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IN THIS ISSUE

Non-Target Effects of Fungicides

Peter H. Dernoeden

Arriving at the decision of whether to apply a fungicide to any turf area is often difficult and based on economic considerations. Aside from cost, the primary determinants in using a fungicide are based on the prevailing environmental conditions, the susceptibility of the host species and cultivars present, and the pathogen(s) involved. Unique factors in turfgrass pathology include the intensity and nature of turfgrass cultivar, which greatly influence plant vigor and therefore the severity of diseases.

Promoting vigorous grass growth through sound cultural practices is the first step in minimizing disease injury. Frequently, however, environmental stresses, traffic and poor management practices weaken plants, predisposing them to invasion by fungal pathogens. When disease symptoms appear, it is imperative that a rapid and accurate diagnosis of the disorder be made. The prudent manager also attempts to determine those environmental and cultural factors that have led to the development or contributed to the intensity of the disease. A common cause for extensive disease injury on golf course turf frequently can be related to improper management practices. Cultural practices that tend to exacerbate diseases include frequent and close mowing, excessive grooming during periods of environmental stress, light and frequent irrigation or excessive irrigation, and applications of inadequate or excessive amounts of nitrogen fertilizer. The development of excessive thatch and/or mat layers, shade, poor air or water drainage, traffic, and soil compaction also contribute significantly to disease problems. **Despite hard work and adherence to sound cultural practices, however, diseases may become a serious problem. This normally occurs when environmental conditions favor disease development, but not plant growth and vigor.** For example, summer patch (*Magnaporthe poae*) and brown patch (*Rhizoctonia solani*) are most damaging when high summer temperatures stress plants and impair their growth and recuperative capacity. In this situation, fungicides may be recommended in conjunction with cultural practices that promote turf vigor.

Fungicides may be applied preventively (i.e., before anticipated disease symptoms appear) or curatively (i.e., when disease symptoms first become evident). **Preventive fungicide treatment is recommended for chronically damaging diseases.** This is particularly true on golf course putting greens in regions where **snow molds, Pythium blight** (*Pythium aphanidermatum*), **brown patch, summer patch,** and **anthracnose** (*Colletotrichum graminicola*) are common. Successful management of **gray leaf spot** (*Pyricularia grisea*) on perennial ryegrass (*Lolium perenne*) fairways in some regions of the United States also is best achieved with preventive sprays. **Curative applications are more economically wise for less severe or chronically damaging diseases** such as **red thread** (*Laetisaria fuciformis*), **Helminthosporium leaf spots** (*Bipolaris* spp. and *Drechslera* spp.), **rusts** (*Puccinia* spp.), and **stripe smut** (*Ustilago striiformis*). The key to a successful curative fungicide program is vigilant scouting.

Contact fungicides are generally less expensive and provide good control. Contact fungicides, however, may only provide 7 to 14 days of control under conditions of high disease pressure. Penetrants applied preventively generally

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provide 14 to 21 days protection during high pressure disease periods. **Where sudden and severe, or chronic disease problems occur, a penetrant fungicide plus a contact fungicide may be needed.** In general, **once a disease appears the application of a contact fungicide or contact plus a penetrant fungicide is preferred.** Tank mixing a contact plus a penetrant fungicide provides a quicker knockdown, a longer residual effect, and a wider spectrum of control. Frequently, a fungicide may only be needed to help the turf better survive a high pressure disease period. Favorable changes in weather conditions, such as a shift from hot and humid conditions to an extended cool and dry period, however, often reduces and sometimes eliminates a disease problem in the summer.

Where extremely high quality turf is required, fungicides will be needed in most years, and in nearly all areas of the United States. **The indiscriminate use of fungicides or employment of numerous, preventive applications of fungicides for all diseases should be discouraged.** Other than economic restraints, some reasons why repeated fungicide applications may be undesirable include: (a) development of fungicide resistant pathogens, which is most likely to occur with those fungi causing dollar spot and Pythium blight; (b) continuous fungicide usage may lead to a build-up of microorganisms that degrade the active ingredient, resulting in reduced residual control; (c) disease resurgence, a phenomenon in which a disease recurs more rapidly and causes more injury in turfs previously treated with fungicides, when compared to non-fungicide-treated sites; (d) a fungicide may control one disease, but encourage another disease; (e) phytotoxicity or objectionable plant growth regulator effects; and (f) encouragement of algae.

