Field tips

Dealing with the unintended consequences of fungicide applications

by Christopher Sann

At first glance, the unintended, nontarget effects of turfgrass fungicide applications appear to pose little if any problem to the average turfgrass manager. In truth, almost all turfgrass managers who have used fungicides have already had to deal with these nontarget effects.

Enhancement in the severity of a disease or an increase in occurrence of other diseases after a fungicide is applied are the most frequently seen nontarget effects.

Here are some examples:

- Test results from a study to measure the severity of Dreschlera leaf spot in the spring following summer applications of a number of commonly available fungicides found that many of the systemic, sterol-inhibiting fungicides substantially increased the incidence of spring leaf spot. It also found that the previous season's use of benomyl (Tersan 1991) produced the highest levels of next spring's leaf spot damage.

- The repeated use, in the late fall and early spring, of even light rates of fenarimol (Rubigan) to control Necrotic ring spot can lead to unexpected infestations of pythium root rot in treated areas, particularly if the spring weather is cool and wet.

- Dramatic increases in the incidence of Brown patch disease following multiple high rate applications of triadimefon to control Summer patch can sometimes occur.

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for turfgrass disease control and their intended target pathogens are listed in Table 1 (See Table 1 on Page 3.). From among these fungicides, triadimefon has the broadest spectrum of activity. Other sterol-inhibiting and benzimidazole fungicides such as propiconazole, fenarimol, thiophanate methyl, and benomyl are similarly quite broad-spectrum. Of the other fungicides, chlorothalonil, iprodione, and mancozeb are among the more broad spectrum fungicides. Fungicides, such as the "Pythium" fungicides etridiazole, fosetyl Al, metalaxyl, and propamocarb, are highly selective, and are toxic generally only to a few closely related fungi.

Although fungicide selectivity has been known for many decades, few of the traditional contact fungicides exhibit a significant level of selectivity. Many of the older, metal-based fungicides such as mercury- and cadmium-based fungicides have little selectivity and are considered to be general biocides. Other metal-containing fungicides like mancozeb and zineb also have little selectivity. However, many of the newer systemic fungicides, introduced beginning in the 1960's, are so selective (e.g., the Pythium fungicides mentioned above) that only certain taxonomic groups of fungi are affected.

Although the general biocides, such as the metal-containing fungicides, possess the potential for greater nontarget effects, we have learned that even some of the newer, systemic fungicides have greater potential for nontarget effects than earlier believed. In general, all fungicides, regardless of their apparent selectivity against target species, have a wide range of biological activities that go well beyond the intended target function.

How do fungicides work?

Fungicides used for turfgrass disease control inhibit a number of metabolic processes in fungal cells. The cellular location and the biochemical pathway inhibited by the toxic action of the fungicide impart selectivity upon the fungicide being used. The specific modes of action of a number of currently available turfgrass fungicides are listed in Table 2 (see Table 2 on Page 5). Generally, all of the turfgrass fungicides fall into major "mode-of-action" classes. Each of the fungicides within a class affect fungal cells in the exact same way.

Fungicides suppress the activity of fungal pathogens either by killing fungal cells (fungicidal) or by simply suppressing growth and reproduction (fungistatic). Those fungicides that act as multi-site inhibitors or those that affect biochemical pathways (such as nuclear functions or membrane biosynthesis) common to a wide variety of organisms are more likely to exhibit nontarget effects. These would include the broad-spectrum contact fungicides such as chlorothalonil, mancozeb, and thiram as well as the broad-spectrum systemic fungicides such as the benzimidazoles (benomyl, thiophanates) and sterol inhibitors (triadimefon, propiconazole, etc.). Many of the newer fungicides act by enhancing natural plant

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- Red thread and other minor turfgrass diseases can become problems in turf stands, where there has not been a history of such diseases, following applications of the benzimidazoles and other sterol-inhibiting fungicides.

Why do these enhancements occur?

How, why, and when this disease enhancement effect takes place will vary greatly depending on the environment at each application site. Perhaps the greatest reason for these nontarget effects, however, is the often dramatic reduction in competition from other non-pathogenic antagonistic microbes that may result from the application of a broad spectrum fungicide. Once the competitors are reduced by the nontarget effects of a fungicide, other uncontrolled pathogenic species can proliferate and become the dominant disease-causing fungi.

This ability to fill the "microbial void" left by the application of a fungicide has been a particular problem with the various Pythium species. They may be a problem-prone species because it grows rapidly and is not controlled by the majority of available broad-spectrum fungicides. Increases in Brown patch, caused by multinucleate Rhizoctonia species, may be the result of reductions in the populations of the highly competitive and antagonistic bi-nucleate Rhizoctonia species which act as natural disease controls. Although both triadimefon and propiconizole may provide adequate Brown patch control, their high-rate use to control Summer patch may well have a deleterious effect on populations of "good" binucleate Rhizoctonia species.

Should turfgrass managers stop using fungicides?

These examples of nontarget effects are not an encouragement to stop using turfgrass fungicides. Rather they are warnings to turfgrass managers that there can be undesir-

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rect. The nontarget effects of fungicide applications may present themselves in a variety of ways that include general effects:

- on microbial activities and biochemical processes in soil,
- on microbial populations leading to increased intensity of certain diseases and reduced natural biological control,
- on disease tolerance of host plants, and
- on the chemical properties of soils which influence, both directly and indirectly, the activities of turfgrass pathogens.

