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Non-Target Effects of Fungicides

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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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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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