The development of fungal biotypes resistant to fungicides is well documented. Resistant biotypes of the dollar spot fungus (*Sclerotinia homoeocarpa*) first developed as a result of repeated usage of cadmium-based fungicides, benomyl (Tersan 1991®) and thiophanates (CL 3336®, Fungo 50®) on golf courses. Biotypes of the dollar spot fungus resistant to iprodione (Chipco 26GT®), and sterol-inhibiting (SI) fungicides (propiconazole = Banner MAXX®; triadimefon = Bayleton®; myclobutanil = Eagle®; terbuconazole = Lynx®; fenarimol = Rubigan®; triticonazole = Triton®) also have been reported. *Pythium aphanidermatum* biotypes resistant to metalaxyl/mefenoxom (Subdue® and Subdue MAXX®, respectively) are well documented. It is important to note that when resistance develops to a fungicide, all fungicides in the same chemical class will exhibit cross resistance. For example, *S. homoeocarpa* biotypes resistant to one SI fungicide also will be resistant to all other SI fungicides. Similarly, *S. homoeocarpa* biotypes resistant to Chipco 26GT® (a dicarboximide), will exhibit resistance to other dicarboximides such as vinclozolin (Curalan®, Touche®, and Vorlan®). The build-up of resistant biotypes of fungi occurs in response to a selection process that eventually enables a small, but naturally-occurring sub-population of resistant biotypes to dominate in the fungicide-treated turfgrass microenvironment. **Resistance problems can be delayed or averted by rotating fungicides with different modes of action, by tank mixing a contact and a penetrant, or by tank mixing known synergists.** Synergistic combinations are those where two or more fungicides with different modes of action are tank-mixed together at low rates. **A synergistic tank-mix provides a level of control equivalent to or better than the normal use rate of either component applied alone.** For example, a tank-mix of one-half the low label rate of Subdue MAXX® plus one-half of the low label rate of Banol® (propamocarb) would be expected to provide a level of Pythium blight control equivalent to or better than either component applied alone at the full rate. There are, however, few well-documented studies demonstrating synergism among tank mixtures.

Perhaps a more common negative phenomenon associated with fungicides, which may be confused with resistance, is reduced residual effectiveness. This phenomenon has been demonstrated in fruit crops, but to date has not been documented in turf. Field observations, however, provide evidence that it also occurs in turf. For example, when Subdue® was first introduced in the early 1980s it was common for it to provide over 21 days of residual Pythium blight control. Today, on numerous golf courses where Subdue® has been used for many years, the fungicide (both Subdue® and Subdue Maxx®) may provide only 5 to 10 days of Pythium blight control. Microorganisms are largely responsible for breaking down pesticides in the environment. Some microbes can rapidly build up in response to the continuous use of certain fungicides from the same chemical class. The microbes use the active ingredient of the fungicide as an energy source. As a result of the fungicide being more rapidly degraded, the residual effectiveness becomes less and less over time. The loss of residual effectiveness may be an indicator that resistant biotypes are building in the turf. In many cases, however, **loss of residual effectiveness is likely due to a build-up of high populations of microbes that use the fungicide as an energy source.** The improper application of fungicides, use of a water dilution less than 90 gallons of water per acre (841 L ha^{-1}), and mowing within 24 hours of spraying also contribute to reduced residual effectiveness.

Some diseases may recur more rapidly and severely in turfs previously treated with fungicides when compared to adjacent untreated areas (e.g., treated fairways versus untreated roughs). Dollar spot, brown patch, and gray leaf spot are probably the most common diseases to exhibit this phenomenon. Resurgence of brown patch and dollar spot in particular are well documented. Disease resurgence is attributed to a fungicide reducing populations of beneficial microorganisms, which naturally antagonize and keep disease-causing fungi in abeyance. **It also is conceivable that non-fungicide-treated turf, which is blighted, yet able**

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Be Careful with Early Germination of Annual Grasses

Fred Yelverton

Annual grasses such as large and smooth crabgrasses, goosegrass, and barnyardgrass are major problems in turfgrasses. As a result, turfgrass managers use preemergence herbicides to prevent the occurrence of these troublesome weeds. When control with preemergence herbicides fails, appropriate postemergence herbicides can be used.

