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IN THIS ISSUE

Maximizing Disease Control with Fungicide Applications:

The Basics of Turfgrass Fungicides

Part Three: Plant and Pathogen Factors Affecting Fungicide Efficacy

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An important consideration when estimating the overall efficacy of fungicide applications is the growth of the turfgrass plants. Vigorously-growing plants not only have a greater natural defense mechanism to pathogen attack, but they also take up penetrant fungicides more readily. Both situations make disease control more effective at lower rates or with fewer applications.

Vigorously-growing turfgrass plants are not to be confused with excessive turfgrass growth. Vigorously-growing plants are those in a balanced state of growth where top growth is such that the root system can supply adequate levels of water and nutrients, maintaining the plant in a metabolic balance.

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Excessively-growing plants are those that are producing more top growth than the root system can adequately handle, creating a metabolic imbalance wherein the turfgrass foliage remains more succulent and susceptible to foliar diseases such as leaf spots and leaf blights. This is particularly the case if the turfgrass foliage remains wet for prolonged periods of time. So, although vigorous growth is desirable, excessive growth should be avoided.

In healthy turfgrass plants, water and minerals move from the soil into the roots where they are translocated to the turfgrass foliage; whereas, the carbon-containing products of photosynthesis are either used for foliar growth and development, or transported to the root system to support root growth and development. These processes of translocation require a vascular system, made up of the xylem (upward translocating elements) and phloem (downward translocating elements), that is properly functioning.

Turfgrass growth and vigor affect fungicide absorption and translocation

The uptake and translocation of fungicides within turfgrass plants is equally dependent on a properly functioning vascular system. Most systemic penetrant fungicides move through the plant by way of the xylem and are thus translocated upward in the plant. One fungicide, fosetyl Al, may actually move in both the xylem and the phloem. The movement of fungicides in plants is further facilitated by transpiration, or the evaporative loss of water through the leaf stomata. This usually increases the upward movement of fungicides in the xylem.

Generally, the more vigorous the growth of the turfgrass plant, the more movement of water and photosynthate through the vascular system and the higher the rate of transpiration; likewise, in a vigorously-growing plant, the greater the uptake and translocation of penetrant fungicides. For maximum efficiency, therefore, systemic penetrant fungicides should never be applied to dormant turf.

Questionable results will be obtained when applying systemic penetrant fungicides to severely diseased turf, particularly if affected by root pathogens. Many root- and crown-infecting fungi may cause extensive damage to root systems long before symptoms appear on the above ground parts of the plant. A dysfunctional root system is unable to properly absorb and translocate penetrant fungicides. Therefore, in cases of severe disease development, contact fungicides would be preferred over systemic penetrant fungicides.

Turfgrass stresses important to fungicide performance

Stresses on turfgrass plants are particularly important considerations in fungicide efficacy. The more compromised the plant, whether due to such things as heat stress, drought stress, traffic stress, soil compaction, or fertility imbalances, the more the plant is weakened and thus predisposed to infection by pathogens that would otherwise not typically be a problem. Similarly, plant infection and disease development may be enhanced in stressed turf allowing pathogens to develop much faster and symptoms to progress much more quickly than would otherwise be the case. Usually, the greater the level of stress, the greater the fungicide application rate and frequency needed to achieve adequate levels of disease control.

Pathogen factors affect fungicide efficacy

Aside from the consideration of the overall health and vigor of the turfgrass plant, there are a number of pathogen attributes, including the life stage, inoculum properties, plant tissues affected, and inherent fungicide sensitivities, that can influence the performance of fungicides.

↠ *Life stage* - Of particular importance to fungicide performance is the life stage of the pathogen. Turfgrass pathogens follow a cyclic chain of events during the development of a turfgrass disease. These events include the developmental stages of the pathogen as well as a progression of plant responses. All infectious disease-causing agents go through such a disease cycle.