Fungicides affect soil respiration

Soil respiration is determined by measuring the consumption of oxygen and the liberation of carbon dioxide. This measurement has been used extensively as an indicator of soil microbial activity. Although respiration measurements reveal little about the specific microbial activities in soils, they do provide some indication of the overall health and fertility of soil. In nearly all cases, the greater the soil microbial activity, the greater the overall health and fertility of the soil.

Following the application of most fungicides, soil respiration is inhibited for only a short time. Respiration rates quickly recover and often exceed levels found in untreated soils. Although the respiration rates return to pre-application levels, the composition of the microbial community may be dramatically altered. Most often the increased activity is due to a few microbial species resistant to the applied fungicide. In some cases the increased respiration rate is due to the microbial metabolism of the fungicide itself.

Broad-spectrum fungicides have the most marked inhibitory effect on soil respiration. These include mancozeb, thiram, and triadimefon. However, this inhibitory activity may be extremely rate-specific and soil-specific. For example, in some soils, quintozene (PCNB) applied at rates of 0.2 - 0.4 oz/1000 square feet was inhibitory, whereas in other soils, applications of quintozene did not significantly affect oxygen uptake until application rates exceeded 4 oz/1000 square feet. At high application rates, triadimefon not only inhibits microbial activity, but the inhibition is irreversible. The inhibitory effects of other broad-spectrum fungicides are equally rate dependent and unpredictable. For example, propiconazole is stimulatory to soil respiration in laboratory experiments when applied at rates less than 17 parts per million, but inhibitory at higher rates. However, in the same soil in the field, rates as low as 1.25 parts per million can be inhibitory to soil respiration.

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able nontarget effects of their fungicide applications and managers should be prepared for that possibility.

What should turfgrass managers do?

Turfgrass managers should take every opportunity to educate themselves about the nontarget effects of those fungicides that they use. When they make a fungicide application decision, they should make sure they have correctly identified the problem. This includes submitting samples to a diagnostic lab when symptoms are unclear. They should also be sure that all other non-pesticide remedial actions have either been tried or ruled out as impractical. They should have determined whether the disease infestation is transient or recurring and has exceeded their treatment threshold for that site. But, most importantly, managers should select the most narrowly-focused fungicide labeled for that disease and apply it at the minimum rates required to suppress the unwanted symptoms.

If the unintended, nontarget disease symptoms become chronic, have posed an historic problem, or are reoccurring with some regularity, then turfgrass managers should look for an alternative treatment method. This may include alternating fungicides to control the original disease problem and making a major effort to identify and correct those site-specific environmental conditions that favor the nontarget pathogen. Turf sites that have chronic disease problems are most likely to show the adverse nontarget effects of the high levels of fungicide applications.

The most effective disease control is no disease

If managers are able to eliminate or reduce many of the contributing environmental factors, such as shade, poor drainage, vulnerable turfgrass varieties, and poor air circulation, then the primary and secondary chronic disease infestations are very likely to disappear.

Now the goal is achieved: Understand the condition and prevent the disease from occurring. ■

0.02 to 0.2 oz/1000 square feet are not inhibitory or even slightly stimulatory to nitrification, application rates as high as 0.12 and 0.8 oz/1000 square feet can be inhibitory. Applications of quintozene (0.2 - 0.3 oz/1000 square feet), anilazine (0.01 - 2 oz/1000 square feet), and benomyl (0.4 - 1.2 oz/1000 square feet) are also known to be inhibitory. It is believed, at least with anilazine, that the inhibitory effect is primarily on species of *Nitrosomonas* which convert ammonium to nitrite and not on *Nitrobacter* species, which convert nitrite to nitrate.

Metalaxyl applied at rates of 0.01 and 0.02 oz/1000 square feet can significantly reduce nitrification, primarily by inhibiting species of *Nitrobacter* that are responsible for the conversion of nitrite to nitrate. Similarly, triadimefon applied at 10 parts per million is strongly inhibitory to *Nitrobacter* species.

In other studies, however, foliar sprays of anilazine, benomyl, thiophanate methyl, thiophanate ethyl, and mancozeb to Kentucky bluegrass turf for 14 consecutive weeks were not inhibitory to nitrification, even though the same fungicides were inhibitory when incorporated into soil. The low toxicity of surface-applied fungicides is believed to be due, in part, to their retention at the soil surface which results from their low water solubility, low volatility, and sorption to clay minerals and to thatch.

The nontarget effects on denitrification and ammonification processes have been studied less. However, both benomyl and thiram have been shown to be inhibitory to denitrification when applied at high concentrations. At low concentrations, these same fungicides may even be stimulatory. Ammonification processes in soil may be stimulated by applications of thiram and quintozene, but inhibited by applications of anilazene, benomyl, or mancozeb.

What are the effects on soil microorganisms?

Reports vary with respect to the effects of fungicide applications on populations of various groups of microorganisms. Surprisingly, following nearly all fungicide applications, populations of bacteria and actinomycetes actually increase in treated soils. Studies conducted at Cornell University nearly 20 years ago indicate that some combinations of fungicides suppress a wider spectrum of soil fungi than a single fungicide applied alone. However, even those fungicides applied singly may be quite suppressive to certain microbial populations. Fungicides such as benzimidazoles (benomyl and thiophanates) and sterol inhibitors (propiconazole, triadimefon, etc.) generally suppress populations of fungi more than do other turfgrass fungicides. Applications of propiconazole, benomyl, or chlorothalonil may reduce both fungal and bacterial populations, but these generally recover to pre-application levels within one month after the last application. Furthermore, applica-