There are several reasons why preemergence herbicides fail to provide season-long control. **One of the most common reasons is that some germination of annual grasses occurs prior to the application of a preemergence herbicide. Most annual grasses will start to germinate when a critical soil temperature is maintained over a few consecutive days.** Table 1 provides a list of critical soil temperatures for germination of various grasses.

The temperatures listed in Table 1 refer to 24-hour average soil temperatures over several days. As a result, it is impossible to place a soil temperature probe in the ground and get a good measure of a 24-hour average soil temperature. For instance, in late winter/early spring, a bright sunny day may produce soil temperatures far above the 55°F (13°C) needed for crabgrass germination. However, at night, soil temperatures fall well below this temperature and as a result, the 24-hour average temperature is somewhat below the critical temperature needed for germination. **Automated weather data recording systems with an attached soil probe are needed for accurate measures of average daily temperatures.** Many portable weather stations can be fitted with a remote soil temperature sensor. **Measuring the soil temperature at your site is the most accurate method to predict weed germination.**

Turfgrass managers can also find excellent information on 24-hour average soil temperatures on the Internet. Many land-grant universities post daily weather data on the Internet. Because many universities have multiple outlying research stations, these data can often be found at a site near you.

It is also important to point out that **most grasses germinate in the upper one-half inch or so of soil. Because most grasses have a small seed, they will not germinate below this depth.** In addition, **many weeds, such as crabgrasses, have a high light requirement for seed germination.** Therefore, the deeper the seed in the soil/thatch layer, the more difficult it will be for this plant to germinate. This is also one of the reasons why dense, healthy turf has less weeds than thin turf. More light penetrates through the canopy of the thin turf, which leads to more weed germination.

In summary, accurate information on soil temperature will allow turfgrass managers to properly time their preemergence herbicide application. Proper timing of application leads to the best control at the minimum herbicide rate.

Table 1.

Weed	Critical Soil Temperature* °F	°C	Scientific Name
large and smooth crabgrasses	55	13	*Digitaria sanguinalis and ischaemum*
goosegrass	60–65	15–18	*Eleusine indica*
barnyardgrass	60–65	15–18	*Echinochloa crusgalli*
foxtails	65	18	*Setaria* spp.

* Watschke, T.L. 1995. Turfgrass weeds and their management. In *Managing Turfgrass Pests.*

Understanding Ice Covers

James B Beard

Too many turf managers think ice covers are synonymous with dead grass and attribute the cause to the ice directly killing the grass. However, this usually is not the case. Frequently, the loss of turf associated with an ice cover is by direct low temperature kill either (a) during the initial ice formation, or (b) during the thawing period when standing water increases the crown hydration level and then is followed by a rapid drop in temperature typically below 20°F (–7°C).

The winter of 2000–2001 has seen conditions that could result in either the low temperature kill associated with an ice cover as just described, or possibly due to an extended ice coverage itself, especially if a *Poa annua* turf is involved. **The 2000–2001 situation involves an extended accumulation of a wet slush to a depth of 4 inches (100 mm) or more, followed by freezing, and then the accumulation of an additional major snow cover that remains in place.**

Pre-ice Cover Kill. There is a possibility that **the turf has already been killed if the wet slushy condition had resulted in crown hydration, and if this was followed by a rapid drop in temperature to 20°F (–7°C) or lower.** This is especially true if the soil temperature was near or below freezing. A simple way to determine if turf kill may already have occurred is to remove the ice and snow cover from two to four areas that have a history of loss during winter ice-snow occurrences, remove 4 to 6 inch (100–150 m) pieces of turf with the lateral stem, thaw the turf slowly, and placing in a greenhouse or in a warm room near a window to observe whether shoot greenup and growth occurs or if the grass is dead.