The overseasoning stage of most fungal turfgrass pathogens occurs in the winter months. During this time, the pathogen persists in either soil, thatch, or in root and crown tissues as a quiescent spore or other form of inoculum. Snow mold pathogens are the exception to this rule as they overseason during the summer months. When temperature and moisture conditions again become favorable, inoculum can be transported to adjacent healthy turfgrass plants by wind, rain, moving water, equipment, etc.

Table 1. Temperature and moisture conditions favoring the activity of turfgrass pathogens.

Pathogen	Disease	Optimum Temperature for Pathogen Activity	Required Moisture Period for Spore Germination
Colletotrichum graminicola	anthracnose	22°-28°C (71°-82°F)	4-6 *hr.*
Rhizoctonia solani	brown patch	23°-32°C (73°-90°F)	5-7 hr.
Rhizoctonia zeae	brown patch	33°C (91°F)	4-8 hr.
Sclerotinia homoeocarpa	dollar spot	16°-27°C (61°-81°F)	8-24 hr.
Magnaporthe grisea	gray leaf spot	24°-28°C (75°-82°F)	16-24 hr.
Dreschlera spp.	leaf spot	12°-16°C (54°-61°F)	12-24 hr.
Bipolaris spp.	leaf spot	25°-35°C (77°-95°F)	8-48 hr.
Leptosphaeria korrae	necrotic ringspot	20°-25°C (68°-77°F)	48-72 hr
Microdochium nivale	pink snow mold	7°-19°C (45°-66°F)	48-72 hr.
Pythium aphanidermatum	Pythium blight	30°C (86°F)	14 hr.
Pythium spp.	Pythium root rot	13°-18°C (55°-64°F)	48-72 hr.
Laetisaria fuciformis	red thread	16°-21°C (61°-70°F)	4-24 hr.
Puccinia, Uromyces	rusts	18°-22°C (64°-71°F)	3 hr.
Entyloma, Urocystis, Ustilago	smuts	10°-18°C (50°-64°F)	24 hr.
Magneporthe poae	summer patch	25°-30°C (77°-86°F)	48-72 hr.
Gaeumannomyces graminis var. *avenae*	take-all patch	20°-25°C (68°-77°F)	48-72 hr.
Typhula spp.	Typhula blight	5°-10°C (41°-50°F)	Days to weeks

Compiled from:

Couch, H. B. 1995. *Diseases of Turfgrasses,* 3rd Ed. Krieger Publishing Company. Malabar, FL. 421 pp.

Smiley, R. W., P. H. Dernoeden, and B. B. Clarke. 1992. *Compendium of Turfgrass Diseases,* 2nd Ed. APS Press. St. Paul. 98 pp.

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Once at the surface of the healthy plant, the spore can then germinate and penetrate the plant tissues. In penetrating tissues, a nutritional relationship is eventually established between the pathogen and the plant. It is at this stage that the plant is considered to be infected. As the pathogen continues to grow between and within cells of the host plant, it can rapidly invade adjacent tissues and organs. It is during this invasive stage that plant symptoms become apparent. Eventually, a new batch of spores are produced on and within infected plant tissues. Once again, these spores can be transported to adjacent healthy plants where they either initiate secondary disease cycles or overseason in a quiescent state.

The dormant overseasoning period of turfgrass pathogens is a particularly important aspect of pathogen biology and is important to the efficacy of fungicide applications. Typically, this dormant phase allows the fungus to survive adverse environmental conditions, usually during the winter months. Also, many other pathogens may have dormant periods throughout the growing season in response to drastic soil environmental changes and certain pesticide applications. During this dormant stage, the pathogen is generally resistant to most fungicides, particularly those with only fungistatic activity (i.e., many of the penetrant fungicides). Only a few contact fungicides will actually destroy dormant pathogen propagules.

The importance, for fungicide applications, of understanding the cyclic nature of diseases becomes apparent when one considers that each stage in the disease cycle is required for the next stage. Most fungicide applications are aimed at preventing spore germination, penetration, and invasion of the fungal pathogen on and in turfgrass plants. For the most part, fungal pathogens prefer continuously moist conditions with temperatures ideal for spore germination, growth, and plant infection (Table 1). Therefore, it can be assumed that, with the exception of those pathogens that prefer exceptionally warm (some *Pythium* and *Rhizoctonia* species) or exceptionally cool (*Typhula* and *Microdochium* species as well as some *Pythium* species) conditions, fungicide applications will have the highest level of efficacy when applied during relatively cool to moderately warm conditions since the majority of pathogens would be in an active state of growth and most sensitive to the applied fungicide. The efficacy of applications at other times will likely be less than optimal.

