2787) or anilazine (Dyrene). Another approach is to tank mix or alternate single-site systemics with different modes of action. Mixing or alternating products within one class of fungicides (e.g. DMIs) will not provide any protection. In most cases, this would be the same as applying one fungicide over and over. Also, cutting application rates and extending application intervals—especially in times of heavy disease pressure—may contribute to more rapid development of resistance.

Perhaps of even greater importance in avoiding disease problems and development of fungicide resistance is the idea of using overall disease management strategies (IPM) instead of thinking only in terms of fungicide management. Use of IPM strategies that take into consideration the overall health of your turf can go a long way toward reducing your dependance on fungicides. Disease pressures can often be reduced by: maintaining adequate and balanced fertility; controlling irrigation amounts and timing; improving localized climates through subsurface drainage, aerification, and increasing air movement and sun penetration; and, reducing cultural (management) stresses—for example by raising cutting heights, reducing mechanical wear, etc.

The current climate is poor for development of new fungicides to replace older products that fail registration or lose effectiveness. Older, multi-site contact fungicides may fall by the wayside. It is important that all turf managers reexamine their fungicide use patterns and disease control strategies, and be more willing to use alternative control methods. ❑

Editor's Note: Dr. Randy Kane is the turfgrass advisor for the Chicago District Golf Association and an adjunct assistant professor of plant pathology at the University of Illinois in Urbana-Champaign. Dr. Hank Wilkinson is an associate professor of turfgrass pathology at UIUC. Both earned their plant pathology Ph.D.s from Cornell University.

Fungicide Manufacturers

Ciba-Geigy Corp.,
Turf & Ornamental Products
Greensboro, NC
(919) 547-1160
DowElanco
Indianapolis, IN
(800) 352-6776
Grace-Sierra
Milpitas, CA
(800) 492-8255
Gustafson, Inc.
Dallas, TX
(214) 985-8877
ISK Biotech Corp.
Mentor, OH
(216) 357-4100
Lebanon Turf Products
Lebanon, PA
(717) 273-1685
Lesco
Rocky River, OH
(800) 321-5325
Miles, Inc.
Kansas City, MO
(800) 842-8020
Nor-Am
Wilmington, DE
(302) 575-2000
O.M. Scott & Sons
Marysville, OH
(513) 644-0011
Rhone Poulenc Ag. Co., Chipco Group
Research Triangle, NC
(919) 549-2000
Terra International
Sioux City, IA
(800) 831-1002 (ext. 225)
The Andersons
Maumee, OH
(419) 893-5050
W.A. Cleary Chemical Corp.
Somerset, NJ
(908) 247-8000

Note: This list was compiled by sportsTURF Magazine. Endorsement of particular products or companies by the authors of the article is neither intended nor implied.

FREE CATALOG FOR LAWN AND TURF MANAGERS!

Think of it as "your store" for the tools and supplies you need! Catalog #43 from Forestry Suppliers, Inc. is packed with quality products to help you with soil sampling and testing, applying chemicals, traffic control and much more!

- Turf Marking Paints
- pH Meters
- Seeders & Spreaders
- Sprayers
- Erosion Control Blankets
- Surveying Instruments
- Soil Probes
- Tensiometers

These are just a few of the many great items you'll find in this 508-page catalog. For your FREE copy...

DIAL-FREE 1-800-647-5368
FAX-FREE 1-800-543-4203

Forestry Suppliers, Inc.
205 W. Rankin St./P.O. Box 8397
Jackson, MS 39284-8397

More than the name implies...

11692

Circle **112** on Postage Free Card