Ice Cover Kill. If the turf has not been killed but is encased in ice, the next question is whether the ice cover itself may cause injury. **If the ice cover remains in place for more than 75 days and the underlying turf is dominated by annual bluegrass (*Poa annua*), then the potential for death caused directly by the ice sheet is great.** The actual cause in this case is the toxic accumulation of respiratory gases in and around the grass shoots caused by encasement in the relatively impermeable ice. For other grasses, such as creeping bentgrass (*Agrostis stolonifera*) and Kentucky bluegrass (*Poa pratensis*), research has shown that encasement in ice for up to 150 days at 25°F (–4°C) did not result in injury. Cultural practices that would reduce turf injury caused by extended ice coverage include (a) maintaining a moderately low nitrogen level, and (b) ensuring a high potassium level.

If a substantial ice accumulation occurs beyond the safe time or threshold period, efforts should be made to remove the excess ice and snow down to within 1 inch (25 mm) of the turf surface by powered mechanical means. Once temperatures rise sufficiently after the removal of the excess ice and snow, the application of a black charcoal or fertilizer material at temperatures of ~30°F (–1°C) or higher will aid in absorbing solar radiant energy, thereby resulting in an enhanced rate of ice thaw.

Post-ice Cover Kill. Once the ice-snow thawing process begins it is important to ensure that the water is removed from the turf area as rapidly as possible. There is a scenario in which kill of the turf can occur during this period. This involves the accumulation of water from thawing ice and snow that increases the crown hydration level and that subsequently is followed by a very rapid freeze to 20°F (–7°C) or lower. In many southern-most regions of the snow belt in the northern United States there typically is a thaw period in February during which conditions of this type can exist. Typically this is when much of the turfgrass kill associated with ice covers occurs but it actually is caused by direct low temperature kill.

Predicting Lethal Temperature Threshold. A question frequently asked is "the temperature on our area dropped to 10°F (–12°C). Has the turf been injured?" **Actually anyone who gives a specific threshold temperature at which kill will occur is not knowledgeable in winter injury problems.** The reason is that the actual killing temperature can vary greatly depending on the degree of crown hydration, the rate of freezing, the rate of thawing, and the length of time frozen. Thus, an absolute threshold temperature at which low temperature kill will occur can not be predicted reliably. There also are cultural and environmental conditions that can affect the threshold duration at which ice coverage results in kill of each individual turfgrass species. Unfortunately, the needed research has not been conducted to define these factors clearly. Thus, **if one is considering the removal of an ice sheet, it is better to error on the short side than to wait too long.**

FEATURE ARTICLE

Ranking the Grub Insecticides

Daniel A. Potter

Every year, turf entomologists employed by universities and some private companies conduct dozens of independent research trials to evaluate the performance of new insecticides against the old standbys. Pesticide manufacturers must submit efficacy data—that is, proof that a new insecticide is effective—as part of EPA's registration process. The manufacturer usually pays a testing fee, called a grant-in-aid, to the university. Part or all of these funds can be used by the researcher to pay student assistants, purchase equipment, or otherwise support their research. Many extension turf specialists also conduct efficacy trials so that they can make informed recommendations regarding product performance. Scientists who do such trials often publish their results in *Arthropod Management Tests* (formerly *Insecticide and Acaricide Tests*), a hefty, soft-cover volume published annually by the Entomological Society of America.

As a turf entomologist I'm often asked which grub insecticide works the best. Even in my own trials, however, insecticides don't always perform consistently. Thatch thickness, soil moisture, formulation, application method, irrigation, target grub species, and other factors all can affect insecticide performance. What works best in the clay soils of Kentucky may not work as well in the sandy soils of Massachusetts. Relatively small differences in "% control" usually aren't meaningful. The best products are those that can be relied upon to give consistently good results.

Dr. David Shetlar, the "BugDoc" at The Ohio State University, performs a valuable service by periodically compiling data from *Arthropod Management Tests* into summary tables that facilitate comparisons of different products' performance across a large number of tests. The accompanying tables, provided by Dr. Shetlar, will be of interest to turf managers. Table 1 shows the efficacy of most of the insecticides marketed for grub control in the past 25 years. Some products that have been withdrawn from the market are included as a frame of reference. **The last column, percentage of tests in which the insecticide provided relatively poor (less than 70%) control, provides an index of reliability.**