➻ *Inoculum properties* - The germination of spores is a particularly sensitive stage in the life cycles of fungal turfgrass pathogens. Nearly all of the fungicides used in turfgrass management are capable of inhibiting spore germination, as well as spore production and other active stages of the life cycle. Some fungicides, however, are more limited in action and only inhibit spore germination, but not spore production (e.g. iprodione); as a result, under certain environmental conditions, these fungicides may not be as effective as other fungicides against some pathogens.

The density of inoculum (i.e. the population level of the pathogen) and the nutrition of the pathogen will greatly affect the efficacy of fungicide applications. The higher the pathogen population, the higher the rates of fungicides needed to achieve effective control and, possibly, the more frequently applications need to be made.

Additionally, the greater the nutrition and vigor of the pathogen, the less sensitive the fungus will be to fungicide applications. During active disease development, usually both the nutrition and the population level of the pathogen are elevated, making disease control more problematic. This is the reason that most turfgrass fungicide labels contain both low and high label rates. If applied before the disease has a chance to develop to any significant degree, the lower rates are generally suitable for effective disease control. If, however, the disease has been allowed to progress, greater amounts of fungicide are required for the same level of disease control. This issue in particular emphasizes the need for timely and accurate disease diagnoses.

➻ *Plant tissues affected* - The plant tissues most commonly infected by the target pathogen will influence not only the choice of fungicide, but also the effectiveness of a given fungicide. Whereas fungicide applications for the control of foliar diseases are relatively straightforward, the control of root diseases is often more difficult. The control of perennial infections in root tissues presents special logistic problems that generally require the use of penetrant fungicides; once pathogens infect root tissues, they are inaccessible to contact fungicides. Furthermore, unless penetrant fungicides are absorbed by roots or translocated to root tissues, diseases from root-infecting pathogens will not be effectively controlled. In most instances, proper fungicide selection can overcome some of the difficulties with root diseases.

Pathogen sensitivities to fungicides vary

It is also important to note that fungal pathogens vary widely in their inherent sensitivity to fungicides. While it is clear that pathogens causing different diseases vary in their sensitivity to specific fungicides, different strains of a single pathogen may also vary in their sensitivity to the same fungicide. I have observed, on several occasions, specific fungicides that, while effective on certain parts of golf courses, fail miserably when applied to other parts of the same course. This also raises some important considerations when interpreting University fungicide trials; this topic will be covered in a later part of this series on fungicides. Those fungicides that are most efficacious in a fungicide trial may not necessarily be the most effective on your particular site. While results of research trials with various fungicides may reveal some general trends in fungicide efficacy and the variability of pathogen sensitivities, applicator experience is often the best estimation of the variability of turfgrass pathogens and the efficacy of fungicides in specific turfgrass sites.

Fungicide resistance

One of the more important and emerging problems with the widespread use of fungicides with a narrow mode of action is the problem of fungicide resistance. Fungicide resistance becomes particularly serious when prolonged and continued applications of fungicides with the same mode of action are made to the same turfgrass site (Fig. 1). The reasons for the development of such resistance are related largely to the toxic properties of the fungicides and to the biology of turfgrass pathogens.

For the most part, many of the fungicides used for turfgrass disease control, especially the penetrant fungicides, do not actually kill pathogen populations. Rather, they stop the mycelial growth and spore germination of the fungus, often forcing the fungus into a dormant state. This generally results in the production of more fungal spores which serves to increase the population level in soil. This has been observed occasionally with soil populations of *Pythium* species following the application of *Pythium*-selective fungicides. As mentioned previously, in this dormant state, the fungus can remain alive, but is no longer sensitive to the applied fungicide; therefore, disease resulting from the germination of previously-dormant spores may make it appear as if the pathogen was resistant to the fungicide when, in fact, it was not sensitive only because of its dormancy.