Note that **two preventive insecticides, Merit® and MACH2®, both registered during the 1990s, have been consistently strong performers. Meridian®, a new thianicotinyl insecticide (registration expected in early 2001), joins the ranks of these highly effective preventives.** The remaining synthetic insecticides on the list are all short-residual organophosphates or carbamates, used for curative control when grubs are present. **Of the products still registered, Dylox® has been the most consistent performer for curative control. Of the nematode-based products, those containing *Heterorhabditis bacteriophora* have been more efficacious than those with *Steinnernema glaseri* or *S. carpocapsae,* but none of the nematodes has been as consistent as the synthetic insecticides.** Note, too, that chlorpyrifos (Dursban®) has never been a premier product for white grub control, mainly because of the tendency for its residues to be bound in thatch. **Recent EPA restrictions on Dursban® reduce our options for controlling surface-feeding pests, but won't have a big impact on grub control.**

Table 2 shows how the timing of application affects performance of preventive grub insecticides. Trichlorfon (Dylox® or Proxol®)—a fast-acting curative—is included for comparison. **All three of the preventives provide a broad application window from mid to late May until egg hatch in late July or early August.** Efficacy begins to drop in mid-August, as grubs grow larger. Although MACH2® is the only preventive that has also been marketed for early curative control, the data suggest that both Merit® and Meridian® provide comparable efficacy against first and second instars. **Late curative or "rescue" treatments applied from mid-September onward, or after damage appears, tend to provide only partial control at best.** None of the insecticides are fast-acting enough against large grubs to discourage skunks and other predatory varmints once they have started digging.

Optimal timing for preventive treatments is during the month or so before egg hatch. This treatment window generally is early June to mid-July in the transition zone, or about 2 weeks later in more northern states. Regardless of the product, curative insecticides work best if applied soon after egg hatch, when grubs are still small.

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Ranking the Grub Insecticides

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Table 1. Ranked Efficacy of White Grub Insecticides: 1976–1999[a]

Insecticide	Rate (lb ai/ac)	Average (% control)	Number of tests	Range (% control)	% of Tests Below 70%
Thiamethoxam[b] (= Meridian®)	0.2	99.3	17	94–100	0
Halofenozide (= MACH2®)	1.5	95.4	50	10–100	6
Imidacloprid (= Merit®)	0.3	93.7	58	58–100	7
Isazofos (= Triumph®)[c]	2.0	88.8	69	46–100	10
Isofenphos (= Oftanol®)[c]	2.0	82.3	85	38–100	19
Bendiocarb (= Fican®, Turcam®)[c]	3.0	82.3	30	0–100	13
Ethoprop (= Mocap®)	5.0	76.7	38	48–97	34
Trichlorfon (= Dylox®, Proxol®)	8.0	77.4	89	0–98	20
Carbaryl (= Sevin®)	8.0	74.3	40	13–100	37
Fonofos (= Crusade®, Mainstay®)[c]	4.0	70.8	21	8–100	29
Diazinon[d,e]	4.0	69.9	19	47–99	42
	5.5	74.8	41	25–100	29
H. bacteriophora	0.5 bill	57.7	3	15–92	67
Chlorpyrifos (= Dursban®)[f]	4.0	54.6	32	0–96	59
S. glaseri	0.5 bill	31.3	14	0–71	93
S. carpocapsae	1.0 bill	21.5	10	0–61	100

[a] Data from *Insecticide and Acaricide Tests & Arthropod Management Tests,* Entomological Society of America (using masked chafers and Japanese beetle evaluations 1977–2000 and label recommended application timing). Compiled by D.J. Shetlar, October 2000.
[b] New product from Novartis, expected registration in 2001.
[c] No longer manufactured (1997–2000).
[d] Not for use on golf courses or sod farms.
[e] 5.5 lb ai./a rate reduced to 4.0 on current labels.
[f] Discontinued for residential use in 2001.

Table 2. Comparison of Grub Insecticide Efficacy by Time of Application[a]

Insecticide	Rate (lb ai/ac)	Average % Control (Tests) for Treatments Applied During: May	June	July	Aug. 1–16	Aug. 17–Sept. 10
Halofenozide (= MACH2®)	1.5	99.4 (5)	96.8 (18)	96.4 (12)	92.8 (12)	80.9 (20)
Imidacloprid (= Merit®)	0.3	97.7 (6)	90.8 (14)	93.1 (11)	95.1 (11)	93.7 (8)
Thiamethoxam (= Meridian®)	0.2	100.0 (3)	98.7 (10)	98.4 (5)	100.0 (3)	87.4 (3)
	0.26	97.9 (2)	100.0 (2)	98.5 (1)	100.0 (2)	100.0 (1)
Trichlorfon (= Dylox®/Proxol®)	8.0	—	—	—	91.0 (2)	82.6 (11)

[a] From studies published in *Arthropod Management Tests (1997–2000),* using Japanese beetle and masked chafer efficacy data where checks had 4+ grubs per square foot and significant results.

Compiled by D.J. Shetlar, October 2000.

...Fungicides

Continued from page 2

to recover due to a shift in environmental conditions, is better prepared to resist future infections due to natural defense systems in plants having been activated by the initial attack.

Fungicides applied to control one disease may encourage other diseases. Benomyl (Benlate® or Tersan 1991®) has been reported to enhance red thread, Helminthosporium leaf spot, and Pythium blight. Thiophanates (CL 3336®, Fungo 50®) may increase rust (*Puccinia* spp.) in perennial ryegrass and Helminthosporium leaf spot; iprodione (Chipco 26GT®) can increase yellow tuft (*Sclerophthora macrospora*); azoxystrobin (Heritage®) and flutolanil (ProStar®) may enhance dollar spot; and chlorothalonil (Daconil®) can increase summer patch and stripe smut in Kentucky bluegrass (*Poa pratensis*). Encouragement of disease in these situations again may be attributed to offsetting the delicate balance between antagonistic and pathogenic microorganisms in the ecosystem. **It is important to note that using a selected fungicide will not invariably result in an increase in a non-target disease.** These problems are sporadic and enhancement of non-target diseases cannot occur unless environmental conditions are conducive for the disease to occur naturally. Hence, when dollar spot is active, fungicides like Heritage® and ProStar® should be avoided or if they are needed they should be tank-mixed with a fungicide that targets dollar spot.

The phytotoxicity that accompanies the usage of some fungicides is generally not severe. **Most phytotoxicity problems occur when fungicides are applied to annual bluegrass (*Poa annua*) and creeping bentgrass (*Agrostis stolonifera*) putting greens during periods of high temperature stress.** Fungicides formulated as emulsifiable concentrates are most likely to cause a foliar burn when applied during hot weather. A misapplication of excessive rates of ethridazole (Koban®) can be very injurious to putting greens. Copper-based fungicides (e.g., Junction®) and pentachloronitrobenzene (Penstar®, Quintozene®, Terraclor®) may yellow turf when applied during warm weather. Chlorothalonil (Daconil®) can severely injure some cultivars of creeping red fescue (*Festuca rubra* spp. *rubra*), Chewings fescue (*F. rubra* ssp. *commutata*), hard fescue (*F. longifolia*), and blue fescue (*F. glauca*). Repeated applications of sterol-inhibiting fungicides such as propiconazole, triadimefon, myclobutanil, and other SI's often elicit a blue-green color and suppress the foliar growth of most turfgrass species. Applying sterol-inhibiting fungicides with some plant growth regulators (e.g., paclobutrazol = Trimmit® and flurprimidol = Cutless®) may cause objectionable levels of discoloration or injury, particularly in annual bluegrass and bentgrasses. Interestingly, Trimmit® and Cutless® are chemically related to SI fungicides and they have been shown to suppress dollar spot. Conversely, use of the growth regulator mefluidide (Embark T & O®) can intensify Helminthosporium leaf spot and red thread.

When used repeatedly, certain fungicides have been shown to slightly increase thatch accumulation, but these increases are agronomically insignificant. Benzimidazole fungicides, such as benomyl and the thiophanates, and sulfur-containing fungicides such as mancozeb, maneb, and thiram can cause thatch to accumulate by acidifying the soil. The effect of acidifying fungicides is indirect, that is they inhibit the thatch decomposition capacity of microorganisms by lowering soil pH. **The primary mechanism by which fungicides enhance thatch, however, is by promoting stem, stolon, and rhizome survival rather than suppressing microbial activity. While some fungicides can reduce selected species of fungi and bacteria in soil, their overall impact on soil microbial activity is negligible.** Furthermore, fungicides have been shown to have no impact on the Acremonium endophyte in perennial ryegrass. A few fungicides, however, have been shown to restrict mycorrhizal development in roots of some grasses. **Fungicides may also contribute to thatch build-up by being toxic to earthworms.** Earthworms help reduce thatch by mixing soil with organic matter. **Benomyl, thiophanates, and various insecticides and nematicides have been shown to be toxic to earthworms.**