Even though fungicide applications may be effective in stopping the immediate development of the disease, they tend to maintain soil populations of turfgrass pathogens, thus insuring that the same disease will appear time after time if environmental conditions are appropriate. By remaining alive in the presence of a fungicide, more insidious biological processes can take place. Because of the genetic diversity within most fungal pathogen populations, a small proportion of the population of any turfgrass pathogen will be insensitive to a given fungicide. If the fungicide to which that small proportion is resistant is applied continually to the same site or applied at less than optimum rates, this provides a means of selection for that resistant portion of the pathogen population. Therefore, as the fungicide continues to suppress the sensitive population, the resistant population slowly dominates, becoming even more resistant and eventually making the fungicide totally ineffective for that disease on that particular site.

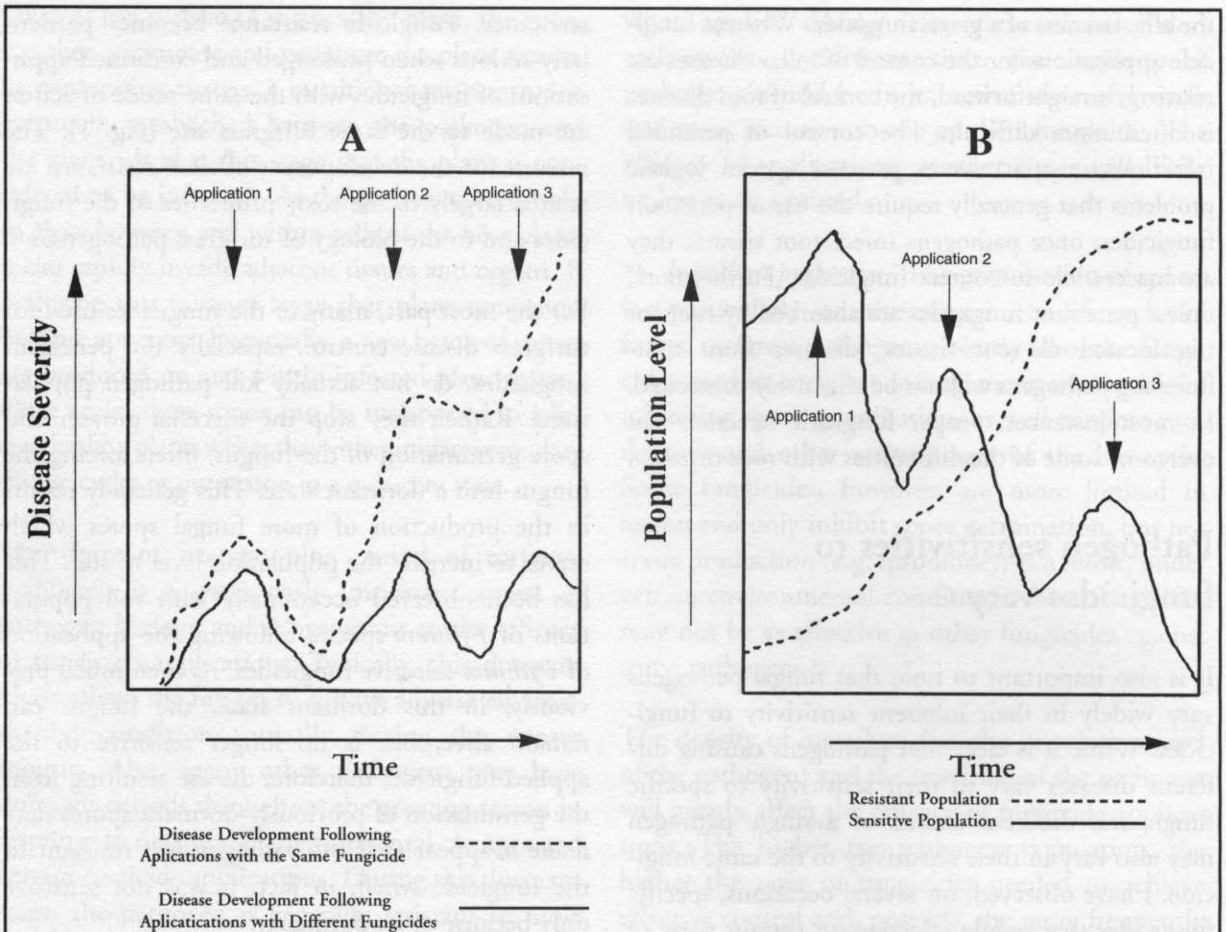

Figure 1. Hypothetical scenarios illustrating the possible effects of continuous and rotated applications of fungicides on disease severity and the development of fungicide-resistant pathogen populations. A) Effects on disease severity, B) Effects of continuous applications of the same fungicide on the sensitive and resistant proportions of the pathogen population.

Take steps now to minimize the potential for developing fungicide resistance

Whenever possible, the frequent and continued use of the same fungicide or combinations of fungicides with the same modes of action should be avoided. For the specific modes of action of all commonly used turfgrass fungicides, refer to Part 1 of this series (*Turfgrass TRENDS*, February 1996). Similarly, rates less than those specified on the label should also be avoided since reduced rates allow an even greater proportion of the potentially resistant population to survive and proliferate. The following steps should be considered in any attempt to reduce the risk of fungicide resistance problems:

1. As the first line of defense against any disease problem, incorporate disease-resistant or disease-tolerant turfgrass cultivars or varietal mixtures into the turfgrass site whenever practical.

2. Attempt to minimize the problem by employing cultural or biological methods of

disease control. No known resistance has occurred in response to a cultural or biological disease control strategy.

3. If you must use fungicides, make sure that the same fungicide is used for no more than two successive applications before rotating to a different fungicide with a different mode of action.