Sterol-inhibiting fungicides may promote the growth of blue-green, filamentous algae on putting greens. The mechanism for this phenomenon is unknown. Open canopies or less dense turf favor algal growth in part by improving sunlight penetration to the thatch or soil surface. It is possible that the growth regulator effects of SI fungicides may cause leaves to grow more upright, thus promoting sunlight penetration to the thatch layer. Conversely, chlorothalonil (Daconil®), copper hydroxide (Junction®), and mancozeb (Fore Rainshield®) have been shown to suppress algal growth on putting greens.

It should be noted that the harmful side effects just described often are isolated events or occur only after repeated use of one chemical class of a fungicide over the course of several years. As a general rule, non-target effects are sporadic and they do not invariably occur in most situations. It is also obvious that scientists do not understand the mechanisms that cause these deleterious effects to occur. Experienced turfgrass managers have long recognized that tank mixing or rotating fungicides with different modes of action greatly minimize these potential problems. **The importance of rapid and accurate disease diagnosis, and the judicious use of fungicides are integral in management programs where fungicides are commonly employed.**

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Research Summary

Carbon Storage in Soils

The summary in a paper published by CAST states "As an important constituent of soils, organic matter contributes greatly to plant productivity and ecosystem stability. **Soil organic matter also is an important repository for carbon (C) and plays a central role in the global C-cycle.** Soils may act either as a source, releasing C to the atmosphere, or as a sink into which C from the atmosphere is deposited depending on season, time of day, vegetative cover, weather conditions, and land management. But land management is the critical determinant of whether the net change in soil C is a gain or loss. Since the beginning of the industrial revolution, land use changes, such as conversion of temperate forests and prairies to agricultural fields, have contributed significantly to the recorded increase in concentration of atmospheric CO_2." The body of the paper is devoted to historical aspects of carbon sequestration, followed by discussions of new technologies to fully understand the factors controlling sequestration, along with the need for monitoring and verification of soil carbon levels as affected by various agricultural soil management practices. They conclude that **soil C-sequestration can provide an important opportunity for limiting the increase for atmospheric CO_2,** especially if action is taken world-wide during the next three decades.

Comment: Nowhere in this issue paper is there a mention of the potential role that permanent grass covers play in carbon sequestration. Rather, it is entirely focused on agricultural cropping practices. Actually, if funding were made available for the appropriate studies, they would probably show that **turfgrasses offer one of the best ecosystems available for the sequestration of carbon in soils.** Environmentalists proclaim the great virtues of carbon sequestration in the forests of the tropics. Why does no one mention the key role that grass vegetations play in carbon sequestration?

Storing Carbon in Agricultural Soils to Help Mitigate Global Warming. Issue Paper Number 14 April 2000. The Council for Agricultural Science and Technology, Ames, Iowa, 8 pp.

Ask Dr. Beard

Q *Why has there been a major increase in moss and algae problems on putting greens in the last five to ten years?*

A The most obvious response to this question relating to the past 10 years is that the cutting height has been lowered significantly. The cultivars of both warm- and cool-season turfgrasses traditionally used on putting greens lack tolerance to these closer mowing heights of 1/8 to 1/10 inch (3.2 to 2.5 mm). The result is significant thinning of the turf that allows sunlight to reach the soil surface. Both algae and moss require sunlight for growth, and thus they have become an increased problem in recent years.

One other aspect that is overlooked in many situations is the root zone dimension. It is frequently observed that moss and algae problems occur on high-sand root zones, such as USGA constructions, which many people assume should tend to be on the dry side. Moss and algae are favored by high soil moisture. There is a situation where this condition can occur. That is, even if the proper high-sand root zone specifications have been employed in the original construction, the desired drainage of excess surface water can be negated through the topdressing practices. Even a single, thin layer of topdressing containing a particle size significantly more fine than the original construction can result in a perching of excess water near the surface. This in turn can result in a wet condition that is particularly favorable for moss and algae development, especially when combined with an increased sunlight level.

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