4. Avoid applications at less-than-label rates. To assist in this, make sure that the proper amounts of fungicide are placed in the spray tank and mixed with the appropriate amounts of water. Care should also be taken to assure that your equipment is properly calibrated and delivering the correct levels of fungicide to the turf.

5. Make sure that you are getting complete spray coverage, avoiding skips and overlaps.

6. Finally, avoid preventive applications whenever possible. There is no point in introducing a fungicide into the environment if it is not warranted. This simply provides more selection pressure for a potentially-resistant pathogen population. The only exception to this would be the necessary preventive application of fungicides for summer patch control. If you suspect a summer patch problem, be sure to have it properly diagnosed before making any preventive fungicide applications the following season.

Management recommendations

The best advice here is to constantly monitor your sensitive turfgrass sites, and get early diagnoses on potential disease problems. Early detection and diagnosis will allow you to apply the proper fungicide at the earliest stages of disease development when plants are still functioning relatively well and the pathogens are clearly active yet only beginning to build up populations. Following these principles will increase the likelihood of getting adequate fungicide uptake and distribution inside the plant, and of catching the pathogen at its most sensitive stage. This should also reduce the amount and frequency of the fungicide applied, making for more economical applications and more effective disease control. Finally, always be aware of the potential of fungicide resistance and take the proper precautions to avoid it.

In the June issue, I will discuss a number of points related to the handling, applying, and monitoring of fungicide applications.

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Terms to Know

Inoculum - The pathogen or parts of the pathogen that can cause infection. Inoculum consists of spores, mycelium, sclerotia, etc.

Phloem - Food conducting tissue in a plant that moves sugar from the leaves down to the root system.

Photosynthate -The product of photosynthesis: carbohydrates.

Stomata - Pores in the surface of the foliar parts of plants that allow for gas and water exchange. Stoma = (singular)

Translocation - The transfer and movement of materials, including fungicides, through a plant.

Transpiration - The loss of water from the surface of leaves.

Vascular System - The water and nutrient-conducting tissues of a plant (e.g. Xylem and Phloem).

Xylem - Nutrient- and water-conducting tissue in a plant that moves water and nutrients from the root system up to the above-ground portions of the plant.